ZOOLOGY

CHORDATA, HISTOLOGY & EMBRYOLOGY

BLOCK I – CHORDATA

BLOCK II – HISTOLOGY

BLOCK III – EMBRYOLOGY

Dr. B.R.AMBEDKAR OPEN UNIVERSITY
HYDERABAD
1993

COURSE TEAM

Editor
Sri Dost Ali Ashraf

Associate Editor
Dr. (Mrs.) Girija Neti

Writers
Dr. V. Lakshmipathi
Dr. K. Bhakthavatsala Rao
Sri K. Kailasapathi
Dr. R.R. Patwari

Cover Design & Graphics
M. Ramesh

Dr. B. R. AMBEDKAR OPEN UNIVERSITY
Hyderabad

First Published in 1984 Re - Print - 1995

This text forms part of an Open University Course.

Further information on Open University Courses may be obtained from the Director (Academic), Open University, Hyderabad.

Printed by :
R.K. OFFSET Printers, Amberpet, Hyderabad - 13. Phone: 868366

PREFACE

This book deals with the topics in Chordata, Histology and Embryology included in the syllabus for the Second Year of the Zoology course offered by the Andhra Pradesh Open University. These topics generally cover the "Core" area of the subject to be studied in the Second Year of the Three Year Degree Course in Science (B.Sc.). The syllabus for the sake of convenience is divided into Blocks. Each Block generally covers a specific area of the subject. The units are prepared by specialists in accordance with a format so designed as to enable the student to read and understand them without much difficulty. Each unit begins with a statement of its objectives followed by synopsis and has at its end assignment intended to test the student's comprehension of its subject matter. Technical terms with which the student may not generally be familiar are given at the end of each unit under the head 'Glossary'.

The course material of this paper is divided into three blocks. The Blocks are in turn divided into 36 units. The first 30 units dealt with the Chordates. The last six units focuses on Histology and Embryology.

In Unit - 1 the general characters, classification, origin and evolution of vertabrates are briefly discussed. In Unit - 2, the general characters, classification and affinities of cyclostomes are discussed. The Units 3 to 10 presents a general studfy of fishes cartilagenous, bony fishes and lung fishes. A special study on edible fishes of Andhra Pradesh and fisheries are included under Unit - 9.

Unit - 11 presents a general study on Amphibians. Units 11 to 21 deals with reptiles and aves. Under the class Aves, important topics like flight adaptations and migration of birds are included. Units 22 to 30 exclusively deals with the class Mammalia. This includes generally study of mammalia and detailed study of various systems of Rabbit, laying stress on its physiology.

The last six units briefly gives an account on histology and embryology. Under embryology, a study on the development of Amphioxis is discussed.

General accounts of type animals like scoliodon, calotes, pigeon, and rabbit are also discussed under the respective chapters.

The university hopes that this material will help the student to get acquainted with the principal issues in Chordata. Histology and Embryology which make for its distinctiveness and significance.

CONTENTS

BLOCK – I
VERTEBRATA (CRANIATA)

Unit – 1 VERTEBRATA – GENERAL CHARACTERS AND CLASSIFICATION

Contents

1.1 OBJECTIVES

To know the characters of vertebrates, their different groups, their origin and their diversification in geological time scale.

1.1 INTRODUCTION

Vertebrates also referred as craniates (with cranium - crain case), include, jawless animals (Agnaths) fishes, amphibians, reptiles, birds and mammals. They possess a distinct skull, paired limbs, a highly complex brain, the heart being always ventral, is muscular with three or four chambers, red blood corpuscles are almost always found.

The vertebrata or craniata are referred as Euchordata, (in which the notochord is not continued to the end of the snout, but ends before the fore-brain. Some distance from the anterior end of the body).

1.3 GENERAL CHARACTERS

Vertebrates are bilaterally symmetrical, triploblastic metazoans. They have well defined body regions - head, trunk and tail. There is a strong tendency towards cephalisation - a concentration

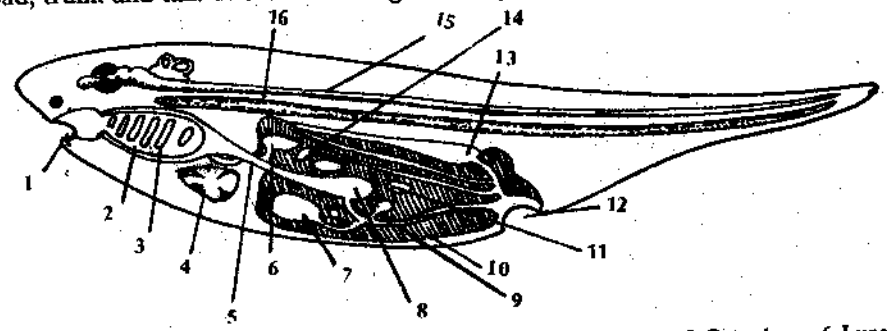


Fig 1.1 An idealised Vertebrate (diagrammatic). 1. Mouth 2. Pharynx 3. Gill slits 4. Heart 5. Oesophagus 6. Lung 7. Liver 8. Stomach 9. Intestine 10. Coelomic cavity 11. Spleen 12. Cloaca 13. Kidney 14. Gonad 15. Neural tube 16. Notochord.

of structures such as mouth, brain and functions at the anterior end of the body. In lower water breathing vertebrates the neck is not present. In all higher land dwelling vertebrates a neck is present. Reduction of the gills and shifting to lung breathing habit might have aided in appearance of a distinct neck. The trunk which is the main part of the body has body cavities enclosing the viscera. Among the vertebrates we find a well developed tail or caudal region beyond and trunk) which is a propulsive organ in fishes. In Amphibians and Reptiles the long tail is stout at the base. It is shortened in birds and is lost completely as an external structure in some forms, such as man (Fig. 1.1).

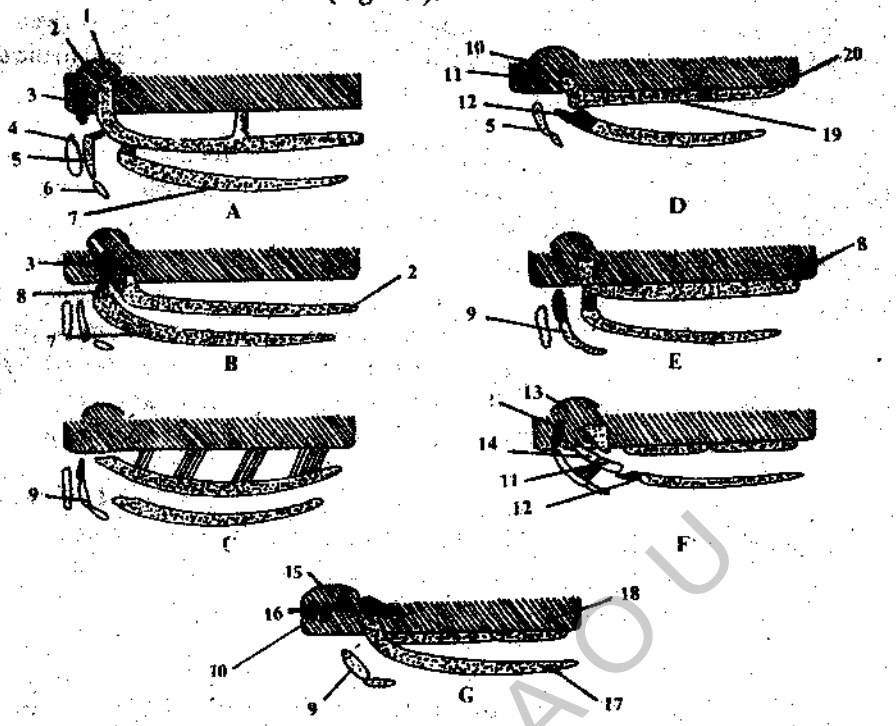


Fig 1.2 Jaw suspension in Vertebrates. A. *Amphistylic* B. *Hyostylic* C. *Autodiastylic* D. *Autosystylic* E. *Holostylic.* F *Methystylic* G. Craniostylic 1. Otic region 2. Palatoptery go- quadrate bar 3. Hyomandibular 4. Gill slit 5. Ceratohyal 6. Basihyal 7. Meckel's 8. Ligaments. 9. Hyoid arch 10. Stapes (Hyomandibular) 11. Quadrate 12. Articular 13. Metapterygoid 14. Symplectic 15. Malleus (Articular) 16. Incus (Quadrate) 17. Dentary. 18. Upper jaw. 19. Pterygoid 20. Palatine.

Notochord is a long flexible rod like structure which is present in every embryo of a vertebrate. It is an outgrowth along the dorsal median line of the primitive gut. It is subsequently replaced by the vertebral column or back bone.

All the vertebrates possess endoskeleton consisting of skull, Lower jaw, hyoid vertebral column, pectoral girdle, fore limbs pelvic girdle and hind limbs. The skull has three parts - **chondrocranium** which is made up of cartilaginous cranium or brain box and the sense capsules enclosing the sense organs **Splanchnocranium** forming the skeleton of jaw, and **Dermatocranium** consists of dermal bones of the skull.

In the vertebrates having jaws, the splanchnocranium plays an important role in suspending the lower jaw with the cranium.

The following are the different types of jaw suspensions. (Fig 1.2)

(i) **Amphistylic** - The upper Jaw is attached to the cranium directly by ligaments. Both mandibular and hyoid arches are attached to the cranium E.g. *Heptanchus.*

(ii) **Hyostylic** - The upper Jaw and lower Jaw are suspended through hyo-mandibular which is attached to the otic region of the chondrocranium. e.g. *Elasmobranches* and bony fishes

(iii) **Autodiastylic** - The Jaws are attached to the cranium directly by liagments. e.g., extinct bony fishes under Acanthodii

(iv) **Autostylic** - The upper Jaw is fused with the cranium, the lower jaw is articulated in different ways - the lower jaw is articulated with the upper Jaw, Holostylic e.g *Holocephali*) the lower jaw is articulated to the upper jaw with the quadrate (Autosystylic e.g. tetrapods except mammals), the lower jaw is suspended from the symplectic bone derived from the hyomandibula (Methyostylic e.g. Teleosts), the lower jaw is directly attached to the squamosal of the osteocranium craniostylic e.g. Mammals.

The digestive tract of vertebrates is modified in various ways, related to the types of food utilised and the problems of absorption. The oesophagus is short in fish, is elongated in land vertebrates with the development of neck.. The stomach is quite similar in all vertebrates but the intenstine is longer in herbivores than in carnivores. Two digestive glands arise as outgrowths of the alimentary canal - (i) Pancreas and (ii) liver. The presence of internal gills in the embryo, it not in the adult is the distinctive feature of vertebrates. These are a paired series of clefts or pouches leading outwards from an interior part of the gut (pharynx) - pharyngeal gills slits. Gills happen to be the primary breathing organs in lower aquatic vertebrates. In higher vertebrates the gills are functionally replaced by lungs and the gill pouches are embryonic.

The circulatory system is of closed type. The heart is ventral, composed of three to four chambers and the blood contains red blood corpuscles. Haemoglobin present in red blood corpuscles carries large amounts of oxygen to the tissue. The separation of the heart chamber seen first in the lung fish is incomplete in amphibians and reptiles and is complete in birds and mammals.

The central nervous system lies in the dorsal median line, and is tubular in its origin. Its fore-end develops into a complex brain enclosed in a brain case or cranium, hence vertebrates are called craniates. Fore-brain is well developed in those fishes which find food through the sense of smell. The mid-brain is most developed in birds and those bony fishes which use sight for getting food. The cerebral hemispheres become increasingly important as association centres. the olfactory sense is found in all vertebrates. There is a definite system of endocrine glands.

Organs of nitrogenous excretion and osmoregulation in vertebrates are the paired kidneys. These are derived from mesodermal coelomoducts. The fishes excrete ammonia, the amphibians excrete urea. Most birds and many reptiles excrete uric acid crystals, where as mammals excrete a solution of urea.

Among vertebrates, the sexes are separate. The general trend in the reproductive systems of vertebrates has been towards a reduction in the number of zygotes which must be produced to maintain the species. This has been accomplished by three factors (i) fertilisation is often internal rather than external (ii) although many vertebrates lay eggs a large number of forms give birth to living young (iii) many vertebrates care for the young until the young are sufficiently grown to take care of themselves.

If the developing zygote is retained within the female's reproductive tract, the new individual has an even better chance of surviving. This retention is found among some fishes, reptiles and in all but a very few mammals. Among those forms which lay eggs, there are difference

in care. Some fishes guard their nests and young carefully, but most reptiles simply deposit the eggs and show no care. Birds and mammals show the greatest care during the period of development and early period of helplessness of the young.

The evolution of the vertebrates has been characterised by four main features.

These are :

(i) The appearance of paired appendages

(ii) The appearance of jaws

(iii) The movement to land

(iv) The development to homiothermy

Unpaired or paired fins serve as accessory organs of locomotion. Probably they were developed as stabiliser when animals moved from land to water. Paired appendages became vitally important as locomotive organs.

Jaws help in grasping and holding the food materials in vertebrates. They also permit ingestion. Pharynx helps in sucking the food material in jaw-less forms.

Some of the vertebrates adapted several changes when they moved to land. The Reptiles have a thickened and cornified epidermis which resists water loss: their eggs have protective shells. The embryos have a series of membranes around them. Many conserve body water by excreting crystalline uric acid rather than urine. Birds and Mammals like the Reptiles are well able to resist dessication on land .

Colder areas are closed to such terrestrial animals as the Reptiles and Amphibians because their internal temperatures are close to those of the external environment. Their activities are controlled by the environmental temperatures. The ability to maintain body temperature constant through internal control despite the variable temperatures of the land environment is called homiothermy. Birds and Mammals exhibiting this phenomenon have spread to all parts of the world.

1.4 CLASSIFICATION OF VERTEBRATES

Sub phylum vertebrata has two super classes - **Agnatha** and **Gnathostomata.**

1.4.1 Agnatha

These are the animals with out jaw in the mouth. The living agnathans are cyclostomes. They show an interesting method of feeding. The living cyclostomes are parasites and suck blood as adults. The larval lampreys feed on minute particles using an endostyle. They employ muscular contraction rather than ciliary action to produce a food current. Agnatha have a distinct head and skull but cephalisation is of a low order. The brain is primitive and parts of its roof are non-nervous. The paired appendages are absent. Notochord persists permanently. The vertebral column is poorly developed because there are no centra. They are monorhinous having a single median nostril which open into a hypophysial sac. Aganthans are hence called **Monorhina.**

Super-class **Agnatha** has the following two living classes.

1. **Petromyzontia**

2. **Myxinoidea**

1.4.2 Gnathostomata

This superclass includes all vertebrates with upper and lower jaws. It is divided into seven classes.

1.	Placodermi.	Extinct Jawed vertebrates.
2.	Chondrichthyes	Jawed fish possessing cartilaginous skeletons and placoid scales (Elasmobranchii)
3.	Osteichthyes	Jawed fish typically possessing a skeleton of bone scales may be cycloid, ctenoid or ganoid. e.g.*Labeo*
4.	Amphibia.	Vertebrates possessing a moist skin, usually without scales. Often with an aquatic larva and terrestrial adult. e.g. ***Rana*** (Frog): and *Salamanders*.
5.	Reptilia.	Vertebrates possessing scaly skins : eggs with well developed membranes.
6.	Aves.	Vertebrates possessing feathers : eggs with embryonic membranes, - warm blooded with aerial adaptation e.g. **Columba** (Pigeon). **Apteryx** (Kiwi) and **Struthio** (Ostrich).
7.	Mammalia.	Vertebrates having the body covered with hair: warm blooded: nourish young by means of mammary glands. e.g. *Ornithorhyncus* (Duck billed *platypus)* *Macropus* (Kangaroo): *Oryctolagus* (Rabbit): *Cebus* sp. (Monkey): Homo sp. (Man) etc.

1.4.3 Origin and Evolution

The first known vertebrate fossils are those of Ostracoderms as fragments of bony plates from the Ordovician and abundant fossils in the extinct Silurian and Devonian about 400 million years back. They were characterised by the absence of jaws and the possession of bony armour. They could feed on the bottom detritus. A variety of forms evolved in the Silurian and the Devonian. The cyclostomes are the living representatives of this group.

The first jawed vertebrates, the placoderms have evolved from an ancestor like the ostracoderms by a conversion of the first gill arch into the upper and lower jaws. Variety of prey was captured when the placoderms diversified and became a wide spread heterogenous fish like group of vertebrates with one common feature, namely, the second gill arch bore a normal gill and had no role in the suspension of the jaws. Some of the placoderms like the **Acanthodians** had between the pectoral and pelvic fins a series of paired fin-lets. It indicated the origin of fins from the fin folds. There were other forms like of **Arthrodires** with an articulation between the thoracic and head sections of the armour. **Stegoselachians** were like armoured rays. Except Acanthodians all became extinct by the end of the Devonian.

Table I : Showing Geological and Climatic conditions and Animal Groups that have evolved during the period

Era	Period	Major Geological and climatic conditions	Animal groups that have evolved during the period
Coenozoic	Quaternary	Maintain building-erosion. Short lived invasion of the Sea-cooler and glacial conditions. Temperate forests to extensive grass lands	Transition from primitive mammals to modern orders in Mammalia - Evolution of Man
75	Tertiary		
	Cretaceous	Spread of epicontinental seas, extension of mountain building, cooling of climate	Extinction of archiac birds and many reptiles
135			
Mesozoic	Jurassic	Warm and stable climate with little seasonal variation	High Reptilian diversity. First birds appeared.
165	Triassic	Continents were high with shallow seas. Warm climate, extensive deserts	Earliest true mammals. Replacement of mammal like reptiles by predecessors of dinosaurs
205			
	Permian	Higher land area cool-progressive warming of the climate	Diversity of Mammal like Reptiles - wide spread extinction of Amphibians
230			
	Pennsylvanian	Warm and humid glaciation in southern hemisphere	Large arthropodfauna. Specialised amphibians. First appearance of Reptiles
Palaeozoic	Mississippian	Mountain Building - arid conditions	Radiation of amphibians, extinction of some fish
280	Devonian	Land was higher - climates cooler. Fresh water basins	First winged insects. Disappearance of Jawless forms, radiation of fishes
325			
	Silurian	Uplifting of land - Shallow seas - Warm climate	Eiru[terods - First terrestrial arthropods. First gnathostomes appeared out of Jawless forms
360			
	Ordovician	Shallow seas - warm climate	Variety of large Invertebrates, wide-spread jawless fish fossils.
425			
	Cambrian	Extensive shallow seas in the equatorial regions warm climate	Trilobites & Brachiopods. First remains of vertebrates.
505			
	Proterozoic	Changes in litho sphere. High land masses. Shallow seas.	Many invertebrates.
Precambrian	Archaeozoic	Formation of earth, slow development of lithosphere, hydrosphere and atmosphere	Development of life in the hydrosphere

From the Acanthodian-like ancestors arose both the **cartilaginous fishes** and **bony fishes.** The sharks have evolved by degeneration of bone or more probably by **neoteny** (retention of Juvenile characters into adult life).

The bony fishes were of two distinct types from the beginning the ray finned ones **(Acanthopterygii)** and the lobe finned ones **(Crossopterygii).** Allied to the later are the present lung fishes.

The Palaeoniscoidea was the stem group of the ray finned fish, which evolved into a multiplicity of fish forms. Chondrostei and Teleostei are successive stages in the progress of the group. Teleostei show rich distribution since the Jurassic.

The lobe finned fishes while flourishing in Devonian supposed to have become extinct since the Cretaceous. In the Devonian period the pools dried up and the fishes the *Latimeria* had to shift from pool to pool and the lungs proved helpful to them. The basal lobes of the fins had also the skeletal elements and they became the basis of penta dactyle limbs of their descendants, the land vertebrates. Amphibia flourished in the Carboniferous period and formed numerous varieties. One of the groups, **Seymouriamorpha** was more adopted to land life than other and it was so much like reptiles. Most of the Amphibia became extinct. Today we find only frogs, loads salamanders newts and a few limbless burrowers.

The Reptilia spread all over the land throughout the Mesozoic era. They flourished on land in water and even in the air. The first reptiles were cotylosaurs. An earlier branch of the reptilian stock was the Synapsida, mammal like reptiles. By the end of Mesozoic the fantastic reptiles which were bipedal carnivores, some were herbivorous, huge and amphibious, became extinct. The crocodiles are the only living survivors of the ruling reptiles. The ramnants of another group of reptiles are the lizards and *Sphenodon* .The snakes are the modified descendents of the lizard group.

Birds are derived from the ruling reptiles. The connecting link **Archaeopteryx** from the Jurassic, very much like reptiles but with feather. Since the beginning of Tertiary (Coenozoic era) with flight adaptation, the birds ruled the air, with their uniform organisation, they have adapted themselves for life in all types of habitat.

Mammals have evolved from the mammal-like reptiles. The gap is bridged by the synapsid reptiles. The last of them the **Ictidosouria** of the Jurassic could hardly be distinguished from the first mammals. The living representatives of primitive mammals are found in the southern lands, like Australia and Newzealand.

Marsupials - the pouched mammals of Australia radiated into all environmental niches with appropriate modifications forming groups parallel to the placentals elsewhere. Outside Australia they were replaced by the more advanced mammals, the placental mammals but in South America which was isolated from other lands before the placentals could reach it, they flourished and are still numerous.

The earliest placentals were insectivorous. One of the groups of the placentals adapted to life on trees and became **Primates** which include lemurs, monkeys and apes. Out of the ape stock about a million years ago arose man who assumed erect posture and started using forelimbs for skilled manipulation. Another group of early placentals resulted in the highly specialised terrestrial carnivores like the cat the lion, the tiger and the fox and an aquatic group the seal, the sea lion and the walrus. The even toes ungulates evolved along another line starting from about the same origin as the carnivora. All developed special dentition and

Some Diagnostic Features of Vertebrates								
Group	Skin	Skeleton	Appendages	Breathing	Heart chambers	Ferti-lization	Develop-ment	Other Characters
Agnatha	Smooth	Permanent	without	Gills	2	External	In water	Without Jaws cold blooded without neck without lungs single nostril
Chondrichthyes	Denticles	Embryonic notochord adult cartilage skeleton	Paired fins	Gills	2	External	In water	With Jaws cold blooded without neck without lungs
Osteichthyes	Scales	Embryonic notochord, adult bony skeleton	Paired fins	Gills, lungs in some	2	External	In water	Swim bladder in most cold blooded without neck
Amphibia	Smooth glandular	Embryonic notochord, adult bony skeleton	2 pairs of limbs	Gills and lungs	3	External	In water	Cold blooded without neck
Reptlia	Scales	Embryonic notochord, adult bony skeleton	2 pairs of limbs	Lungs	Imperfe-ctly di-vided ventricles	Internal	On land	With neck cold blooded
Birds	Feathers	Embryonic notochord, adult bony skeleton	Legs and wings	Lungs	4	Internal	On land	With neck warm blooded aerial adaptation.
Mammals	Hair	Embryonic notochord, adult bony skeleton	2 paired limbs	Lungs	4	Internal	Mostly within female	Warm blooded nurse young non-nucleated mature. b.c. Mammary Gland

some even specialised stomach for masticating and digesting their particular food. Other mammalian lines are the ant caters with reduced dentition, elongated snout and tongue and well developed claws, the highly successful and the most numerous group was is the Rodentia with dentition adapted for gnawing.

An efficient mode of reproduction with intrauterine development and a constant temperature which stabilises the rhythm of vital functions and metabolism helped the mammals to attain success.

The development and functioning of the cerebral cortex, neopallium and perfect double circulation consisting of the greater (systemic) and the lesser (pulmonary) circulations have helped the Mammals to a greater success on the evolutionary ladder of vertebrates.

1.5 SUMMARY

The vertebrate body is differentiated into head [cephalisation], trunk with two pair of appendages and tail. Gill breathing [pisces] is replaced by lungs in tetrapods. laws suspended through hyomandibular in lower vertebrates while in Dipnoi and tetrapods, the hyomandibular is modified into stapes. Anteriorly, the dorsal tubular nerve cord is swollen into brain. Cerebrum reached its height in mammals. Kidney evolved in 3 stages viz., pro, meso & metanephric to excrete nitrogeneous wastes, Réptiles and birds are uriotelic. Sexes separate, fertilisation often internal and parenilal care is well is seen in many groups of vertebrates particularly in birds and mammals. Birds and mammals are warm blooded animals. Supphylum Vertebrata is divided into 2 Super classes: **Agnatha** [jawless] & **Gnathostomata.** (Jawed) The latter includes pisces and tetrapods while Agnatha includes Cyclostomes [Lampreys & hagfishes]

1.6 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Describe the general characters of vertebrates.
2. Give an account of origin of vertebrates.
3. Out line the classification of vertebrates.

II. Answer the following in about 10 lines.

1. Types of jaw suspension in vertebrates.
2. Define "vertebrata".
3. Agnatha.
4. Ostracoderms.
5. Placoderms.
6. Archaeopteryx.
7. Marsupials.

Unit – 2 CYCLOSTOMATA - GENERAL CHARACTERS AND CLASSIFICATION

Contents

2.1 OBJECTIVES

- To know the distinctive features of cyclostomes and their classes and affinities.

2.2 GENERAL CHARACTERS

The cyclostomata (Gr cyclo: circular: stomata; mouth) has been coined for those primitive agnaths which are in possession of a circular oral opening. These are characterised by

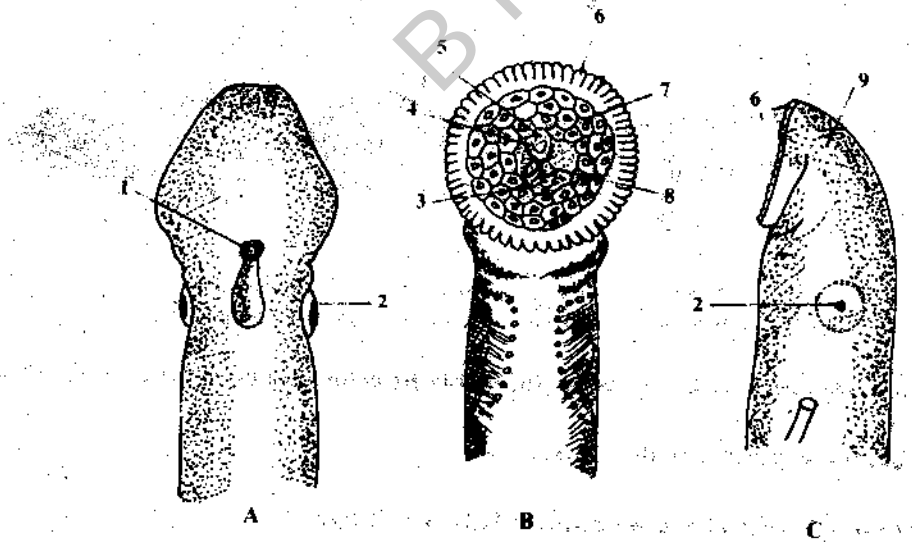


Fig 2.1 Head of *Petromyzon* A. Dorsal view B. Ventral view C. Lateral view 1. Nasal aperture 2. Eye 3. Intra oral tooth plate 4. Mouth 5. Supra-oral tooth 6. Papillae 7. Lateral tooth 8. Tongue 9. Buccal funnel.

(i) Eel like forms with rounded cylindrical body, and laterally compressed tail.

(ii) The anterior end bears a suctorial mouth in the form of a circular aperture with fleshy papillated margins and horny teeth. The mouth may be in the form of depression edged with tentacles. Jaws absent.

(iii) The tongue is a muscular rasping organ bearing epidermal horny teeth.

(iv) No exoskeleton, the skin is soft, smooth and highly glandular. It is devoid of scales but richly supplied with unicellular slime glands.

(v) The endoskeleton is cartilaginous with persistent notochord in the vertebral column.

(vi) Paired appendages are absent. The median fins provided with cartilaginous fin rays.

(vii) The nostril is a single median aperture.

(viii) Respiration by means of 6-14 pairs of internal gills lodged in a pair of pouches like gill chamber.

(ix) Heart, two chambered enclosed in a peri cardial cartilage derived from the hinder visceral arch.

(x) Internal ear with one or two semi-circular canals. Pineal body sensitive to light.

(xi) Spleen and pancreas absent. Kidney has segmentally arranged tubules.

(xii) Fertilisation external, development either direct or with a larval form.

(xiii) The adults are either parasites or scavengers but the larvae are micro-phagous.

2.3 CLASSIFICATION

2.3.1 I. Class: Petromyzontia

1. Both fresh water and marine forms.

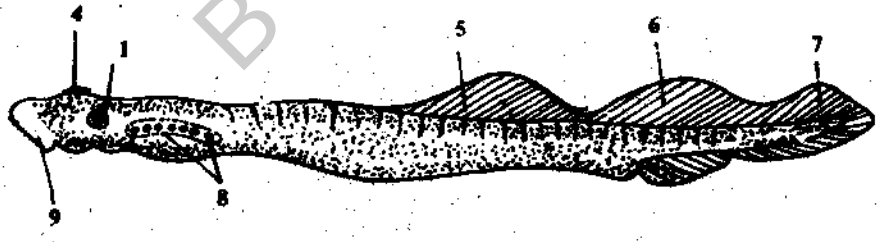


Fig 2.2 *Petromyzon* 1. Nasal aperture 2. Eye 3. First dorsal fin
4. Second dorsal fin 5. Caudal fin 6. External fill apertures 7. Buccal funnel.

2. Fresh water forms are free living but the others are ectoparasites on fishes and turtles.

3. Eel like forms having cylindrical bodies.

4. Range in size from a few centimetres to 120 cm. in length.

5. Dorsal fin well developed Caudal fin present.

6. Branchial basket complete.

7. Seven pairs of gill clefts behind the head.

8. The branchial funnel possesses horn, teeth and a piston like rasping tongue provided with teeth.

9. Nostril is a single dorsomedian opening continued into a nasohypophysial pouch which ends blindly.

10. Eyes well developed.

11. Internal ear has two semi circular canals.

12. Sexes are separate. There is a larva in the life history, which undergoes metamorphosis and is called an **Ammocoetes** (Fig. 2.3). The larva is without the sucking mouth, tongue or teeth of the adult. The head is small, with a hood like upper lip and separate lower lip. There is a velum at the top of the pharynx, ciliated bands and an endostyle. Seven pairs of incipient gill pouches open directly from the pharynx to the exterior. Pharynx and oesophagus form a continuous tube. The eyes are partly hidden beneath the skin. The delicate dorsal fin is continuous.

Fig. 2.3 Ammocoete larva of *Petromyzon* 1. Eye 2. Oral hood 3. Gill slits.

13. The metamorphosis is complete within a few weeks with the following changes in the larva.

(i) Buccal region elongates to form buccal funnel with horny teeth.

(ii) Paired eyes appear.

(iii) Velum disappears.

(iv) Gills develop in the gill slits and open into pharynx.

(v) The continuous dorsal fin becomes divided into two dorsal fins and a single caudal fin.

(vi) The colour of the skin changes from light brown to mottled greenish brown.

14. It migrates from river to sea, where it changes into adult, leading parasitic mode of life. e.g. *Petromyzon* (lamprey), *Lampetra*

2.3.2 Class: Myxinoidea

1. Eel like slimy bodies, with soft integument, without scales.

2. Exclusively marine.

3. Live as scavengers mostly on the dead fishes.

4. Sucking funnel absent.

5. Mouth is terminal having four pairs of tentacles around the margin of the mouth. The mouth is without jaws and is furnished with a single hooked palatal tooth.

6. Dorsal fin is absent. A continuous median fin is present which runs from the middle of the dorsal surface up to the cloacal pit.

7. The eyes are rudimentary.

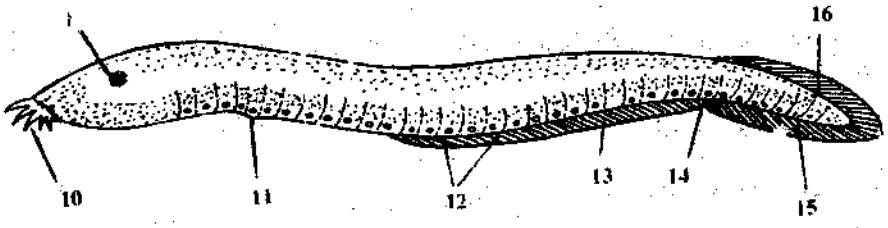


Fig. 2.4 *Myxine* 1. Eye 2. Tentacles 3. Single external gill aperture 4. Mucous pores 5. Anal fin 6. Cloacal Pit 7. Caudal fin 8. Tail.

8. Nostril is terminal, which opens into hypophysial sac, opening posteriorly into the mouth.

9. There are 6 to 14 gills which open by ducts to the outside by external branchial apertures.

10. Internal ear possesses a single semi-circular canal.

11. A large number of mucus glands are present in the integument which open to exterior by numerous apertures situated in two rows from head to tail.

12. The method of feeding is unique. Biting is possible by two protrusible dental plates, which move against each other horizontally.

13. Cloaca is an invaginated pouch having openings of anus, excretory ducts and genital pores.

14. Eggs large, development is direct with no larval stage. e.g *Myxine* (Hag fish) *Eptatretus (Bdellostoma)*

2.4 AFFINITIES OF CYCLOSTOMATA

Cyclostomes are the living agnathans which are primitive in many respects but specialised in others.

2.4.1 Primitive Features of Cyclostomata

1. True jaws are absent.
2. True teeth are absent, which when present are actually the epidermal thickenings
3. True stomach is absent.
4. Gonoducts are absent
5. Paired appendages of fins are absent.
6. Medullated nerve fibres are absent.
7. Conus arteriosus and renal portal system are absent.
8. A diphycercal caudal fin is present.
9. An incomplete cartilagenous cranium is present.

10. Pronephors is present.
11. Unconstricted notochord is present.
12. Segmentally arranged vertical cartilagenous rods attached to the sides of notochord as neural and interneural arches are present.
13. Poorly developed pancreas is present.
14. Straight alimentary canal is present.
15. Intestine is with or without poorly developed spiral valve.
16. Endoskeleton is cartilagenous.
17. Myotomes undivided into dorsal and ventral parts except in branchial region.
18. Brain is small and cerebellum is poorly developed.
19. IX and X cranial nerves arise from the brain behind the cranium; dorsal and ventral nerve roots are separate.
20. Sympathetic nervous system poorly developed.
21. Ear with single semi-circular canal is present.
22. Heart is simple and in the form "S" shaped tube is present.
23. A single median nostril is present.
24. Ciliated groove and endostyle, velum are present.

2.4.2 Features of Advancement over Protochordates

1. A distinct head is present.
2. Poorly developed cranium is present.
3. Though primitive brain is present, it is better developed than that of Amphioxus.
4. Heart is in the form of "S" shaped tube.
5. Pronephric, and mesonephric kidneys are present.
6. Many layered epidermis is present.
7. Dorsal spinal nerves are ganglionated.
8. Though rudimentary, vertebral column is present.
9. W - shaped myotomes are present.
10. Eyes and internal ear are present.
11. Sympathetic nervous system is present.
12. Definite liver is present.

2.4.3 Secondarily Specialised Features in Accordance with Habitat.

1. Presence of suctorial mouth which is used for attachment.
2. Presence of suctorial buccal funnel beset with horny teeth along the margin for attachment and scrapping of flesh from the host.
3. A rasping tongue bearing horny teeth
4. Branchial skeleton around the gills
5. Sac like gills are present.
6. Presence of hypophysial sac.
7. Nasal opening is a single mid dorsal aperture through which the hypophysial sac also opens.
8. Eggs are large with large quantities of yolk. Cleavage meroblastic and incomplete.
9. Development indirect in Petromyzontia.

Degenerate Features

1. Exo-skeleton is absent.
2. Unossified cartilagenous endo-skeleton is present.
3. Poorly developed liver is present.
4. Gall bladder, and bile duct are absent.
5. Paired fins and girdles are absent.
6. Muscles supporting the median fins are absent.
7. Eyes are rudimentary, without eye lids are present.

2.5. SUMMARY

Cyclostomes are jawless, ectoparasitic (or scavengers) primitive vertebrates skin naked with single nostril, opening into the nasohypophyseal tube. Pineal eye present. Endoskeleton cartilaginous with unconstricted notochord. Vertebrae importantly formed 5 to 16 pairs of marsupobranchi. Heart 2 chambered, 'S' shaped tube. Dorsal and vertical nerve roots remain separate. Inner ear with 1or 2 semicircular canals. Adults with liver, sympathetic nervous system (poorly developed) and a ganglios on dorsal nerve root. Sex differentiation occurs very late in life. Development direct or with a larval stage (ammocoetes). It includes lampreys and rag fishes.

2.6. GLOSSARY

Endostyle:	A ciliated glandular groove in the ventral wall of the pharynx.
Micro-phagous:	Eating micro food material.
Myotome:	Muscle segments.

Pineal body:	An out growth on roof of diencephalon (part of fore brain). It's removal retards growth.
Pronephros:	The first vertebrate kidney to form in the embryo functional in most vertebrate larvae and in adults of a few fish.
Sympathetic nervous: System	A division of autonomic nervous system.
Velum	A membrane or membranous partition.

2.7 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Describe the general characters of cyclostomes.
2. Discuss the affinities of cyclostomes.

II. Answer the following in about 10 lines.

1. General characters of the class Petromyzontia.
2. General characters of the class Myxinoidea.
3. *Annocoetes.*

Unit – 3 PISCES - GENERAL CHARACTERS AND CLASSIFICATION

Contents

3.1 OBJECTIVES

- To know the distinctive characters of cartilagenous fishes and their organisation.

3.2 GENERAL CHARACTERS

Fishes are aquatic cold blooded vertebrates. paired appendages are in the form of fins. They breathe by gills - vascular outgrowths of the pharynx, bordering gillclefts and supported by gill arches. in Dipnoi a single or double out growth from the gut-the air or swimbladder - functions as a lung, air being inspired at the surface of the water. In most osteichthyes swimbladder is typically hydrostatic. The skin bears numerous scales mainly or wholly formed in the dermis, but covered by a layer of epidermis, which may produce enamel. the skin also bears sensory structures, usually aggregated on the head and arranged in one or more "lateral lines" along the trunk. the myotomes persist in adult life. In many the gut ends in a cloaca, in others a distinct anus lies in front of the genital and urinary aperture, or apertures. The nostrils are paired and do not communicate with the mouth by the posterior nares; they are purely olfactory organs. There is no tympanic cavity or tympanum or ear ossicles. The heart has one auricle and one ventricle and contains only venous blood except in Dipnoi. The auricle shows hints of partition into two and receives arterial blood from the lungs and the venous blood from the body. In case of Dipnoi, there is a sinus venosus and there is often a muscular conus arteriosus. There is a bulbus arteriosus at the base of the ventral aorta in teleostei. Except in Dipnoi the paired posterior cardinal veins receive blood from the liver, kidneys and from the posterior region of the body. The kidney is usually a mesonephros. Cranial nerves are ten pairs. Sexes are separate. Most fishes lay eggs which are fertilised in the water. Compared with the cyclostomes, the fishes show a distinction in the following points:

(i) Jaws formed from the first visceral arch. (ii) the scales (iii) occurance of bone (iv) the true teeth (v) the paired nostrils (vi) the three semicircular canals (vii) the renal portal system (viii) the spleen (ix) and the genital ducts.

Fishes have been considered as Super class which contains three classes (i) **Placodermi** (ii) **Chondrichthyes** and (iii) **Osteichthyes**. The placodermi (Aphetohyoidea) survived from Devonian to Permian period. They were known as armoured fishes. the hyoiden gill slit is complete. The hyoiden arch does not support the jaws. Suspension of jaws is autodiastylic. Tail is heterocercal.

3.3 SUMMARY

Fishes are aquatic cold blooded vertebrates with fins. Body covered by dermal scales. They breathe by gills. Swimbladder [hydrostatic organ] is present mostly. Heart is generally described venous heart. Kidney is mesonephric 10 pairs of cranial nerves present. Tympanum absent sexes separate. The super class Pisces is divided into 3 classes viz., placoderm, chondrichthyes & osteichthyes. The placoderms were armoured and with autodiastylic or holostylic jaw suspenssion.

3.4 MODEL EXAMINATION QUESTIONS

1. Discuss the general characters of pisces pointing out the advancement over oyclostomes in about 30 lines
2. Write short answer on Aphetohyaidea.

Unit – 4 CHONDRICHTHYES (ELASMOBRANCHII)

Contents

4.1 GENERAL CHARACTERS

They have cartilagenous skeleton. Voracious carnivorous fishes Placoid scales are present in the skin. They have heterocercal tails. There are claspers on the pelvic fins of the males. Except in Holocephali there is no gill cover. Anterior to these there is often a spiracle with a rudimentary gill. The gill clefts are separated by complete septa, and the gill filaments are attached throughout their length to the septa. The mouth extends transversely on the ventral side of the head. The nostrils are also ventral. There is no air bladder. A spiral valve is present in the intestine. Into the cloaca the terminal part of the gut, the genital and urinary ducts open. The ventricle of the heart has a contractile conus arteriosus. Fertilisation is internal. The ova are few and large i.e. with much yolk. Large egg-purses are common but some elasmobranchs are viviparous.

4.2 SUBCLASS : SELACHII

This subclass includes living as well as extent sharks, rays and dog fishes having **hyostylic** or **amphistylic** suspensorium. Jaws are with several rows of sharp pointed teeth. There is no operculum. Nasal openings are paired. This subclass has four orders- **Cldosclachii. Pleurocanthodii, Protoselachii** and **Euselachii.**

4.2.1 Order : Cladoselachii

They existed from Devonian to Permian. They had fusiform body, a heterocercal tail with a large lower lobe. There were two dorsal fins and a keel like horizontal fin. The body was covered with small denticles. The large notochord was unconstricted. There were paired nostrils and large scale like denticles surrounded the eyes. e.g. *Cladoselache*

They were slender, fresh water, shark like fishes, which extended from the upper Devonian until the early triassic. Scales have not been observed. The cartilage of the skull, the amphistylic jaws and the branchial arches where some times well classified. The teeth were bipronged and had a central cusp. e.g.*Pleuracanthus*

4.2.3 Order:Protoselachii

They were found in the late Palaeozoic and Mesozoic ages. The pectoral fins were no longer fin folds but became notched at their posterior margins. The pelvic claspers had arisen in the males. e.g. *Heterodontes*

It includes sharks and rays. They are abundant in equatorial and temperate seas. The living and extent orders from the Jurassic onwards are distinguished by having numerous teeth developed in continual succession and by the pectoral fins having three basal pieces (pro, meso and meta-pterygium), from which a number of Preaxial radials spread out.

Suborder pleurotremata includes sharks in which the gill slits are lateral. Body is spindle shaped. Tail is heterocercal. Suborder Hypotremata includes skates and rays. The body is depressed i.e. dorsoventrally flattened. The gill slits are situated on the ventral side. e.g.*Scoliodon* (Dog fish)

Sphyrna (Hammerheaded shark) (Fig. 3/A)

Squalus (Spiny dog fish)

Spiracles are always present on the dorsal side. Pectoral fins are enlarged and jointed to the side of the head and body. There are five pairs of gills. *e.g. Pristis* (Saw fish)

Trygon (Sting ray)

Torpedo (Electric ray) Fig 3.1

Raja (Skate

4.3 SUBCLASS : BRADYODONTI

Chimaera and its allies only are surviving now. This subclass contains two orders

4.3.1 Order : Eubrodyodonti

This teeth were crusling plates. After period of successful expansion disappeared at about the end of the palaezoic. e.g. *Helodus.*

4.3.2 Order : Holocephali

They arose in Jurassic.There is a fold or operculum which covers four gill clefts leaving only one external opening on each side. Spiracles are absent. First dorsal fin with strong spines is situated far forwards. Tail is slender and whip like. Scales are absent in the adult. Each jaw is provided with a large tooth plate. Urinogenital aperture is separate from the anus e.g. *Chimaera* (Fig. 3.1.E)

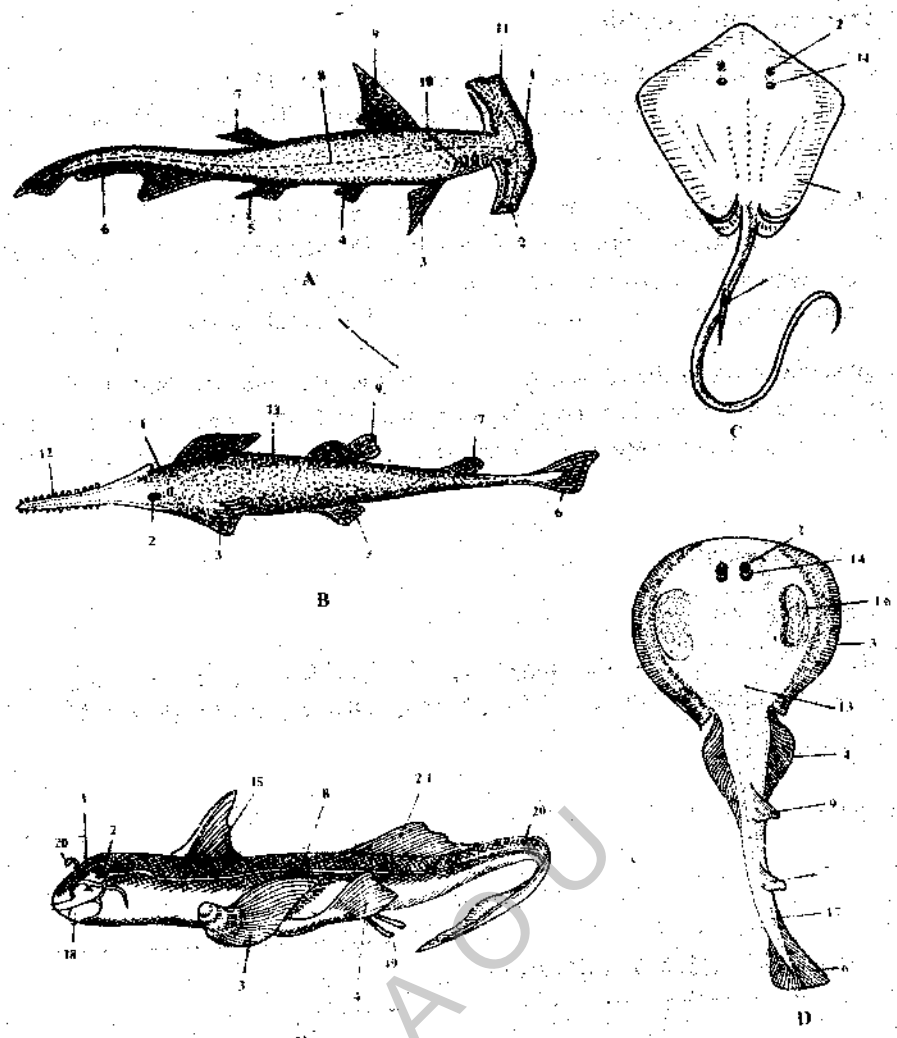
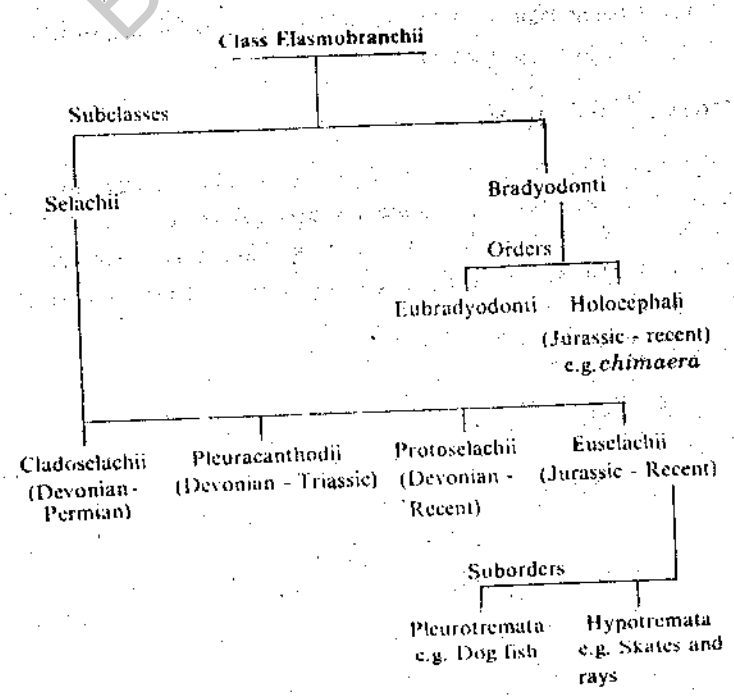


Fig 3.1 Elasmobranch fishes. A. *Shhyrna.* B. *Pristis* C. *Sting Ray* D. *Electric Ray* E. *Chimaera* 1. Head 2. Eye 3. Pectoral fin 4. Pelvic fin 5. Anal fin 6. Caudal fin 7. Second dorsal fin 8. Lateral line 9.First dorsal fin 10. Gill slits 11.Head lobe. 12.Rostrum 13. Trunk 14. Spiracle 15. Spine 16. Electric organ 17. Tail 18. Mouth 19. Clasper 20. Frontal clasper 21. Dorsal fin.



4.4 SUMMARY

The class Elasmobranchii includes the cartilaginous fishes. They are peculiar in several respects: skeleton cartilaginous, skin with placoid scales, males with claspers; mouth and nostrils ventral, intestinal spiral valve, cloaca and internal fertilisation. Ova few, large and laid in egg-purses-some elasmobranchs are viviparous with yolk sac placenta eg. sharks, rays skates.

4.5 MODEL EXAMINATION QUESTIONS

I. **Answer the following in about 30 lines**

1. Give an account of the classification of Elasmobranchs into orders with examples.
2. Out line the general characters of fishes.

II. **Answer the following in about 10 lines**

1. Holocephali.
2. Euselachii.
3. Chondrichthyes.

Unit - 5 MORPHOLOGY AND EXO-SKELETON OF SHARK

Contents

5.1 OBJECTIVE

- To know the external features of Indian dogfish and the skin derivative Placoid scales.

5.2 INTRODUCTION

Scoliodon is commonly called as dogfish as the mouth of this fish resembles the mouth of the dog. They are found in all parts of the seas. *Scoliodon sorrakowah* found in the seas of India and in seas upto Malaya Archipelago. Scoliodon has a wide range of distribution occuring in Red sea, Indian Ocean, Bay of Bengal and also around the coasts of West Indies, Zanzibar, Ceylon and the Philippine Islands. It has also been recorded in Eastern Coasts of South America. Scoliodon is carnivorous and scavenger. They are very swift swimming forms as the body is perfectly stream lined without having rigid projections.

The swimming is effected by the alternate contraction and relaxation of the myotomes of the two sides of the body. The fins maintain equilibrium. They are viviparous (give birth to young ones). Fertilization is internal. During copulation, the copulatory organs are inserted into the body of the female and through its canal the male introduces the sperms into the vagina of the female.

Shape

It has a long, laterally compressed, spindle shaped body, which tapers at both ends. Adult specimen measures about 0.60 m, in length. The colour of the body is dark grey above and pale white beneath. The posterior parts of the caudal fins are more or less dark; therefore, it is also called black finned shark. The body can be divided indistinctly into head, trunk and tail.

5.3 HEAD

The Head is dorso-ventrally compressed and is produced in front into a flat, pointed snout. There are two large, circular eyes situated laterally on the head. Each eye is provided with a movable nictitating membrane, which is situated along the antero - ventral border and can

cover the eye in time of danger. The pupil is narrow and vertical. There are two obliquely placed crescent shaped nostrils which are situated one on each side of the angle of the mouth. Each nostril is partially covered by a small fold of skin on each side. The function of nostril is only olfactory and not respiratory.

Nostrils are not connected with the mouth. As such, there are no internal nostrils. Behind he eyes are situated five vertical slits called the bronchial or gill clefts. These apertures open nto the gill pouches and there into the pharynx. On the ventral side of the head there is a white crescentric opening called mouth. It is bounded by upper and lower jaws. Each serrated edges. They are homologous with placoid scales. The teeth of scoliodon are not embedded in the cartilage of jaws but are anchored in the dermis by the fibres of connective tissue. They are polyphyodont i.e. there is an unlimited succession of teeth.

Jaws are helpful for catching the prey and this is possible by raising the snout and pushing the mouth forward. Trunk is elliptical in transverse section and its thickest part is situated in the middle of the body. The trunk is followed by a tail which is gradually tapering and is laterally compressed. It is also slightly bent upwards. The tail is heterocercal.

A faint line runs on each side of the body from head to tail, which is called lateral line, underneath which a canal runs along each side of the body and possesses special receptor organs.

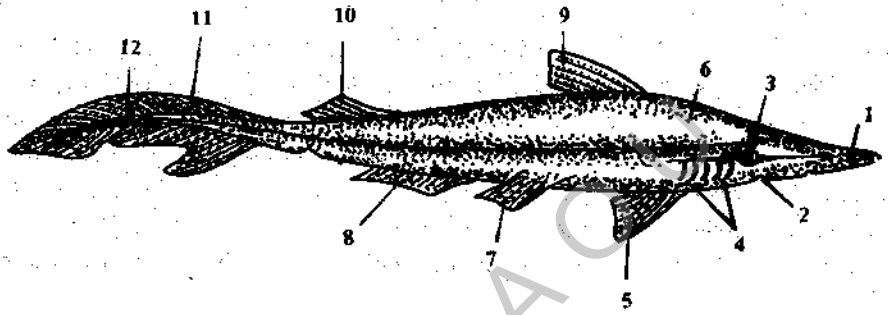


Fig 5.1 Side view of *Scoliodon* 1. Snout 2. Mouth 3. Eye 4. Gill slits 5. Pectoral fin 6. Trunk 7. Pelvic fin 8. Anal 9.First dorsal fin 10.Second dorsal fin 11. Caudal fin 12. Heterocercal tail.

5.4 FINS

There are two types of fins in Scoliodon. (a) unpaired or median fins and (b) paired or lateral fins.

Unpaired fins : First dorsal median fin is triangular in shape and is situated a little in front of the middle of the body. The second dorsal fin is also triangular in shape but is very small and is situated between the first dorsal fin and the tip of the tail.

Ventral median fin is situated in the mid-ventral line just opposite the space between the two dorsal fins, more or less in front of the second dorsal. The basal edges of the two dorsal and ventral fins are produced behind into basal lobes, which are long, narrow and fleshy processes.

Fringing the dorsal and ventral parts of the tail there is a caudal fin. The dorsal lobe is very much reduced and starts by a notch called the caudal pit, which is also on the ventral side. The ventral lobe of the caudal fin is well developed and is divided into two parts, the anterior which is large, while the posterior is smaller and less extensive.

Paired fins : There are two paired lateral fins: the anterior pectoral fins and the posterior pelvic fins. Pectoral fins are situated behind the gill clefts along the ventrolateral margins of the body. The pelvic fins are much smaller than the pectorals and are placed close together from the ventral surface at the junction of the trunk and tail and enclose a cloacal aperture. In males the pelvic fins possess on their inner side a clasper or myapterigium.

5.5 EXOSKELETON

The skin or integument consists of two layers : an *outer epidermis* made up of many layers of epithelial cells, among which are situated numerous unicellular mucous glands and an *inner dermis* is composed of dense connective tissues together with smooth muscle fibres, pigment cells, blood capillaries, and nerves.

The dermis is firmly attached to the under-lying muscles, and as such the skin is tightly fitted over the body. In living condition, the skin is smooth but, in the preserved specimens, the skin is rough due to the presence of placoid scales, which are embedded in the dermis with spiny projections directed backwards from the surface of the skin.

Structure of the Placoid Scales

Each placoid scale consists of a basal plate, which is embedded in the dermis and spine.

Basal Plate: It is rhomboidal or diamond shaped plate formed of a cement like substance. It lies embedded in the dermis and is firmly attached to it by strong fibres of connective tissue. The basal plate is perforated by a small opening which leads into pulp cavity of the spine. In living condition the blood vessels nerve fibres and lymph channels enter the pulp cavity through this opening. The pulp cavity contains a kind of vascular tissue called dermal cup containing numerous odontoblasts or dentine forming cells, blood vessels, nerves and lymph channels. The basal plate is formed of calcified tissue similar to the cement of our teeth.

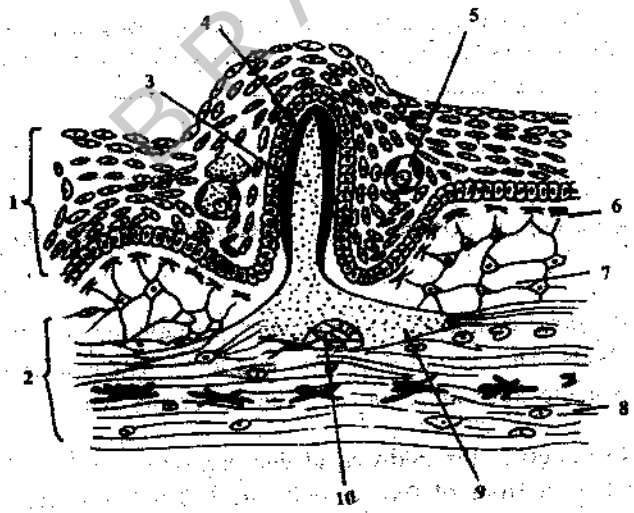


Fig 5.2 Skin of Dog fish. 1. Epidermis 2. Dermis 3. Spine 4. Enamel 5. Unicellular epidermal gland 6. Melanophore. 7. Loose layer 8. Compact layer 9. Root 10. Dermal papilla.

The Spine : It is a flat, backwardly directed trident structure projecting out of the integument and giving it roughness. The spine is composed of hard canaliculized substance, the dentine, coated with enamel like substance called vitro-dentine.

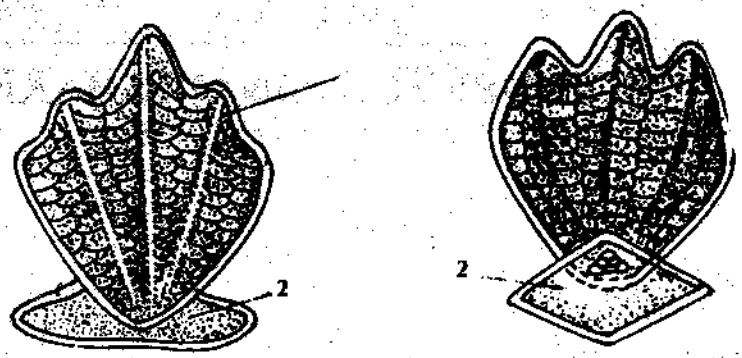


Fig. 5.3 Placoid scales of Scoliodon 1. Spine 2. Basal plate.

5.6 SUMMARY

Scoliodon is commonly called as the Indian dog fish which has wide distribution. They are fast swimmers with carnivorous habit. Body is divisible into head, trunk and tail. Head dorso-ventrally compressed. Mouth ventral with backwardly directed, polyphyodont teeth. Tail fin heterocercal type. Skin is rough due to the presence of placoid scales. Lateral line sense organs present.

5.7 MODEL EXAMINATION QUESTIONS

I. Answer the following in 30 lines.

1. Describe the external characters of Dogfish.

II. Answer the following in 10 lines.

1. Write an account on "Placoid scales" .

Unit - 6 ENDOSKELETON OF SHARK

Contents

6.1 OBJECTIVES

- To study the axial and appendicular skeleton and viscera of the Indian dog fish

6.2 ENDOSKELETON

The endoskeleton is entirely cartilagenous. There is no bone at all. It is divided into (a) Axial skeleton consisting of the vertebral column, skull and gill arches (visceral skeleton). (b) Appendicular skeleton consists of pectoral girdle, pelvic girdle, pelvic fin and pectoral fin.

6.2.1 Axial skeleton

The vertebral column : The vertebrae in dog fish are about 130 in number. These are cartilagenous, solid structured, pierced by the notochord. Vertebrae are of two types (a) trunk vertebrae (b) tail vertebrae. Each vertebra is hollow at both the ends. Such types of vertebrae are called amphicoelous (Fig.6.1).

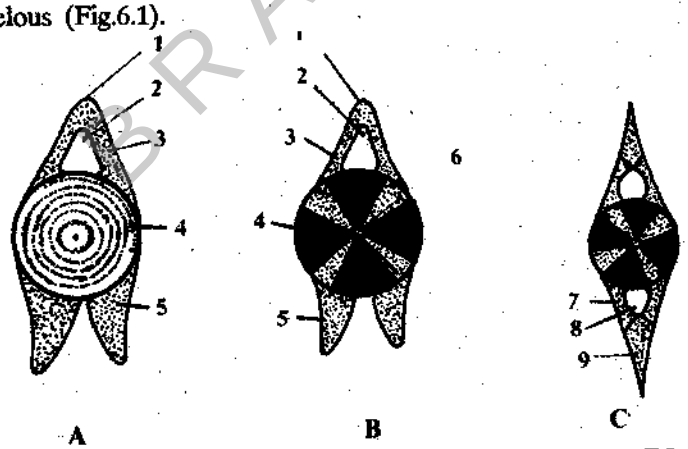


Fig 6.1 Vertebrae of *Scoliodon* A. Trunk vertebra (Anterior view) B. T.S. of trunk vertebra C. T.S. of Caudal vertebra 1. Neural spine 2. Neural canal 3. Neural arch 4. Centrum 5. Transverse process 6. Passage for notochord 7. Haemal arch. 8. Haemal canal 9. Haemal spine.

The vertebra consists of a centrum which is concave at both ends and the hollows of centra are filled with the remains of the notochord. The centra articulate with one another, end to end. Each centrum bears dorsally the neural arch enclosing spinal cord. Attached to the centrum laterally are a pair of transverse processes, which are short in the anterior region of the trunk, and longer and bent downwards in the posterior part; they bear short ribs lying in the transverse septum. Caudal vertebrae are distinguished from the trunk vertebrae by the

presence of haemal arches, enclosing the caudal artery and the caudal vein. Alternating with neutral arches, are the intervertebral neural plates (inter dorsals). The neural spines are formed in the spaces between the upper ends of vertebral and inter vertebral neural plates.

The skull of the *Scoliodon* is entirely made up of cartilage with deposits of calcium salts at some places. Bone is completely lacking. The condition of the skull is not a primitive character but is secondarily degenerate.. The skull is made up of (a) **Chondrocranum** having neurocranium enclosing the brain, olfactory capsule (ethmoid region) and an auditory capsule (auditory region) (b) **splanchnocranium** or **visceral** skeleton consisting of jaws, suspensorium and skeleton of gills (Fig 6.2).

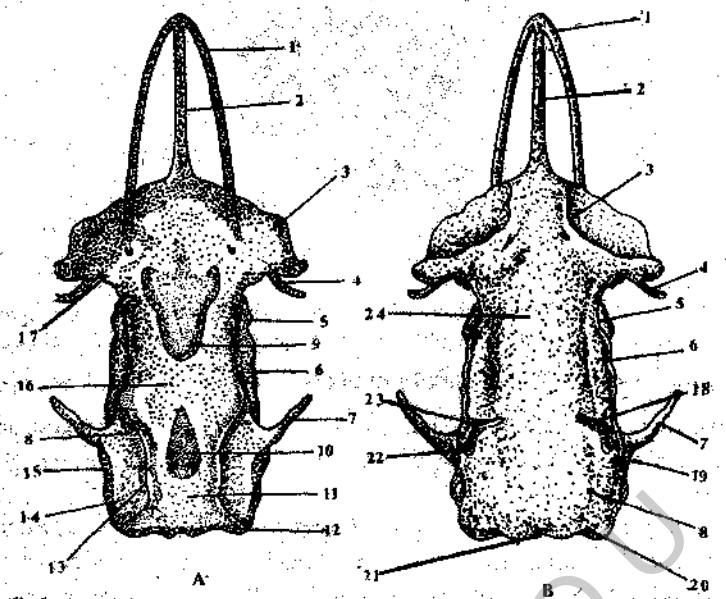


Fig 6.2 Skull of *Scoliodon* A. Dorsal view B. Ventral view 1. Dorsolateral cartilage of rostrum 2. Ventro-median cartilage 3. Olfactory capsule 4. Preorbital process 5. Accessory cartilage of infra orbital ridge. 6. Floor of the orbit 7. Post orbital cartilage 8. Auditory region 9. Anterior fontanelle 10. Parietal fossa 11. Occipital crest 12. Posterior vertical semicircular canal 13. Anterior vertical semicircular canal 14. Horizontal semicircular canal 15. Articular surface for hyomandibular 16. Roof of cranium 17. Foraman for opthalmic 18. Opening for internal carotid artery 19. Articular surface for hyomandibular 20. Foramen for tenth nerve 21. Foramen magnum 22. Carotid canal 23. Opening of stapedial artery 24. Floor of cranium.

Cranium is in the form of a cartilagenous cylinder enclosing the brain. The cranium can be divided into four regions (a) **occipital** (b) **auditory** (c) **orbital** (d) **ethmoidal.** The occipital region forms the posterior part of the cranium forming the median, large opening **foramen magnum** through which the brain is continued into the spinal cord. On either side of the foramen magnum there is an **occipital condyle** for articulation with the first vertebra.

The auditory region consists of an **auditory capsule** and a part of the cranium with which they are fused. The large laterally projected auditory capsules possess the auditory organs. The orbit lodges the eye balls and muscles. The ventral side of the cranium is broad and flat and possesses towards its posterior end two obliquely transverse grooves called **carotid canals** situated one on each side. At the anterior end the cranium becomes narrower and on the ventral side, olfactory capsules are found anteriorly. The ethmoidal region of the cranium consists of olfactory capsule, and rostrum. The olfactory capsules are separated by cartilage called **internasal septum.** On the dorsal side, the cranial roof is incomplete due to the presence of anterior fontanelle.

The visceral skeleton is composed of seven visceral arches. The first arch is the mandibular arch. It borders the mouth and gives rise the upper and lower jaws. Each half of the arch is divided into a dorsal segment, the **palatoquadrate** and a ventral segment **meckel's cartilage.**

The palato-quadrates of the two sides grow forwards along the margin of the mouth and give rise to the upper jaw; similarly the meckel's cartilages grow forward along the lower

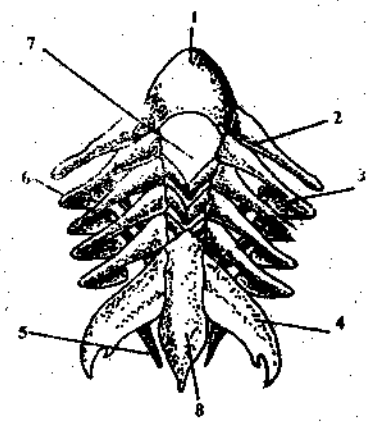


Fig. 6.3 Ventral view of the Visceral arches of *Scoliodon*. 1. Basihyal. 2. Cardohyal 3. Epibranchial. 4. Ceratobranchial 5. Fused IV and V pharyngeobranchial 6. Ceratobranchial. 7. Hypobranchial

margin of the mouth, parallel to the **palato-quardrate and** form the lower jaw (Fig. 6.3). At their hind ends, the palatoquadrates and meckel's cartilages are hinged and move on one another; anteriorly the two halves of the upper and lower jaws are joined by ligaments.

The second visceral arch is hyoid arch. Each half is composed of a dorsal segment hyomandibular and a ventral segment, the ceratohyal. The ceratohyals of the two sides meet in a median basihyal. The hyomandibular is a stout rod articulating above with auditory capsule, and below with the upper and lower jaws at their junction. The upper jaw is attached to the cranium by ligaments and suspended from the skull by the hyomandibular this method of suspension is termed hyostylic.

The remaining five visceral arches termed branchial arches and support the wall of the pharynx between the gill slits. Each half of the arch is supported by four cartilages. They are from above, the pharyngo branchial, the epibranchial, the cerato branchial and the hypobranchial. The hypobranchials of the two sides meet below in a median basibranchial.

6.2.2 The Appendicular Skeleton

Fins : There are two kinds of fins, the median, or unpaired and the lateral or paired. Both arise as ectodermal folds into which extends the mesenchyme which gives rise to the supporting cartilages.

The median fins are supported by a series of jointed cartilagenous rods, the pterygiophore on somactidia attached to the vertebral column by ligament. The pterygiophores support distally the horny fin rays or cerato-trichia arising as a double series in the skin or either side of fin. The ceratotrichia, though termed horny rays do not contain true horn, which is epidermal, but has elastin of mesenchymatous origin.

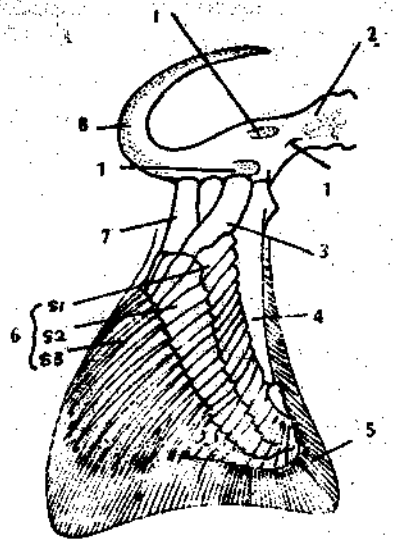


Fig. 6.4 Pectoral Girdle and fin of Scoliodon (Ventral view) 1. Foramen for the branchial artery and nerve 2. Caracoid cartilage 3. Mesopterygium 4. Metapterygium 5. Ceratotrichia 6. Somactidia 7. Prop

Pectoral Girdle and Pectoral Fins

The pectoral girdle (Fig 6.4) is a hoop of cartilage, in complete dorsally and embedded in the body wall behind the last branchial arch. The paired pectoral fins are attached to this laterally, more or less in the middle of each half, and the surfaces of attachment are the glenoid facets.

The portion dorsal to the glenoid facet is distinguished as the scapula and that ventral to it as the coracoid. The coracoids of the two sides are continuous across the ventral line where as the scapulae leave a gap for the vertebral column.

The pectoral fins have for their skeleton, each three large basal cartilages named proterygium, mesopterygium, and metapterygium followed by a number of radial cartilages or pteregyophores and the latter in their turn bear a series of ceratotrachia which support the web of the fin.

Pelvic Girdle and Pelvic fins

The pelvic girdle is a transverse bar of cartilage (ischiopubic lying in front of the cloaca. The pelvic fins are attached to it on either side (Fig. 6.5).

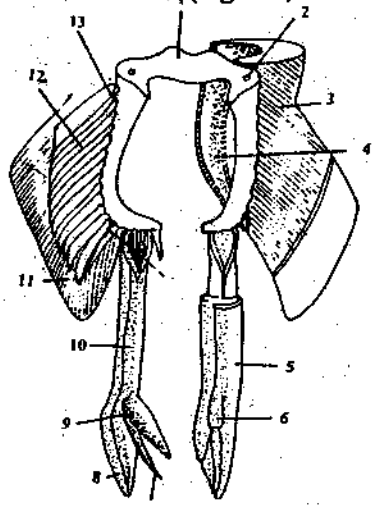


Fig 6.5 Skeleton of Pelvic girdle and Pelvic fin of male *Scoliodon* 1. Ischopubis 2. Foramen 3. Pelvic fin (Dorsal view) 4. Siphon 5. Clasper (mixipterygia) 6. Accessory cartilage. 7. Style 8. Ventral plate 9. Dorsal plate 10. Axial cartilage of clasper 11. Ceratotrichia 12. Somactidia 13. Basipterygium.

Each pelvic fin has a single backwardly directed basal cartilage (basipterygium) articulating with the pelvic girdle. Attached to the basipterygium are the radial cartilages and they are followed by ceratotrichia which support the web. In the male shark, the posterior radial cartilage of each side is enlarged and grooved to form the clasper (Fig. 6.5).

6.3 SUMMARY

The endoskeleton of the shark is formed of cartilage. The endoskeleton can be divided into axial and appendicular skeletons. The vertebrae are amphicoelous, numbering about 130. Caudal vertebrae can be identified by the presence of haemal arches. The splanchnocranium is composed of 7 pairs of visceral arches. The hyomandibular acts as a lever suspending the jaws from the auditory capsule, hyostylic type of jaw suspension. The pectoral girdle is hoop-like while the pelvic girdle is a transverse bar. The posterior radial cartilage of each pelvic fin is modified as a clasper.

6.4 MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Give an account of the appendicular skeleton in dogfish.

II. Answer the following questions in about 10 lines each.

1. Describe the skull of Dogfish.
2. Give an account of Chondrocranium and Splanchnocranium.

Unit – 7 VISCERA OF SHARK

Contents

7.1 INTRODUCTION

Viscera includes all those vital organs of the body that lie within the space of the abdominal cavity (coelom) and are surrounded by peritoneal tissues. The cavity around the visceral organs is also referred to as Perivisceral cavity. The body cavity is divided into two unequal compartments by a septum transvessum; exterior smaller compartments and the pericardial cavity and the posterior larger one, the abdominal cavity. It opens out through a pair of abdominal pores situated on the papillae, can be either side of the cloacal aperture

7.2 HEART

Heart is a dorso-ventrally bent muscular tube made up of four chambers. (i) Sinus Venosus, (2) Atrium or auricle, (3) Ventricle,(4) Conus arteriosus.

7.3 ALIMENTARY CANAL

The Alimentary Canal consists of mouth, buccal cavity, pharynx, oesophagus, stomach, intestine and rectum. Mouth is a crescentic opening, situated on the ventral side. Mouth opens into spacious dorso-ventrally compressed buccal cavity.

Buccal cavity is lined with thick mucous membrane raised ventrally into thick fold, so as to form a non-muscular and non- glandular tongue. The mucous membrane is rough due to the presence of dermal denticle. In the jaws these denticles are modified into teeth which are oblique, sharp, compressed cusps. Teeth are found in inner margins of lower and upper jaws, arranged in several parallel rows. They are all alike in shape and are homodont and polyphyodont. The buccal cavity opens into the pharynx. Internally the cavity of the pharynx is lined with mucous membrane. Possessing a large number of dermal denticles

Oesophagous is very short, and has a thick muscular wall widens behind, so as to form a large muscular stomach. The stomach is a 'J' shaped organ, having two limbs, proximal limb is longer and is called cardiac stomach, where as the shorter distal limb is called pyloric stomach. At the junction of cardial and pyloric stomach there is a blind growth called the blind sac, a pyloric valve, which guards the entrance of pyloric stomach in to a small thick walled muscular chamber called bursa entiana which is continuous with the intestine.

The intestine is a wide tube; it runs straight backward and opens behind into the rectum. The internal surface of the intestine is increased by the presence of characteristic fold, a mucous membrane called the scroll valve; one edge of the scroll valve is attached to the inner wall of the intestine and the other is rolled up longitudinally on itself so as to form a scroll, having an anticlockwise spiral of about two and half (2 1/2) turns. the scroll valve increases the absorptive surface and also check the rapid passage of the food through the intestine.

Intestine opens in to the rectum which in turn opens behind into the cloaca. In the rectum the rectal gland opens dorsally. Into the cloaca the alimentary canal as well as the urino-genital ducts will open.

Liver is a long yellowish gland made up of two lobes which extend backwards along the greater part of abdominal cavity. The two tubes are jointed anteriorly where they are attached to the wall of the abdominal cavity by a ligament. Situated in the anterior part of the right lobe of liver is a 'Y' shaped thin walled sac called the gall bladder. It's function is to store the bile secreted by the liver.

Pancreas: It is a compact and bilobed gland situated between the two limbs of the stomach. The dorsal lobe is to parallel to posterior part of the cardiac stomach, which the ventral lobe is applied to the pyloric stomach. The pancreatic duct opens into the intestine just opposite to the opening of the bile duct.

Spleen: Spleen is bilobed non-digestive gland (a) Proximal lobe extending along the outer curvature of the cardiac stomach while (b) the other elongated, distal lobe is situated parallel to the pyloric stomach. Spleen is a lymphoid organ, structure it such produces lymphocytes and filters out invading foreign bodies.

The food of the *Scoliodon* is mainly consists of other fishes but it also feeds on lobsters, rock-crabs etc.

Scoliodon cannot masticate its food, as the teeth are not suited to this purpose, but it swallows its food. There are no salivary glands in the mouth and therefore digestion does not take place in mouth, buccal cavity and oesophagus. The mucous membrane of the buccal cavity produces mucous which lubricates the food. Digestion begins in the stomach which contains hydrochloric acid and pepsin, which convert the proteins into peptones and proteoses where the semidigested food enters into intestine, it is affected by the bile and pancreatic juices. The bile juice makes the food alkaline and helps the action of the pancreatic juice. The pancreas secretes trypsinogen, which secretes trypsin and starch splitting ferment called amylopsin, and fat splitting ferment the lipase. The food is digested and is absorbed in the intestine, which possesses great absorptive surface. The waste products are then passed out.

7.4 URINOGENITAL SYSTEM

In *scoliodon* and other vertebrates the organs of reproduction and those of excretion are closely associated. Therefore they are studied together.

Male Urinogenital System: The kidneys in the male are a pair of long strap shaped structures. They extend almost entire length of the body. They are mesonephric in origin. Each consists of anterior slender part genital mesonephros and posterior thicker part called renal or caudal

mesonephros. This type of kidney is called opisthonephros kidney. Testis are pairs of elongated structures. Each testis jointed to its anterior end with kidney of its own side by a few minute ducts called vasaefferentia which open in to the greatly coiled wolfian duct of vas deferens. Behind the thicker part of the kidney vas deferens enlarges to form the vesicula seminalis. The two vesicula seminalis open into a large triangular chamber called urinogenital sinus which opens into cloaca. On either side of the urinogenital sinus is situated club shaped sperm sac. Siphons are a pair of long glandular sacs are also personal (Fig 6.5)

Female Urinogenital System : In the female there is no direct connection between kidneys and genital organs. The anterior part of the kidney is extremely reduced while posterior part extends into the cloaca. Ureters are long. They open directly into cloaca.

Ovaries are paired situated on either side of the vertebral column behind the base of the liver. The oviducts of the Mullerian ducts are independent ducts having no connection with the kidneys. Both the anterior ends of the oviducts meet to form a longitudinal slit called oviducal funnel. Just behind the funnel, oviducts curve around towards mid-dorsal line till each enlarges to form a shell gland, which is the dilated part of the each oviduct. In the posterior region each oviduct expands into uterus in which 4-6 embryos develop. The two uteri unite to form a vagina which opens into cloaca by a large median aperture.

7.5 SUMMARY

Viscera includes all the vital organs. The digestive system includes the tongue, digestive tract and the digestive glands like liver pancreas and the intestinal glands. Teeth homodont and polyphyodont and intestines with scroll value.

The shark kidney is mesonephric. It is differentiated into the anterior genital and a posterior renal part. A pair of testes in males and a pair of ovaries in females are present. The wolfian duct or vasdeferens enlarges into seminal vesicle in males while in female, the mullerian duct (oviduct) enlarges into a shell gland and uterus. A pair of claspers, sperm sacs and siphons are present in male shark. Cloaca is also seen.

7.6 MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Describe the alimentary canal of dogfish.

II. Answer the following in about 10 lines.

1. Out line the female urinogenital organs of Dogfish

7.7 GLOSSARY

Clasper : Organs of copulation

Heterocercal : Unsymmetrical tail fin. It is two lobed with terminal part turned upwards

Ligament : Band of collagen connecting two bones

Mesonephros	:	A type of kidney found in the embryos of all vertebrates and retained as the functional kidney in animates
Olfactory organs	:	Organs pertaining to the sense of smell
Polyphyodont	:	The teeth are replaced continuously throughout life - a phenomenon seen in lower vertebrates
Spiracle	:	Remnant of the first gill slit in many fishes (in case of vertebrates)

Unit – 8 OSTEICHTHYES – GENERAL CHARACTERS AND CLASSIFICATION

Contents

8.1 OBJECTIVES

- To know the distinctive features of bony fishes and their diversity of forms.

8.2 GENERAL CHARACTERS

The Osteichthyes comprise the bony fishes which form the majority of the living fishes. The first bony fish was found as fossil in the early Devonian age; as such the class is older than Elasmobranchii and their bony skeleton is a retention of their ancestral forms specialised and perfected for modern needs. They are found in marine and fresh waters. The exoskeleton is in the form of cycloid, ctenoid or ganoid scales. The mouth is usually terminal. There is always a gill cover operculum. The interbranchial septa are much reduced. The gill filaments project freely from the gill arches. There is usually a swim bladder. There are no claspers, no naso-buccal grooves. There is no cloaca nor spiracles. Olfactory lobes and cerebellum are small.

The caudal fin is diphycercal. The ova are small and numerous. Cleavage usually meroblastic, some times holoblastic. The oviducts are continuous with the ovaries. Fertilisation is usually external.

The class Osteichthyes has two sub classes 1. Actinopterygii 2. Crossopterygii.

8.2.1 General Characters of Actinopterygii

The earliest known actinopterygians came from fresh waters of the mid Devonian. These forms got their name from the structure of the paired fins. The modern forms have the fins with basal supports (bony) reduced almost to vanishing point. The structure of the scales is ganoid. Absorbing surface of the intestine usually enlarged by elongation of the intestinal tract. The respiratory arrangements have changed from a gill condition near the laminar type to the fully filamentar. The conus arteriosus is extended into bulbus arteriosus. The brain structure is characteristic in having the large **corpora**, striata, **cerebellum** and **medulla**, presence of the **valvula cerebelli** and in the absence of cerebral lobes. There is no trace of internal nostrils. Little muscle or other soft tissue extends into the paired fins. These depend essentially on flexible dermal rays for their support. Example: *Acipenser* (Fig. 8.1 A) *Polypterus* (Fig. 8.1 B),

Lepisosteus (Fig. 8.1 C), *Amia* (Fig. 8.1 D), *Anabas* (Fig. 8.2 B), *Hippocampus* (Fig. 8.2 C), *Exocoetus* (Fig. 8.2 A).

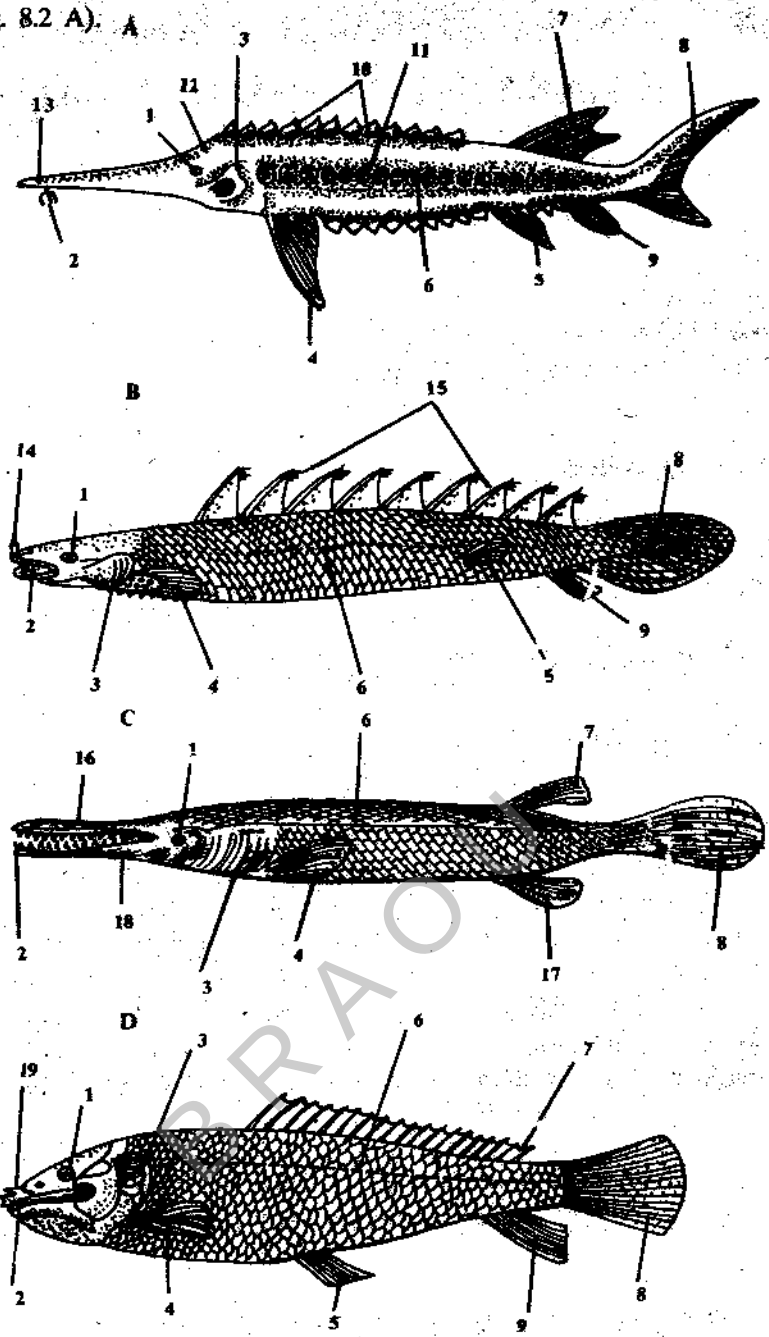


Fig 8.1 Some Actinopterygili fishes A. *Acipenser* B. *Polypterus* C. *Lepidosteus* D. Amia 1. Eye 2. Mouth 3. Operculum 4. Pectoral fin 5. Pelvic fin 6. Lateral line 7. Dorsal fin 8. Caudal fin 9. Anal fin 10. Scutes 11. Trunk 12. Head 13. Rostrum 14. Nostril 15. Dorsal finlets 16. Upper jaw 17. Ventral fin 18. Lower jaw 19. Nasal tube 20. barbels.

8.2.2 General Characters of Crossopterygii

This sub class was once abundant but it is reduced to one, recently discovered coelacanth and to a few species of Dipnoi. They have paired fins with a scale covered lobe around which fin rays are attached. Skeleton of pectoral fin is with central pointed axis having radial extension on each side. Tail is diphycercal. Internal nares or choane are present.

Examples :

(1) *Latimeria* (Living fossil)
(2) *Neoceratodus*
(3) *Protopterus* Lung fishes (Fig. 9.1)
(4) *Lepidosiren*

Latimeria

In 1938 a fisherman collected a curious fish from the east coast of South Africa. It was five feet long weighing 127 lbs. This was sent to Miss. Cairtenary Latimer who sent a sketch of this to Dr. J. L. B. Smith, Ichthyologist of Rhodes university college at Grahamstow. He recognised it as a surviving member of one of the main divisions (coclacanthus) of the crossopterygii and named it as *Latimeria Chalumnae* is named after the discoverer and locality. Another coelacanth was captured in the same locality in 1952 by Dr. Smith. Latimeria is said to be the living fossil. The entire body is covered with cosmoid scales with an enamelled surface. The tail is diphycercal with small central projecting lobe. The paired fins are lobed. There are two dorsal fins. The anterior one is supported by a bony plate and the posterior by an osseous structure not unlike that of pectoral fin. The anal fin is also lobed. The notochord is persistent and unconstricted. Its anterior end projects as far as the region of forebrain. The vertebral column is unossified except the spines. The skull possesses a powerful and freely movable hinge on the dorsal surface between the parietals and post parietals. The air bladder is very small and is hydrostatic in function. The liver is bilobed and a gall bladder occurs. The brain is very small. There is a spiral valve in the intestine. The anterior nasal opening lie at the tip of the nasal tube. The kidneys are fused. The ureters are symmetrical and each dilates behind to form a bladder.

Lung Fishes

There are three living genera of lung fishes grouped as Dipnoi, are discontinuously distributed. These genera are *Neoceratodus* from Burnett and Mary rivers, Queensland, Australia; *Protopterus* from the rivers of West Africa and *Lepidosiren* from the swamps of Amazon basin of South America. The details are described in Unit No. 10.

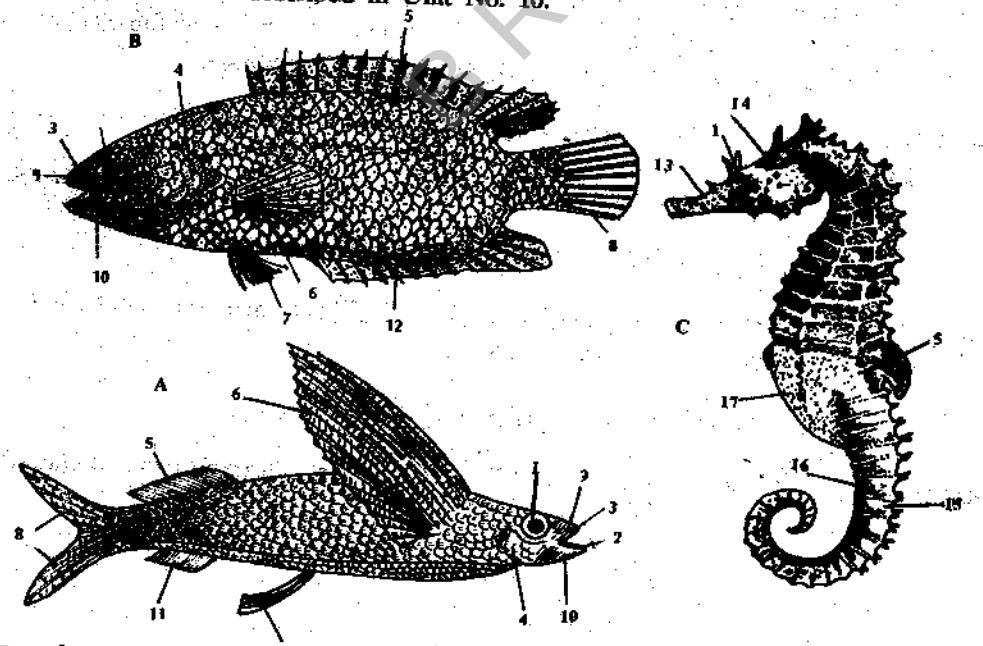
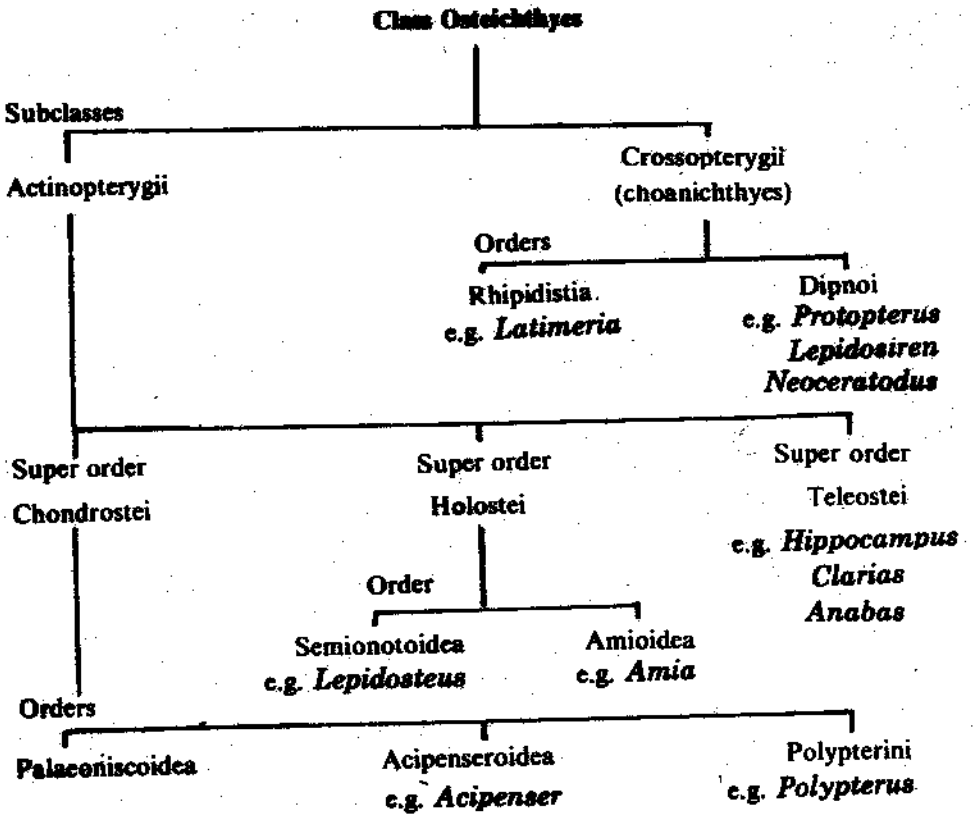


Fig 8.2 Some Actinopterygii fishes. A. *Exocoetus* B. *Anabas* C. *Hippocampus* 1. Eye 2. Mouth 3. Nostril 4. Operculum 5. Dorsal fin 6. Pectoral fin 7. Pelvic fin 8. Caudal fin 9. Upper jaw 10. Lower jaw 11. Ventral fin 12. Anal fin 13. Snout 14. Head 15. Ring like plates 16. Prehensive tail 17. Brood pouch.



8.3 SUMMARY

Osteichthyes (bony fishes) enjoy wide distribution. Body covered by cycloid, ctenoid or ganoid scales. Gills are covered by operculum. Gill filaments are free and usually a swim bladder is present. Neither cloaca nor spiracles seen. Cerebellum is small. Caudal fin homocercal or diphycercal. Cleavage meroblastic. Fertilisation external. Osteichthyes are divisible into two subclasses viz., Actinopterygii (rayfinned fishes) and crossopeterygii (lobe finned fishes). The paired fins of crossopterygii are built on basic plan of **archipterygium.**

8.4 GLOSSARY

Barbel : A bend - like appendage present at the mouth

Continental Shelf : The zone extending from the line if permanent immersion to the depth usually upto 120 meters.

Estuary : The wide lower tidal part of a river

Plankton : All the floating or drifting life of the pelagic division of the sea.

8.5 MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Describe the general characters of class Osteichthyes. What are the main differences between Actinopterygii and Crossopterygii.

II. Answer the following questions in about 10 lines.

1. Describe the general characters of Actinopterygii. Give few example.
2. Classify Osteichthyes into sub classes with suitable examples.

Unit – 9 COMMON EDIBLE FISHES OF ANDHRA PRADESH

Contents

9.1 OBJECTIVES

To know the edible fishes , a major resource and their availability in the state of Andhra Pradesh

9.2 INTRODUCTION

Both marine and fresh water fishes exist in Andhra Pradesh. The annual landings of marine fish in Andhra Pradesh were 28.846; 29,464; 56,720 metric tons during 1958, '59 and '60 respectively. Important shoaling fishes caught are the oil sardines (**Sardinella longiceps**) mackerell,silver bellies, ribbon fishes, cat fishes and soles. Catches by travelers include mostly the bottom feeding fishes like rudder fishes (*Lethrinus* sp.) snappers (*Lutjnus* sp.) rock perches (*Epinerphelus* sp) and the spade fish (*Ephippus orbis*). Some of the important edible fishes of Andhra Pradesh are dealt in this lesson, which are found in marine and fresh waters. (rivers, tanks and ponds).

9.3 MARINE FISHES

Eleutheronema tetradactylus (Tel : Buddatamaga, Boddumaga and Magasahala)

It is abunduntly available in coastal waters. The Dorsal surface of the fish is green with silvery shadow. The ventral and lateral surfaces are whitish yellow. It attains a length of 1.8 metres, weighing 140 kilograms. It is a delicious edible fish. These fishes when caught in large numbers are preserved in salt .

Trachinotus. (Tel : Talepara)

This fish has blunt snout. Small scales cover the body. Tail is split into two, This fish feeds on molluscs, crustaceans. Found in Ganjam. This delicious food fish has good smell.

Lactarious. (Tel : Sudumu, Sudumbu)

It lives in saltish waters of Puccilipeth, Gopalpuram and Uppada. Lower Jaw is extended a little. There is a black spot behind operculum. Convalescing people like this fish as food.

Leiognathus (Tel : Karachepa, Karalu)

Body is rectangular and slightly compressed. the surface below the operculum is saw like. Dorsal fin has a spine. The surface of the head and dorsal surface do not contain any spots. Caudal fin is black. It feeds on insects and crustaceans. They are abunduntly available from August to April. This is common man's food. Along Konada, Puccilipeta, Bhimunipatnam, Gopalpuram, Pudimadaka, Uppada, Polavaram and Kalingapatnam these fishes are available (Fig9.1B)

Latis calcifer (Tel : Panduchepa)

Its body is covered with large scales and is rectangular in shape. It is an inhabitant of estuarial water. Caudal region is round. It is a domesticated fish of fresh water. It is an edible fish. It is found abunduntly in Ganjam.

Plectorhynous niger (Tel : Kuranti)

The stout lips are turned backwards. Lower portion of the operculum has saw like margin. It feeds on prawns, crabs and small fishes. It is a food fish taken with great pleasure. Because of its good taste there has been a local proverb: "Have this fish even by selling the child".

Sardinella longiceps (Tel : Nunekavalu)

The ventral surface is covered with spiny scales. The dorsal surface is bluish green and ventral surface is silvery white. Gold colour. A spot is present on the operculum. It is extensively used as food in the fresh and cured conditions, apart from its usage of oil.

Mugil cephalus

It is the largest of grey mullets. It is widely distributed along the coastal waters migrating into estuaries and rivers. It attains a length of about 90 cm.

Chanos chanos (Milk fish)

Palabontha. Body is compressed, beautifully shapped, scales small, mouth small and toothless. It breeds in estuaries. It is of great blood value.

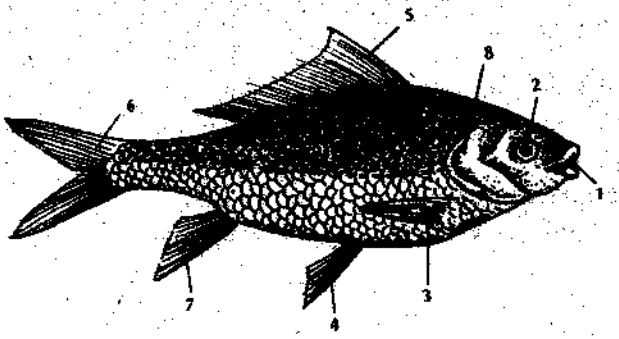
9.4 FRESH WATER FISHES

Puntius sarana. (Tel : Kangoo)

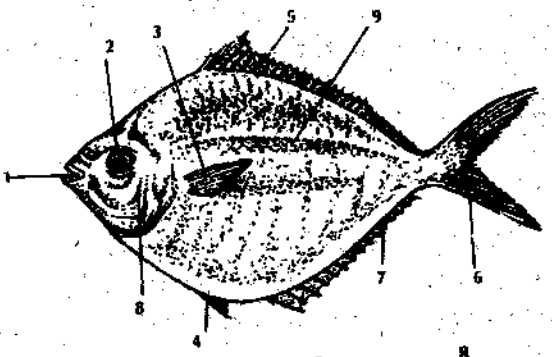
It is a common fresh water fish of ponds, lakes and rivers of our state. The operculum is stout with golden colour. The body is covered with large scales. Scales are absent on the head. Small barbels are present. The dorsal fin is opposite to anal fin. Caudal fin is bifurcated. this fish is also used as food.

Callichrous bimaculatus (U. patroo)

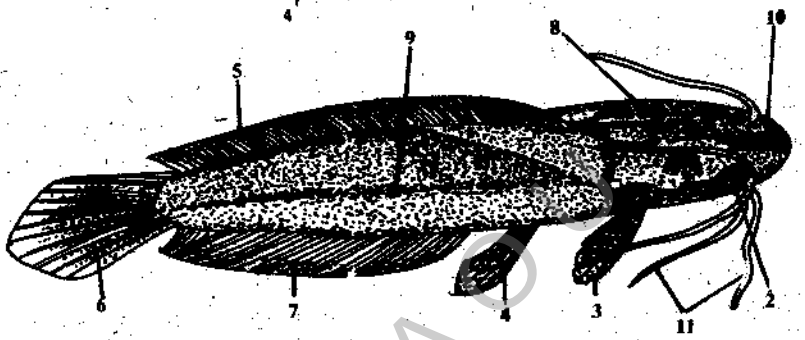
The body is elongated and compressed. Head is small, broad and depressed. Snout is bluntly rounded. Caudal fin is forked. There is only one pair of mandibular barbels. Anal fin is very long. It is found in tanks and rivers.



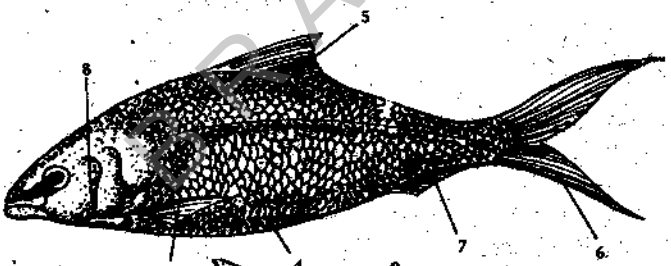
B



C



D



E

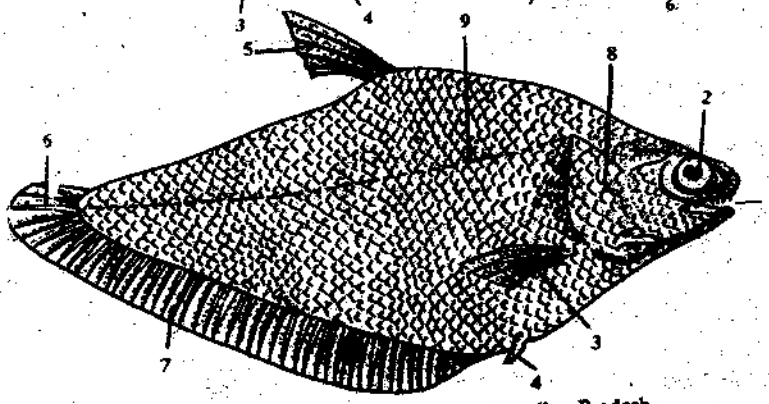


Fig. 9.1 Some of the edible fishes of Andhra Pradesh.

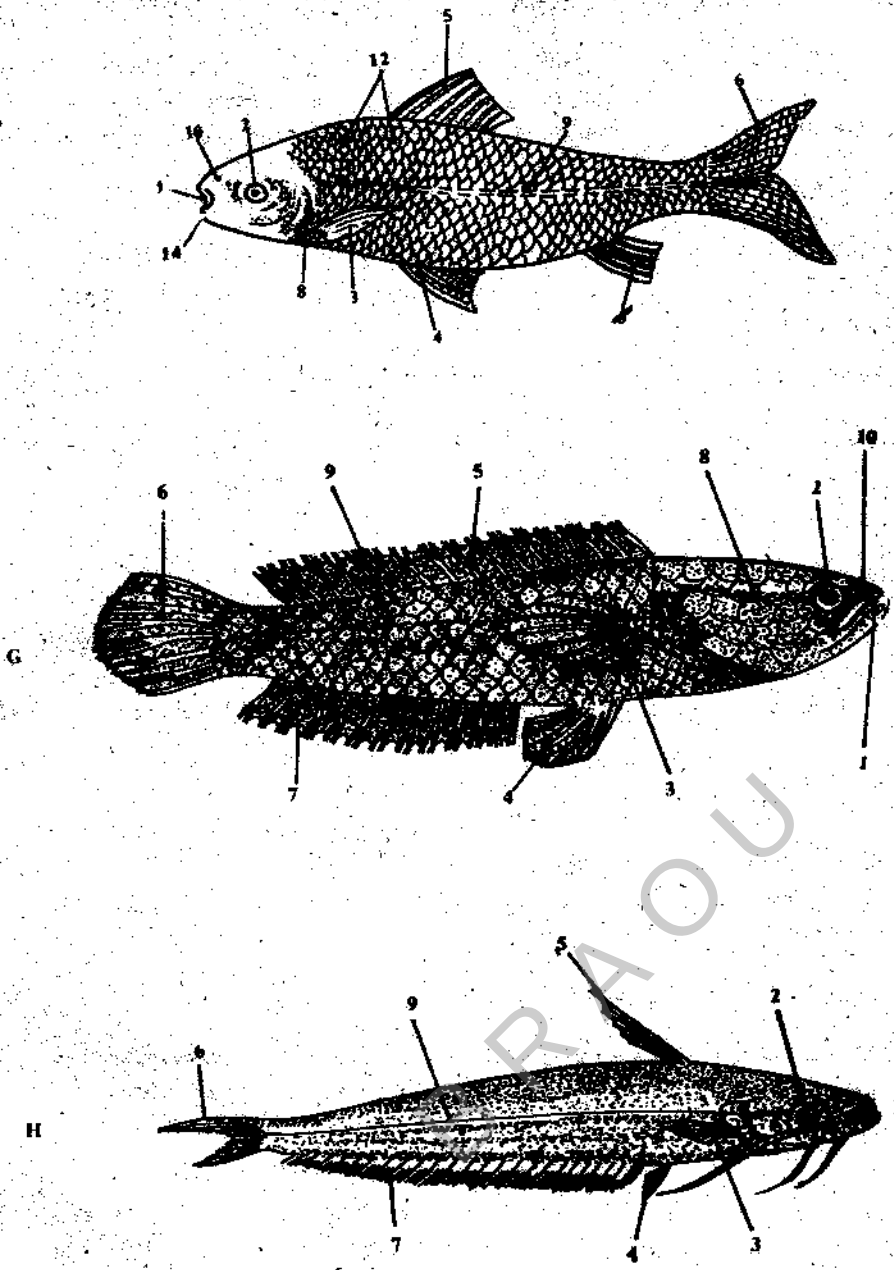


Fig. 9.1 Some of the edible fishes of Andhra Pradesh. A. *Catla catla* B. *Leognathus* Sp. (Sea fish) C. *Clarias batrachus* D. *Labeo calbasu* E. *Notopterus* Sp. F. *Hilsa ilisha* G. *Ophiocephalus* Sp. H. *Wallago attu* 1. Mouth 2. Eye 3. Pectoral fin 4. Pelvic fin 5. Dorsal fin 6. Caudal fin 7. Anal fin 8. Opercuium 9. Lateral line 10. Nasal aperture 11. Barbes 12. Scales 13 Maxillary barbel.

Catla catla (Fig. 9.1 A)

The body is laterally compressed fusiform. Scales are cycloid. There are no barbels without teeth Jaws and protrusible pectoral fins are without spinous fin rays. Dorsal fin is large. This fish is found in Godavari, Krishna, Manjira and Tungabhadra rivers.

Cirrhina mrigala (Tel : Moyyz)

Body is elongated and compressed. Abdomen is rounded. Lower Jaw is sharp with a small tubercle at the symphysis. Caudal fin is forked. It is found in Krishna and Godavari rivers.

Clarias batrachus (Tel : Marpoo) (Fig. 9.1 C)

It has an elongated and compressed body. Head region is covered with osseous plates. Lips are fleshy papillated and subequal. Pectoral fin has strong spine. Caudal fin is almost rounded. It is found in big and small tanks usually covered with weeds, not common in rivers.

Heteropneustes fossilis (Tel : Mapujella)

Head is flattened. The body is elongated and laterallly compressed. Dorsal fin is short without spine. Anal fin is elongated. Pectoral fins are with poison spine. Barbels are long and in four pairs. It is found in estuaries and fresh waters.

Labeo calbasu (Rohu) (Fig. 9.1 D)

It has an elongated body with a moderately rounded abdomen. Upper lip is provided with a pair of barbels. Jaws are without teeth. Pectoral fins are without spinous rays. It is found in Godavari and Krishna rivers.

Mastacembelus armatus (Tel : Pogra)

body is eel like, elongated and compressed. Snout is long, conical without transversely striated bony plates on the under surface. Pectoral fin is with depressible spines. Caudal fin is rounded. It is found in tanks and ponds often hiding about in cracks and crevices near the banks. It is the spiny eel.

Mystus vittatus (Katarna)

The body is short and compressed. Abdomen is rounded. Snout is rounded or obtuse. Four pairs of barbels are present. Pectoral fins are with a spine. These fishes are found in fresh waters.

Notopterus notopterus (Satwa) (Fig. 9.1 E)

The body is oblong and laterally compressed. Snout is obtuse and convex. Dorsl fin is small and tuft like. Anal fin is very low and ribbon like. Scales are small. Pelvic fin is rudimentary.

Ophicephalus Sp. (Channa) (Fig. 9.1 G)

One row of spines on each side is present along the spinal column. The body is covered with scales. Dorsal fin is long. Anal fin is long. Caudal fin is rounded. Phool murrel is *O. marulius*. It has white dots arranged like flowers on each side. Kali murrel has black serration along the side. It is found in tanks and ponds. It attains 3 1/2 feet in length. Some people shoot it bv gun when it comes to the water surface for air breathing. *O. Punctatus* is dhoke. *O. striatus* is korra meen. They provide nutritious food.

Hilsa ilisha. (Tel : Palasah) (Fig. 9.1 F)

The body is laterally compressed. Abdomen is serrated. Snout is rounded. Upper Jaw has median notch at centre. Caudal fin is forked. It is the largest among sardines. It is found in the waters of Krishna and Godavari rivers.

Wallago attu (Tel : Valuga) (Fig. 7.1 H)

It is also called fresh water dog fish. Dorsal surface is pointed. Barbels are four and roughly equal. Dorsal fin is short and without spine. Skin is smooth and naked. (It has no spines and is smooth.)

Tor tor (Mahaseer)

The body is elongate. Abdomen is rounded. Head is small, broadly pointed. Snout is angularly rounded. Mouth is inferiorly arched. A scaly sheath is present at the base of dorsal fin. Caudal fin is deeply forked.

The fish diet provides proteins, fats and vitamins A&D. It contains 13 to 30% of proteins and provides 300 - 1600 calories energy per gram. They are a good source of phorphorous, calcium and Iron. The fish consumed in India is 3.9 lbs per person.

9.5 SUMMARY

Some important edible fishes of Andhra Pradesh are described in this unit. About 23 fish species of both fresh and salt waters have been included. There is a substantial increase in total catch from 28,846 metric tons (mt) in 1958 to 56, 720 mt in 1960. In recent years, several fishes like catla, rohu are cultured in villages also. This solves the problem of malnutrition among the people, particularly enhances the intake of vitamins, proteins and fats.

9.6 MODEL EXAMINATION QUESTIONS

I. **Answer the following questions in about 30 lines each.**

1. Write an essay on common edible fishes of Andhra Pradesh.
2. Write an essay on edible fresh water fishes of Andhra Pradesh. Enumerate their food value.

Analysis of some Fresh Water Fishes for Food Value

	Per cent					
	Water	Fat	Protein	Iron	Calcium	Phoso-phorous
Barbus sarana *(Khaul)*	70	9.5	16.5	0.32	0.22	0.12
Barbus ticto (Parkally)	74.8	2.5	17.9	0.61	0.15	0.091
Calllichrous bimaculatus (Patroo)	70.0	4.5	17.5	0.23	0.26	0.25
Catla catla (Bochchi)	73.7	2.4	19.5	0.55	0.31	0.21
Cirrhina mrigala (Yerra mosu)	67.3	4.4	19.4	0.24	0.58	0.31
Clarias batrachus (Maroof)	78.1	1.1	16.1	0.22	0.71	0.31
Heteropneustes fossilis (Singhi)	67.9	0.8	22.5	0.69	0.93	0.62
Labeo calbasu (Rohu)	76.7	1.4	16.6	0.50	0.68	0.15
Mastacembelus armatus (Balhm)	74.8	0.9	16.1	0.37	0.33	0.24
Mystus vitatus	71.0	1.3	15.2	0.21	0.36	0.16
Notopterus notopterus (Satwa)	73.0	2.5	19.8	0.51	0.59	0.45
Ophiocephalus striatus (Kalimurrel)	78	2.3	16.2	0.57	0.14	0.09
Ophiocephalus punctatus (Dhok)	74	2.6	10.4	0.72	0.61	0.53
Hilsa ilisha	53.7	19.4	21.8	0.21	0.18	0.28
Wallago attu	73	2.7	15.4	0.62	0.16	0.49
Tor tor (Mahaseer)	70	2.26	25.2	0.38	0.13	0.28

Unit – 10 DIPNOI

Contents

10.1 OBJECTIVES

- To know the general features and affinities of lung fishes.

10.2 GENERAL CHARACTERS

The peculiar lung fishes are a Devonian offshoot from the crossopterygian stem. They still survive as three degenerate and specialised forms in widely seperated tropical or subtropical, fresh water habitat of a special kind. Lung fishes appear first in mid Devonian deposits, and were well differentiated even then. They flourished moderately in the Permian and Triassic, and then became rare.

Dipnoans are commonly known as lung fishes because they breathe not only by gills but also by means of highly developed lung or lungs with a coordinated arrangement of blood circulation.

They dig into the mud leaving small openings for breathing and can remain in this state for at least six months during aestivation.

Remains of cylindrical burrows found associated with dipnoan bones show that this habit of aestivation has been adopted by the group at least since permian times.

The lung fishes have bony cycloid scales which differ among genera but their relationship with the ancient cosmine scale seems well established.

Dermal fin rays occur. The paired fins however unlike those of any other fishes, are constructed on biserial plan. That is each fin has a jointed bony axis bearing pre and post - axial radials.

The notochord is persistent. There are no vertebral centra and primary cranium persists with little ossification, but with a number of investing bones.

There are four to six cartilagenous branchial arches. The dermal fin rays are slender more or less ossified fibres and are supported by numerous cartilagenous or ossified pterygiophores. The caudal fin is often apparently diphycercal. The pectoral arch is a single cartilage with a

pair of superficial investing bones on each side. The pelvic arch is well developed and cartilagenous. The gills are covered by an operculum. There is dermal skeleton formed by over-lapping cycloid scales. The heart is peculiar. The atrium and sinus venosus are each imperfectly divided into two parts.

The little contractile conus arteriosus which has a spirally twisted form, is partly or completely divided by a longitudinal partition.

A pulmonary artery is given off from the efferent branchial system on each side, and a pulmonary vein opens into the left division of the atrium.

The jaw suspensions is autostylic. In the gut there is no distinct stomach and the intestine is with a spiral value. The food consists of small invertebrates and decaying vegetable matter, which is eaten in large amounts.

The central nervous system is with a well developed brain. the paired oviducts open anteriorly into the coelom, and in male, vasa efferentia carry sperms through the excretory tubules of the mesonephros.

The three surviving genera of lung fishes are mainly inhabitant of rivers (1) **Protopterus** from tropical Africa (2) **Neoceratodus** lives only in the Burnett and Mary rivers in Queensland of Australia. (3) **Lepidosiren** form the rivers of tropical South America. Thus they exhibit discontinuous distribution being confined to small isolated regions.

Neoceratodus (Fig 10.1 A)

1. Found in the stagnant pools or water holes of the rivers of the Australia.
2. It does not aestivate and is said to inhabit only permanent waters. It resorts to aerial respiration when the water becomes foul in dry season. It dies if removed from water.
3. About five feet in length.
4. The scales are of cycloid type.
5. Five pairs of gills slits.
6. Paired fins are leaf like.
7. The male does not possess vascular pelvic filaments.
8. Fin rays are well developed (archipterygia)
9. Air bladder single (lung) (Monopneustia)
10. Kidneys are more elongate.
11. Larva is devoid of external gills.

Lepidosiren (Fig. 10.1B)

1. Found in swamps of Amazon and Paraguay basin of South America.
2. It aestivates during the dry season in borrows, constructed for the purpose. The entrance of the burrow is plugged with a mud stopper ventilated by several round holes.
3. About four feet in length.

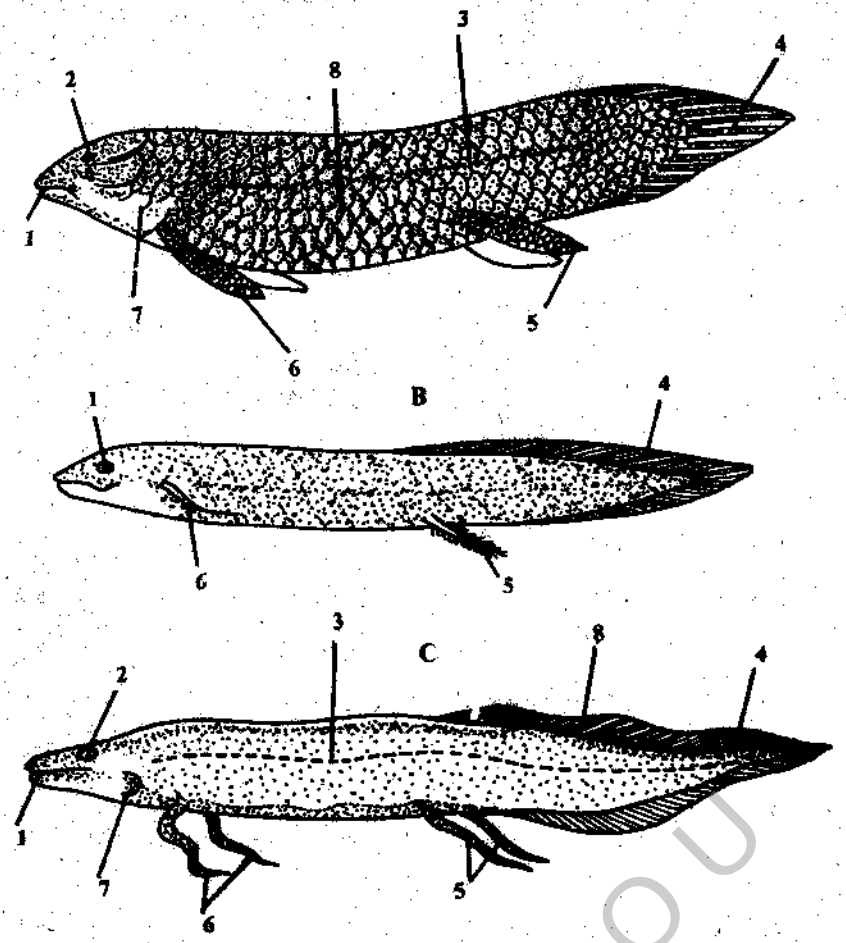


Fig. 10.1 Lung fishes. A. *Neoceratodus*. B. *Lepidosiren* C. *Protopterus* 1. Mouth 2. Eye 3. Lateral line 4. Caudal fin 5. Pelvic fin 6. Pectoral fin 7. Operculum 8. Dorsal fin.

4. The scales are of cycloid type and very small.
5. Five pairs of gill slits.
6. Paired fins are reduced to styliform appendages.
7. During breeding season the pelvic fins of the male develop accessory gills.
8. Fin rays are reduced.
9. Air bladder, double. (lungs) (Dipneustia).
10. Kidneys are not so elongate.
11. Larva possesses four pairs of external gills.

Protopterus (Fig. 10. 1 C)

1. Found in swamps near rivers of central Africa.
2. It also aestivates during the dry season in a cocoon, perforated by a hole.
3. About five feet in length. A specimen of seven feet has also been recorded.
4. The scales are of cycloid type and very small.

5. Four pairs of gill slits.
6. Paired fins are reduced and are long and filament like.
7. Male does not possess vascular filaments on pelvic fins.
8. Fin rays are absent.
9. Air bladder double. (lungs)
10. Kidneys are not so elongate.
11. Larva possesses four pairs of apparent external gills.
    In some species, vestiges of those may be found in the adult just above the opening of the opeculum.

10.3 AFFINITIES

Dipnoi are a group of remarkable fishes that show affinities with bony fishes on the one hand and with the amphibians on the other.

10.3.1 Resemblance with Amphibia

1. Dipnoi are capable of living in marshy places and possess pulmonary respiration for living in addition to the gills.
2. Larvae of *Protopterus* and *Lepidosiren* possess external gills and can be compared with the tadpoles of frog.
3. The heart of Dipnoi resembles with that of an amphibian in having two auricles, and a conus divided by a longitudinal valve.
4. A pulmonary artery and a pulmonary vein are present.
5. An inferior vena cava and an anterior abdominal vein are present as in amphibians.
6. A pair of external nostrils are present and open into buccal cavity.
7. Jaw suspension is autostylic.
8. The brain resembles that of the amphibians in the structure of the cerebral hemispheres and a small cerebellum.

More over amphibians differ from Dipnoi in the absence of scales and in rays and in possessing pentadactyl limbs.

10.3.2 Resemblence with Crossopterygii

Early Dipnoi resemble closely to the primitive Teleostomi in general structure. Both possess similar lobate fins, a layer of cosmine on the scales and power full palatine and splenial teeth.

They also resemble Actinopterygii in the structure of the paired fins, scales and form and function of the air bladder.

10.3.3 Primitive Characters of Dipnoi

A number of characters of Dipnoi may be considered as primitive, such as presence of cloaca a contractile conus, a diphycercal tail and a spiral valve in intestine.

10.3.4 Secondary and Specialised Characters

1. Neurocranium is cartilagenous with no ossification.
2. Maxillae and premaxillae are absent from the skull.
3. Anterior vertebrae are fused with the skull.
4. Dentition is peculiar and is in the form of tooth plates.
5. Lungs are dorsal in position.

10.4 ANCESTRY

Thus Dipnoi constitute a very unstable group of animals which although fish like in a number of characters possess certain features that are not present in any other fish but are found in Amphibia. However they do not appear to be related to Amphibia and can not be included in that group.

According to Jarvik (1955) Dipnoi show structural resemblances with Placoderms, Elasmobranchs and Amphibia as much as with the Crossopterygii but a closer affinity with the latter has not been established. According to Romer on the other hand lung fishes and the Rhipidistians of the Crossopterygii are clearly derived from a common ancestor.

Modern Dipnoi, thus appear to be a group that has not undergone much change during the long period of its existence after the permian times. It is true that they are not ancestral to Amphibia but the ancestors of these two groups were possibly derived from some common stock. Dipnoi are therefore of great significance and help in tracing the evolution of terrestrial vertebrates.

10.5 SUMMARY

The lung fishes share the characteristics of fishes on one hand and that of amphibians on the other. It appears as an off shoot of devonian crossopterygian stem. They afford best example for discontinuous distribution and are considered as degenerate specialised forms. *Protopterus* and *Lepidosiren* have two lungs while *Neoceratodes* (Australia) has one lung. Larvae of *Protopterus* and *Lepidosiren* possess external gills and resemble frog tadpoles. They also resemble amphibians in having 2 auricles, a conus arteriosus, brain and autostylic jaws.

Cloaca, conus, diphycercal tail and the spiral valve are some primitive features. Absence of maxillae and premaxillae, fusion of vertebrae with the skull and peculiar dention in the form of tooth plates, and lungs being dorsal in position are some of the specialised characters.

10.6 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Outline the general characters of Dipnoi.
2. Discuss the affinities of Dipnoi.

II. Answer the following in about 10 lines.

1. Describe the lung fishes.
2. *Protopterus*
3. *Neoceratodus*
4. *Lepidosiren*
5. Specialized characters of dipnoi.

10.7 GLOSSARY

Barbel	:	A small process appended to the mouth of certain fishes
Continental shelf	:	Projection of the continental part into the sea
Estuary	:	A narrow arm of the sea at the mouth of a river, up which the tides penetrate twice daily
Plankton	:	Floating or weakly swimming organisms in aquatic environment, primarily microscopic
Riverine	:	Situated near or on river

Unit – 11 AMPHIBIA - GENERAL CHARACTERS AND CLASSIFICATION

Contents

11.1 OBJECTIVES

To explain the characters of amphibians, to classify them and to give the diagnostic characters of some important amphibians found in South India.

11.2 INTRODUCTION

Amphibians derive their name from the fact that they spend most of their early embryonic life in water and the adult life on land. This statement however is not true in all respects. There are a few species in amphibians which spend their whole life in water alone, while a few others lead the early embryonic life without water.

Amphibians are the first tetrapods that have colonized the land. They originated during the Devonian period of Palaeozoic era. The climatic conditions during this period are said to be unstable and there were periodical droughts which resulted in the frequent drying of pools. This situation forced some of the animals to exploit land as habitat. The urge to avoid predators in waters, search for alternative sources of food and shelter are thought to be the other important factors that have led to the origin of amphibians.

11.3 ANCESTRY

Amphibians are thought to have originated from the rhiphidistian fishes that lived during the Devonian period. The early tetrapods and the osteolepid fishes belonging to rhiphidistia share number of characters. Chief among these characters are

(i) the structure of skull

(ii) the skeleton of limbs (Fig. 10.1)

(iii) the structure of teeth and

(iv) the presence of lungs for air breathing.

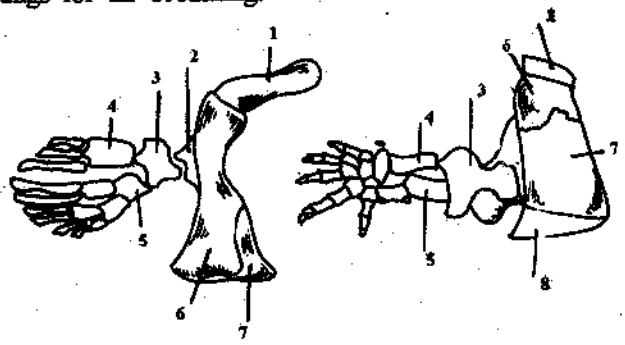


Fig. 11.1. Fore limb skeleton and pectoral girdle of (A) Osteolepid and (B) Primitive Amphibian. 1. Supracleithrum 2. Scapula 3. Humerus 4. Radius 5. Ulna 6. Cleithrum 7. Clavicle 8. Interclavicle.

Lungs are present in lung fishes (Dipnoi) but Dipnoi are considered to be too sepcialized to be the direct ancestors of amphibians.

Having orginated in the Devonian period amphibians were the only vertebrates that have lived on land upto carboniferous period, when the first reptiles are believed to have orignated. They exhibit much diversity during this period, most of them have now become extinct. The modern amphibia are represented by three living orders, the Urodela (or Caudata), the Anura (or Salientia) and the Apoda (or Gymnophiona).

11.4 GENERAL CHARACTERS

Amphibians are distributed widely in fresh waters and on land. They are conspicuous by their absence in marine waters.

1. Amphibians are distinguished from the fishes by the absence of paired fins and instead, they possess pentadactyl limbs (except in Apoda) although in a few species the number of digits is reduced.
2. Like fishes and reptiles they are poikilotherms i.e., their body temperature varies with that of environment.
3. They possess gills for breathing during the larval stage, but in adults, the lungs take over the function of respiration (there are however, a few species which retain gills even in adult life).
4. The skull is autostylic, i.e., the hyoid arch which is fully functional in the early teleostean fishes becomes broken up and the upper hyomandibular becomes converted into columella auris, and lies betweeen the inner ear and the tyumpanic membrane.
5. The skull is flat and the number of skull bones are very much reduced in modern amphibia, particularly in Anura.
6. There is no secondary palate in the skull and the internal nare open far forward in the mouth.
7. The teeth, when present, may be present on premaxillary, maxillary, palatine, vomer, parasphenoid and dentary bones.
8. Skull with two occipital condyles articulates with atlas, a cervical vertebra.

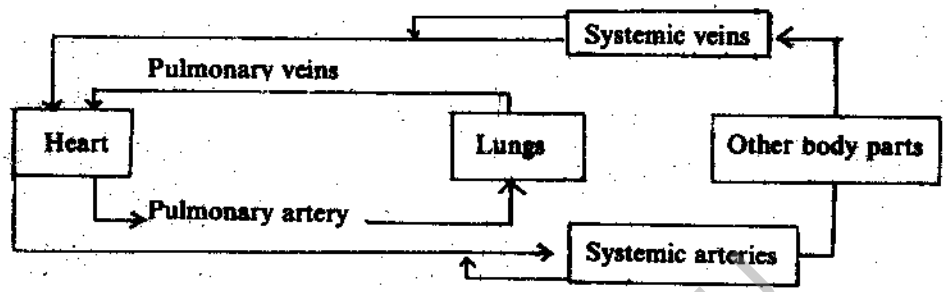
9. The number of vertebrae varies from 10 in Anura to approximately 200 in Apoda. The vertebral column is divisible into four regions, namely the cervical, the abdominal or thoracolumbar, the sacral and the caudal vertebrae. The cervical and sacral vertebra is usually one, but the abdominal and the caudal vertebrae variable.

10. Sternum appears for the first time in amphibians and the ribs are poorly developed.

11. The muscular system also present a typical feature in amphibians. Many changes in the apaxial muscles and the appendicualr muscles also take place which help in the locomotion of animal on land.

12. Heart is three chambered, with two auricles and a ventricle. Sinus venosus lies on the dorsal side of the heart and opens into the right auricle. The oxygenated blood is broguht to the left autricle by pulmonary veins.

13. The type of circulation is double circualtion. The course of circulation can be depicted as follows.



14. Digestive system is smiple and consists of buccal cavity, oesophagus, stomach and intestine and rectum which opens into the cloaca. The mouth contains only mucous glands. Liver and pancreas are the chief digestive glands associated with alimentary canal.

15. Respiration is carried out by gills in the younger stages of life-history i.e., in Tadpoles. They are fiulamentous structres covered with a ciliated epithelium and are covered by a fold of skin, the operculum. In some urodeles the gills are retained even in adult stage

    Lungs are the chief respiratory organs of adult amphibians. They are sae like strucutres either with smooth or folded inner surface. The upper end of trachea in frogs and toads is enlarged to form larynx or voice box.

16. The kidneys are mesonepheric the functional kedney of larval and adult fishes and also amphibians type. The archinephric duct in many amphibians acts both as genital and excretory duct.

17. Gonads are paired structures. In females the oviducts transport the ova to outside which in males the archinephriducts help in carrying sperms to cloaca. Fertilization is external and there are no copulatory organs.

18. Brain is basically like that of fishes. The cerebral hemishperes are slightly enlarged and the cerebellum is very small. Pineal body is found in all amphibians, but the pineeal end organ or parietal body is found only in anurans. There are only 10 paires of cranial nerves. The dorsal and ventral roots of the spinal nerves unite while passing through the intervertebral foramen.

19. Jacobson's organ or vomeronasal organ, which is an evagination of nasal passage and is lined with olfactory epithelium appear for the first time in amphibians, it helps in the tasting of food.

20. The amphibian eye is basically like that of other vertebrates. Lacrimal glands are poorly developed but the eye is kept moist by an oily secretion of Harderian gland.

21. There is a considerable variation in the auditory apparatus among amphibians, while the salamanders and newts lack a middle ear, the anurans possess them. Columella auris, which is a modified hyomandibular helps in the transmmission of sound waves from tympanum to inner ear in frogs and toads. The tympanic cavity is connected with pharynx by means of eustachain tube.

22. The skin of amphibians is important in both respiration and protection. There are a number of mucuous glands which help in the lubrication of the body and keep the body moist for respiration. Some amphibians, especially the toads contain, poisonous glands in their skin, which helps in protecting the animals.

11.5 CLASSIFICATION

It is very difficult to classify amphibians. Different authors adopt different methods of classification. The classification given in Parker and Haswell, revised by Marshall (1974) recognizes two subclasses, the Apsidospondyli and Leposondyli. It includes the living order Anura under the Apsidospondyli, while Urodela and Gymnophiona are kept under the subclass Lepospondyli. This classification is based on the assumption that the three orders have a diphyletic origin. Recent studies however, indicate that the three orders must have evolved from a common ancestor (monophylitic origin) and a separate subclass Lissamphibia is created to include the three modern amphibian orders. Romer, whom Parker and Haswell quotes extensively, in a recent book on the vertebrate body (Romer, A.S. and Parsons, T.S 1977. **The Vertebrate Body)** has recognized the monophyletic origin of these three orders and accepts the creation of the subclass Lissamphibia to include the living orders.

In order to avoid major confusion and detailed discussion on the divergent views on classification, we shall deal with the classification under two separate heads, the extinct and the modern amphbia.

11.5.1 Extinct Amphibia

The extinct amphibia, which flourished through Devonian to Carbonierous period are grouped under two subclasses, the Apsidospondyli and the Lepospondyli.

Sub Class : Apsidospondyli

1. Amphibians grouped under this sub-class are considered to have derived directly from the crossopterygean ancestors.

2. There are two units of centra, the anterior intercentra and the posterior pleurocentra.

3. This subclass is represented by super order labyrinthodontia.

Super Order-Labyrinthodontia

1. The name Labyrinthodontia is derived from the structure of teeth which have prominent radiating infloldings of the enamel surface (Fig. 10.2)

Fig. 11.2 T.S of a Tooth of Labyrinthodonia.

2. The early Labyrinthodonts are represented by Ichthyostega which probably gave rise to two lines of evolution, one Temnospondyls which are represented by **Rhachitomi** and **Stereospondyli** the second, Anthrocosaurs which are represented by **embolomeri**, and **Seymourimorpha**, and have given rise ultimately to the reptiles.

Order - 1 : Ichthyostegalia

This order is represented by three extinct genera, *Elpistotepe, Ichthyostega* and *Ichthyostegopsis*. They are the earliest known amphibians sharing numerous characters with osteolepid fishes of Devonian times.

Order - 2 : Rhachitomi

This order is represented by the extinct **Eryops**. They have rhachitomous vertebrae (Fig. 11.3 C). They flourished during the Permian and Triassic periods.

Order - 3 : Stereospondyli

These arose from Rhachitomes. They have undergone general degeneration and have returned to water. They have stereospondylous vertebrae (Fig. 11.3 D). The order is represented by three extinct genera, *Capitosaurus, Cyclotosaurus* and *Paracyclotosaurus*.

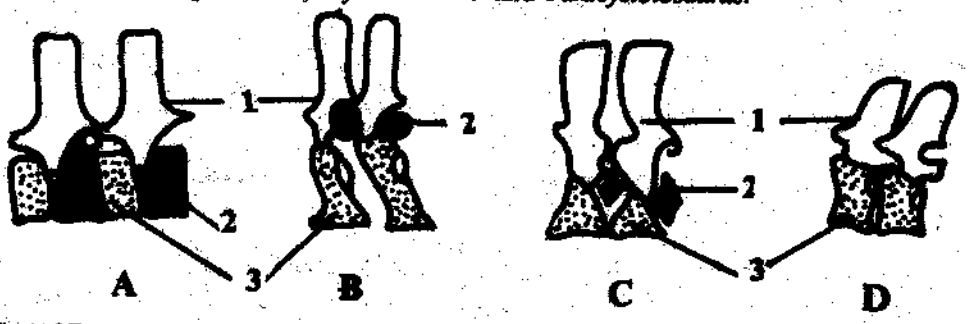


Fig. 11.3 Type of vertebrae found in extinct amphibia. A. Embolomeri B. Ichthyostegalia C. Rhachitomi D. Stereospondyli 1. Spine 2. Pleurocentrum 3. Intercentrun.

Order - 4 : Embolomeri

They spread from Carboniferous to Triassic period. *Palaeogyrinus*, a representative of this order had long cylindrical body with poorly developed limbs. The vertebrae were embolomerous type. The arrangement of bones in the skull were primitive and resembled the osteolepid fishes (Fig. 11.3 A).

Order : Seymouriamorpha

Seymouriamorpha is an aberrant order showing mosaic evolution. It shares number of characters with Reptilia. The recent trent is to inlcude this group under reptiles.

Sub class : Lepospondyli

Members of this sub-class are characterized by the presence of lepospondylous vertebrae. The centrum of this sub-class has originated by the direct ossification of embryonic notochord. These animals appeared in the Carboniferous period but disappeared in the Permian period. The sub-class consists of three orders namely 1. Aistopoda 2. Nectridia and 3. Microsauria.

Order - I : Aistopoda

They are represented by small snake like amphibians that lived during the carboniferous period.e.g. *Ophiderpeton.*

Order - 2 : Nectridia

Sauropleura and *Diplocaulus,* which lived in the upper Carboniferous period belong to this group. They exhibit a number of primitive characters. They share many characters with the primitive labyrinthodonts. Only their vertebrae resemble those of Lepospondyli.

Order - 3 : Microsauria (Adelospondyli)

Animals grouped under this order are often referrred to as Permian urodeles. *Lysophus* is a well known example of this group. It had an incompletely roofed skull, and had lost the circum orbital bones. This species is considered to be a near relative of modern Urodeles by few authors.

11.5.2 Modern Amphibia

All the living amphibians are grouped under one sub-class the *Lissamphibia* which is represented at present by three orders as follows :

1. Anura (or Salientia)
2. Urodela (or Caudata) and
3. Gymnophiona (or Apoda or Caecillia)

Order : Anura (or Salientia)

1. The frogs and toads belong to this order.
2. The oldest known fossils belonging to this order is *Triadobatrachus* which was found in lower Triassic period.
3. The muscular tail which is the chief organ of locomotion in fishes and other amphibians is completely lost in the animals belonging to this order and the order derives its name from this character (Anura - without a tail).
4. The body is generally short.
5. The hind legs are long and powerful. They are useful for leaping movement of the animal on land and water and also help in swimming. The forelimbs are relatively short and contain four digits.

6. Vertebrae are few in number and are partially fused. They do not allow the lateral flexing of the body.

7. The skull is broad and flat with a relatively huge mouth.

8. Tympanum is very large and the columella auris connects it with the inner ear.

9. Adult species are carnivorous and some can capture the large prey as big as the mouse.

10. The croak of a frog or toad is characteristic of the species. It is the principal way of locating the sex partners.

11. Respiration in the larva is by gills but in adults it is by lungs. Skin also aids in the respiration.

12. The skin of some species has poisonous glands which helps them in avoiding predators.

Examples : *Rana tigrina, R. hexadactyla, Bufo, Rhacophorus, Hyla* Fig 11.4

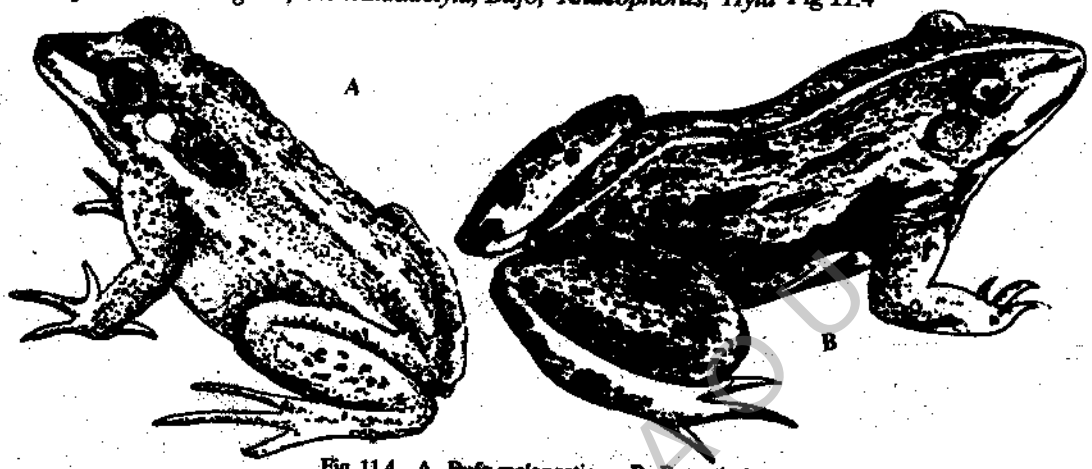


Fig. 11.4 A. Bufo melanosticus B. Rana tigrina

Order: Urodela (or Caudata)

1. This order includes the largest living amphibians like the giant salamanders of China and Japan and also small, inconspicuous, often nocturnal animals, living in North American ponds and rivers.

2. They contain tail in the adult stage, the skin is scaleless.

3. The limbs are short and weak. The fore and hind limbs are equal in length.

4. Both walking and swimming movements of these animals are performed by the lateral undulations of the tail.

5. Skin is an important respiratory organ. In some species e.g. *Desmognathus*, the skin becomes the only respiratory organ and the lungs are lost altogether.

6. The early embryonic life is in aquatic medium. There is a larval stage which metamorphoses into adults. In some species the larval stage is followed by a juvenile stage which lasts for a few years. A few species are viviparous. Some salamanders like *Ambystoma* exhibit neoteny. The larva in these species develops reproductive organs and becomes sexually mature.

Example : *Salamandra maculosa, Ambystoma caralina, Amphiuma* sp., *Protenus* sp. (Fig.11.5 A-D)..

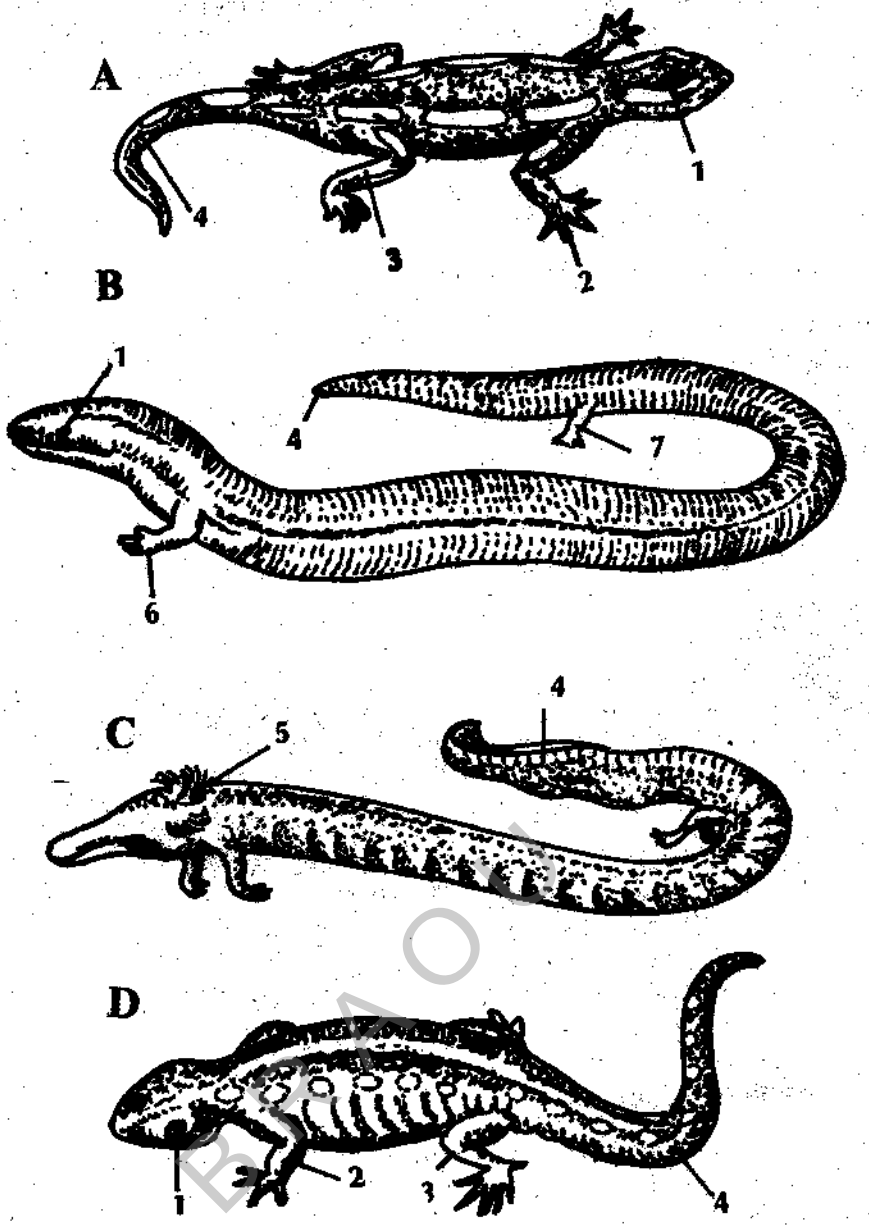


Fig 11.5 Some Urodels. A. Salamandra maculosa B. Amphiuma C. Proteus D. Amblystoma carolina 1. Eye 2. Fore limb 3. Hind limb 4. Tail 5. External gills 6. Vestegial fore limbs 7. Vestegial hind limb.

Order : Gymnophiona (or Apoda or Caecilia)

1. They are found in tropical and sub-tropical regions and are commonly known as caecilians.
2. They live in damp places and burrows in surface soil near streams.
3. They lack limbs compeletely and the eyes are very much reduced and become functionless.
4. The body is covered with a scaly transversely wrinkled skin in which are embedded numerous scales of bony plates. The head is stoutly built and helps in burrowing.
5. The tympanic membrane and the tympanic cavity are absent.
6. The tail is absent or rudimentary.
7. The notochord persists to great extent and the vertebrae are amphicoelous.

8. Limb girdles and limb skeleton are absent.

9. Skull has a complete bony roof.

10. Male possesses penis for copulation. Fertilization is internal.

11. In species which are viviparous, the development is internal and as many as nine young ones are given out, when hatched they have a pair of gill slits and no external gills, and the tail fin is well developed. The larva swims about in the water like an eel and the larval period is long .

During metamorphosis the tail fin and gill slits are lost.

Examples : *Ichthyophis glutinosa* (Fig. 11.1) *Uraeotyphlus menoni* and *Gegenophis carnosus.*

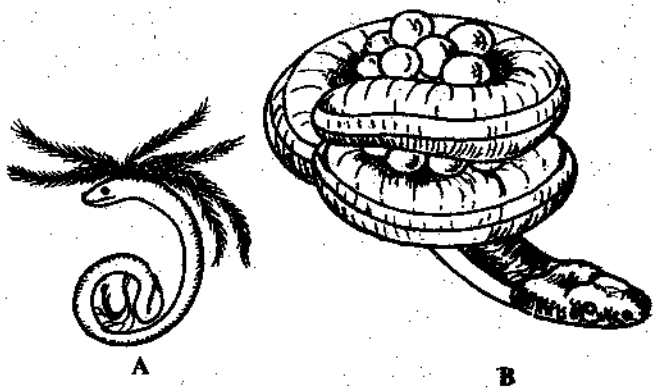


Fig. 11.6 *Ichthyophis glutinosa* A. Embryo with gills B. Adult guarding

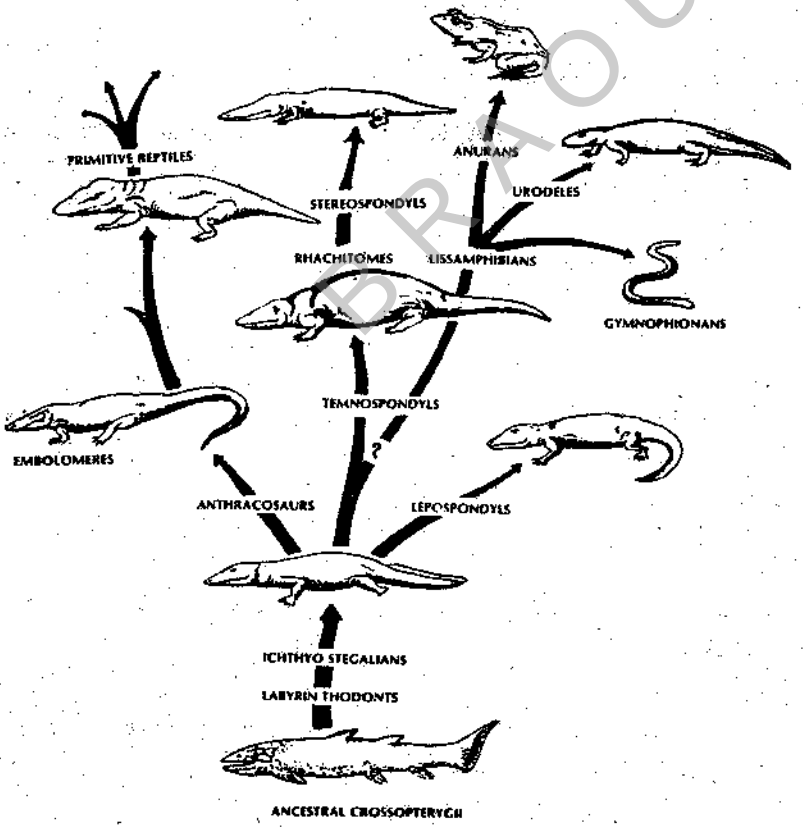


Fig. 11.7 Phylogenetic tree of Amphibians.

11.6 SUMMARY

The amphibian origin, general characters and classification with Indian examples are discussed in this unit. Amphibians are the first tetrapods that have colonised the land during the devonian period. The early tetrapods and the osteolepid fishes (Rhipidistia) share number of characters viz., in skull, limb skeleton, teeth and lungs. Amphibians are poikilothermous, naked, gill less, dicondylic tetrapods. Sternum appeared for the first time. Heart is 3-chambered with double circulation. Salamanders and newts lack middle ear while it is present in anurans.

The class Amphibia is divided into subclasses Apsidospondyli and Lepospondyli to include all the living amphibians advocating diphyletic orgin. However, recent studies support monophyletic ancestry (Romer & Parsons, 1977) thus including all the living amphibians in one subclass Lissamphibia.

11.7 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Describe the general characters of amphibians
2. What do you know about modern amphibia ? Add a note on the general characters of Gymnophiona.

II. Answer the following in about 10 lines.

1. Describe the origin and evolution of amphibians.
2. What are the major amphibian species found in your locality ? Identify and give their diagnostic features.
3. Autostylic
4. Poikilotherms
5. Rhipidistian
6. Labyrinthodontia
7. Urodela
8. Seymouriamorpha
9. Lissamphibia.

11.8 GLOSSARY

Amphicoelous : Vertebrae having both the anterior and posterior faces of the centrum concave.

Archinephric duct : Duct into which pronephric tubules open.

Double circulation : The type of circulation, in which the heart produces two circulations, the pulmonary circulation to the lungs and the other, the systemic circulation, which supplies to the body parts.

Diphyletic	:	Descended from two distinct central groups of dual origin .
Embolomerous	:	(Fossils of most primitive land vertebrates). They give the evidence for double centrum in each vertebra.
Metamerical	:	The external segmentation corresponds to an internal division of the body into similar parts.
Opisthonephric Kidney	:	Kidney which consists of meso and metanephric series of tubles.
Osteolepis	:	These are extinct bony fishes. They lie close to the line of descent from some placoderm ancestor to both the lung fishes and amphibia.
Phylogenetic tree	:	A graphic representation based on closeness of evolutionary descent.
Stereospondylus	:	In modern Amphibia the hypocentrum has become the main centrum and pleurocentrum is reduced or lost. Such vertebrae are known as stereospondylus.
Sternum	:	Breast bone of vertebrates to which ribs are attached in higher forms.
Tetrapod	:	Four footed animal.

11.9 BOOKS SUGGESTED FOR FURTHER READING

1. Chordate Zoology by Dhami & Dhami
2. Fishes by Chandy
3. Fisheries of India by Jhingran
4. Fresh water fishes of India by Jayaram
5. Food fishes of A.P. by Dr. V. Jagannath Rao
6. History of fishes by Norman
7. Introduction to chordates by T.C. Majhupuria
8. Life of Vertebrates by J.Z.Young
9. Origin and Evolution of vertebrates by Colbert
10. Phylum chordata by Newman
11. Text book of Zoology (Vol. II) by Parker & Haswell edited by Marshall
12. Thomson's outlines of Zoology edited by Ritche.
13. Vertebrate Zoology by Yapp
14. Scoliodon - Indian Zoological Memoir - by EM Thaliampalam
15. Sakaserukalu Vols (I) - (IV) of Telugu Akademi
16. Vertebrate Zoology by de Beer
17. A Guide to the West Indian Amphibians by J.C. Daniel (Vol. I, II & III Published in J. Bombay Natural Hist. Soc. 1963 & 1972).

Unit – 12 REPTILIA - GENERAL CHARACTERS AND CLASSIFICATION

Contents

12.1 OBJECTIVES

To introduce the reptiles as successful land vertebrates and their organisation.

12.2 INTRODUCTION

Tortoises, Lizards, Snakes and Crocodiles are classed together as Reptilia. About three hundred million years back reptiles arose as a group much better adapted to land life. They had sprung from the primitive amphibian stock. The factors responsible for their success upon land and significant advances over amphibians and fishes were: "typical pentadactyl limbs which could support the weight of the body on land; dry and scaly skin which helps in conservation of water to prevent evaporation in air; use of lungs as the only respiratory organs and acquisition of foetal membranes during embryonic development which afford protection against injury and desiccation on land besides nourishment".

12.3 GENERAL CHARACTERS

As the first full land-living vertebrates, the reptiles exhibit many characteristics which are closely related to amphibians on one hand, birds and mammals on the other hand.

The reptilian skin is dry, rough and non-glandular typically covered by cornified epidermal scales or scutes.

Limbs are perfected as efficient walking legs in all respects. They raise the body off the ground and support it fully.

Reptilian breathing system is constructed on par with birds and mammals being strictly air breathers. Air is supplied to the lungs through trachea and bronchii via nostrils.

The heart is imperfectly four-chambered with two auricles and a partially divided ventricle. In crocodile, however, the heart is completely divided into four chambers. The arrangement keeps the arterial blood separated from venous. Three pairs of aortic arches persist as in amphibians. Red blood corpuscles are nucleated, biconvex and oval. They are cold-blooded or **ectothermic (Poikilothermic).**

The shape of skull varies greatly in different reptiles. It is hinged upon the first vertebra by a single occipital condyle (monocondylic). A pineal foramen generally penetrates the roof of the skull. The eyeball is surrounded by many sclerotic bones. The parasphenoid is reduced or absent on the floor of the skull. The number and precise location of openings in the lateral region of the skull known as **temporal fenestrae** or fossae serve usefully to classify the group.

In the most primitive forms, the roof and sides of the skull are entire, the anapsid condition which persists in turtles. In a diapsid skull two pairs of lateral fenestrae present. This type is present in all other surviving reptiles. The skulls with a single pair of fossae, the synapsid, and parapsid, are no longer in existence. From the former group the mammals arose. Basic division depending on temporal fenestrae is outlined in Table-I and illustrated in Fig. 12.1. Reptilian skull exhibits two tendencies: the reduction of unnecessary bones and the development of temporal openings in between parietal, postorbital, squamosal and jugal bones. These openings not only lighten the skull but also serve for the attachement of powerful jaw muscles on their inner surfaces (Fig. 12.1).

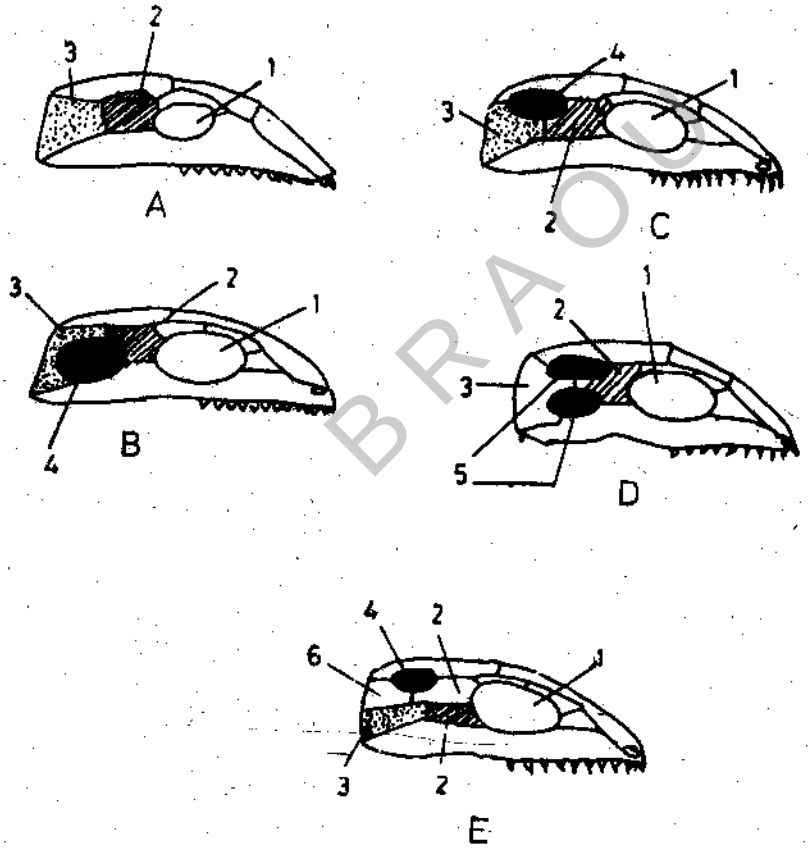


Fig 12.1 Basic skull structure in Reptilia A. Anapsid. B. Synapsid. C. Euryapsid. D. Diapsid. E. Parapsid. 1. Orbit 2. Postorbital 3. Squamosal 4. Temporal fossa 5. Temporal fossae 6. Supratemporal 7. Post frontal.

The adult reptilian kidney is metanephric and is capable of producing a highly hypertonic, water conserving urine, the uricotelic excretion. Terrestrial reptiles excrete a semisolid uric acid, and aquatic forms, urea.

The central nervous system is advanced in possesing a large cerebrum in brain from which arise 12 pairs of cranial nerves. The eyes are notably advanced to distinguish colours, at least, in lizards.

Male reptiles, in general, possess an intromittent organ, a penis either single (Crocodiles) or double (Lizards) for the purpose of internal fertilization.

Table - 1 Temporal Fenestrace of Reptiles

Condition of skull	Temporal Fenestrae		Principal Groups
	Number	Arrangement	
Anapsid	None	Solid roof to skull	Cotylosaurs, Chelonia
Synapsid	One	Low behind the eye with postorbital and squamosal meeting above.	Pelycosaurians and mammal-like reptiles
Parapsid	One	High behind eye, usually with postfrontal and supratemporal meeting below	Protosaurs and sauropterygians
Diapsid	Two	Postorbital and squamosal usually meet between them	Eosuchians, Rhyncocephalia, dinosaurs, Pterosaurs, Squamata, Crocodilia

Reproduction is oviaparous (Snakes). Large shelled eggs containing a heavy store of yolk are laid on land in burrow. A few lay leathery eggs.

Cleavage is meroblastic and the embryo is protected by chorionic, amniotic and allantoic membranes. The latter acts as an embryonic respiartory organ.

12.4 CLASSIFICATION

The skull and teeth are mainly utilised as criteria for classifying the reptiles. The temporal region of the skull as stated earlier is considered as the basis for the purpose. The classification, as adopted by Parker and Haswell, has been followed here.

12.4.1 Sub Class Anapsida

These comprise the earliest primitive forms of Carboniferous period. The temporal region of the skull is not perforated. This subclass is divided into two orders :

Order - 1 Cotylosauria, the oldest stem reptiles which were closest to the early amphibians. They had bony skull with poorly developed jaws and teeth. All these became extinct. e.g., *Seymouria,* with single occipital condyle and imperforate roof, may be regarded as a link between amphibians and reptiles.

Order - 2 Chelonia, are an early offshoot of cotylosaurs which are living now. The temporal region is complete without true fossae. The body is enclosed in between the carapace and the plastron which originate from horny epidermal scales outside and dermal bones inside.

A vertical anus and absence of teeth are most striking features.

Testudo is a land tortoise found in India and Sri Lanka on dry grassy places. On its plates of carapace are large yellow stars (Fig. 12.2).

Trionyx is a turtle found in rivers of India. Its olive carapace is disc like and plastron yellow both covered by skin. Head has a pointed beak and feet are webbed (Fig. 11.2 B).

12.4.2 Sub Class Icthyopterygia

This subclass includes extinct reptiles which lived in waters. Their body was fish-like and skull possessed single fossa. These reptiles are grouped into two orders; the **Mesosauria** which lived in fresh water lakes, had stronger hind limbs. e.g. *Mesosaurus*. The **Icthyosauria** were marine whose limbs were paddle like. eg. *Icthyosaurus*. It was a fish like reptile, without a neck, reached a length of 30 feet and possessed a dorsal fin.

12.4.3 Sub Class Synoptosauria

This sub class consists of extinct aquatic reptiles with a single upper temporal fenestra. The group had much diversified forms. It comprises two orders: the **Protorosauria** characterarised by amphicoelous vertebrae and lizard like appearance. eg. *Araeoscelis*.

Order **Sauropterygia** embraced aquatic reptiles which attained more than 40 feet length. Flattened body, paddled limbs and long narrow neck bearing a small head are some remarkable features. eg. *Elasmosaurus*.

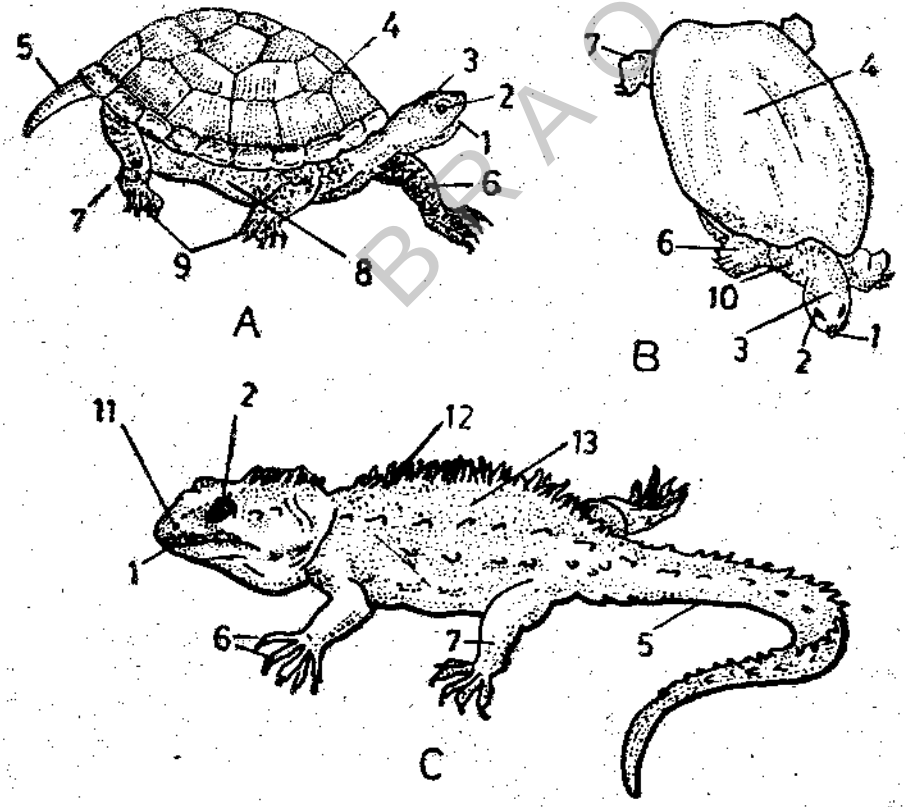


Fig. 12.2 Some reptiles. A. *Testudo*. B. *Trionyx*. C. *Sphenodon*. 1. Mouth 2. Eye 3. Head 4. Carapace 5. Tail 6. Fore limb 7. Hind limb 8. Plastran 9. Claws 10. Neck 11. Nostril 12. Mid dorsal crest 13. Body.

12.4.4 Sub Class Lepidosauria

Representatives of this sub class primitively possess a diapsid skull, typically with two temporal fenestrae an upper and a lower, which in some cases, have become reduced. Out of its three orders, all members of order **Eosuchia** became extinct. The fossils of **Youngina** show much primitive condition.

Order Rhyncocephalia has the lone example, the *Sphenodon* (Hatteria) which represents this ancient group (Fig. 11.2 C). It is lizard like confined to coastal islands of New Zealand. It grows to 2' length lives in burrows. It is nocturnal and carnivorous, feeding on molluscs and small vertebrates. Its vertebrae are amphicoelous. There is a sternum and many abdominal ribs. A parietal foramen contains a non-functional median eye covered with scales, is believed to have been an important sense organ in early forms. The anal opening is transverse. No copulatory organ in male. Due to its primitive features of eosuchnian ancestry it is considered as **'living fossil .**

Order **Squamata** embraces the most successful living reptiles. In this group the skull has lost either one or two temporal fossae secondarily. The former have been included in sub-order **Lacertilia** (Lizards) and the latter in sub-order **Ophidia** (snakes). The skin is covered by horny epidermal scales. The skeletal pecularities being, vertebrae nearly always procoelous, simple ribs, two vertebrae form the sacrum, if present. The quadrate is movable and articulates with skull. The teeth are acrodont or pleurodont. There is a transverse cloacal aperture and in males a pair of eversible hemipenis.

Sub order : Lacetilia The modern lizards live in diversified environments. On land, trees and in water. They posess well developed limbs. Mouth opens to a moderate extent as mandibles are fused anteriorly and palate bones are fixed. Supra temporal fossa is complete. Eyes possess both eyelids and a nictitating membrane. A tympanic membrane stretches over the auditory aperture. Some important examples are given below.

Hemidactylus (Fig. 12.3 A) is the common gecko (Wall lizard), the digits of which are provided with adhesive discs or pads for creeping over the ceilings in an inverted position. The transverse rows of lamellae in each disc, which by pressure create vacuum and make the animal to adhere firmly to the surface. The Geckos break off their tails when chased, by autotomy a mechanism to escape keeping the enemy busy looking at its wriggling cut off tail. A new tail regenerates. Geckos are the only squamata that lay hard- shelled eggs.

Calotes is a garden lizard common throughout India. A detailed description is presented in unit No. 12

Draco, known as the flying lizard or Dragon (Fig. 12.3 B) is found in India, Burma and Malaysia. develops a skinfold, the patagium, between limbs and the body supported by 5 or 6 elongated ribs. The patagium is spread out and used for gliding from a higher to lower branch.

Chamaeleon is arboreal, distributed among India, Africa and Sri Lanka. It has laterally compressed body, head bears a crest, eyelids are fused leaving a small hole. The digits are united and the tail is prehensile, both assist in grasping the branches. A club-shaped tongue is long and protrusible with a sticky end. It has the power of colour change, by melanophores controlled by autonomic nerves (Fig. 12.3 C).

Varanus (Komodo dragon) is the largest among lizards living in Asia, Africa and Australia with semi-aquatic habit (Fig. 12.3 D). Its tougue is very long and forked.

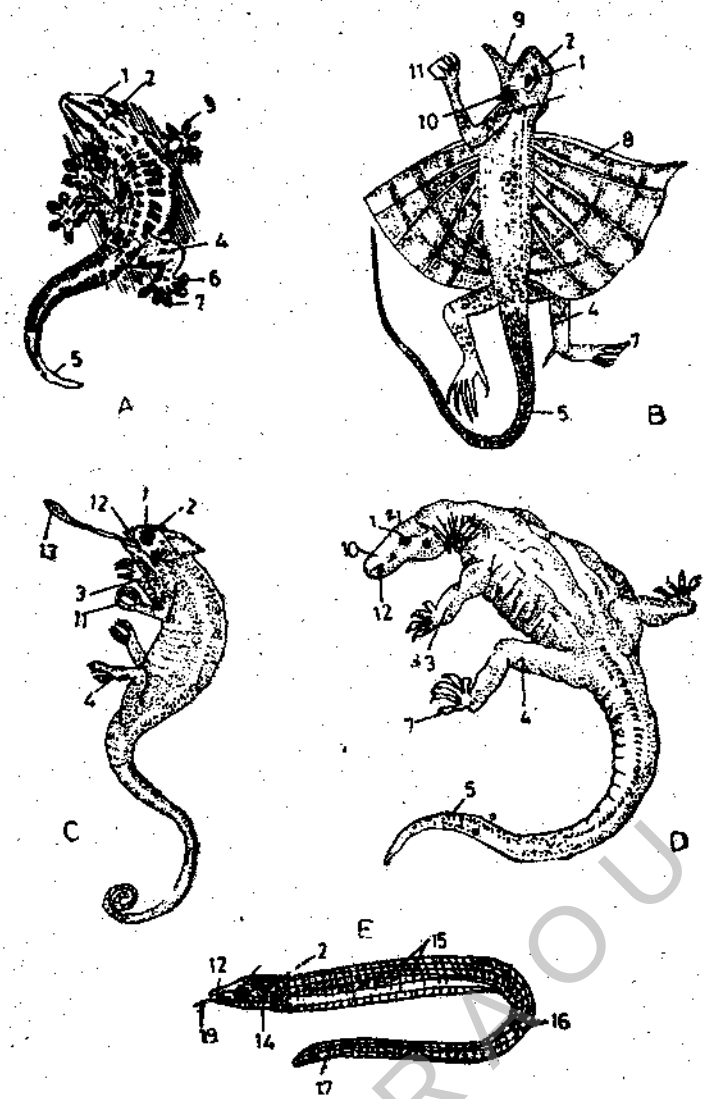


Fig 12.3 Some reptiles A. Gecko B. *Draco* C. *Chamaeleon* D. *Varanus* E. *Ophisaurus* 1. Eye 2. Head 3. Fore limb 4. Hind limb 5. Tail 6. Pad 7. Claw 8. Patagium 9. Gular pouch 10. Cervical appendages 11. Clawed digits 12. Nostril 13. Club-shaped tongue 14. Tympanum 15. Rectangular scales 16. Cloacal spikes 17. Cylindrical tail 18. Snout 19. Tongue.

Heloderma, the Gila Monster, inhabits North and Central America and is known to be only poisonous lizard. *Ophisaurus* (glass snake) (Fig. 12.3 E). *Amphishaenia* and *Anguis* (Blind worm) are limbless, burrowing lizards, found in Europe and North Africa. They have vestigeal girdles.

Sub order Ophidia

The snakes are elongated reptiles with no limbs or girdles except their rudiments in *Python*. The skin is covered with scales and outer most layer is periodically shed as a continuous slough. A sternum, urinary bladder, supra temporal fossa, jugals, lacyrimals and eyelids are absent in contrast to lizards. The mouth can be distended greatly as the two rami of the lower jaw are held together by elsastic ligaments and upper and lower jaws are often similarly jointed by ligaments only. This arrangement facilitates the snake to ingest an animal several times wider than its own diameter.

Snakes have no tympanum, eustachian tubes or external ear openings. Inspite of this they perceive vibrations transmitted through the ground by bones of the jaw. The bifid, mobile

and retractile tongue works as an organ of smell in contact with certain sensory pits on the roof of the upper jaw. Locomotion is produced by undulations of the body exerting pressure on surrounding objects and pushes the snake forwards. Slipping is prevented by ventral transverse scales.

In poisonous snakes, the salivary glands are modified into a pair of poison glands that open into specialized, grooved teeth over the maxillae known as fangs.

Anaconda and **Python** (Fiog. 12.4 A) are the largest snakes. They reach lengths of 30 to 35 feet. They are constrictors and kill their prey winding their boodies around.

Cobras are most advanced poisonous snakes found in Africa and Asia. Their neck can be expanded into a hood supported by cervical ribs to threaten or warn invaders. Pre-maxillae bear a pair of poison fangs. Frangs are fixed in position. King Cobras *(Hamadryas)* are very aggressive. Common Cobra has spectacular marks on the hood eg. *Naja naja* (Fig. 12.4 B).

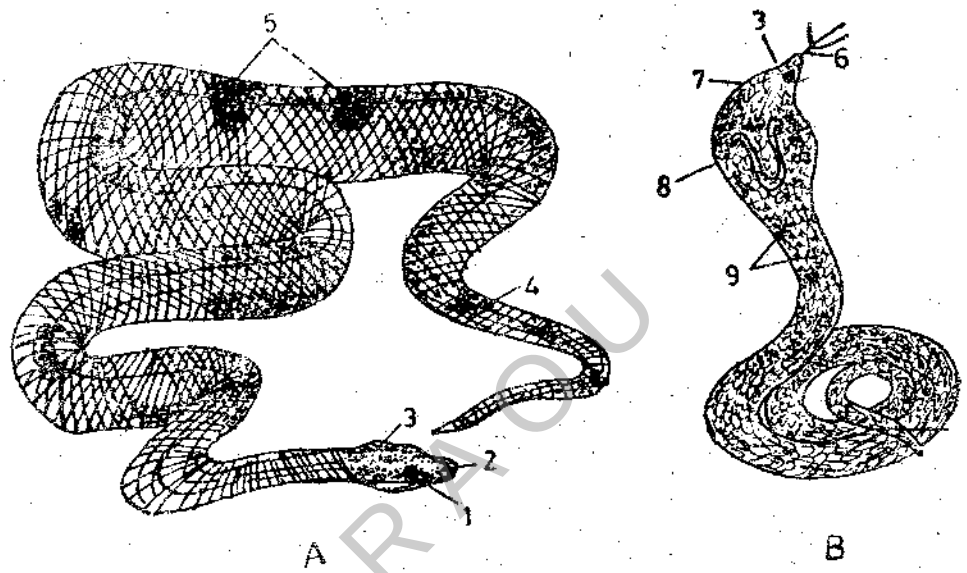


Fig. 12.4 A *Python* B. *Naja naja* (Cobra). 1. Eye 2. Nostril 3. Head 4. Tail 5. Dark bands 6. Tongue 7. Hood 8. Spectacle mark 9. Body scales 10. Eye.

In sea snakes the tail and posterior part of body is flattened laterally forming a swimming organ. They are closely related to cobras and highly poisonous. eg. *Hydrophis* (Fig. 12.5 A).

Vipers group includes poisonous snakes which are confined to hilly areas. In these snakes poison apparatus is highly developed. The fangs are movable and sharp pointed which erect automatically when mouth is opened otherwise tucked back inside the mouth. Vipers have wedge shaped head, broader, behind with a narrow neck region. They are widely distributed; pitless vipers, found in Asia and Africa possess a pair of remarkable sensory pits between eye and nostril which is sensitive to temperature changes and helps the snake to detect the warm-blooded prey. Vipers are viviparous. Rattle snakes and pit vipers are found in America and Europe. They are totally absent in Australia. eg. *Vipera russelli* (Fig. 12.5 B), *Echis, Crotalus.*

Banded Kraits, is another small group of poisonous snakes, common throughout India. Its poison is more virulant than a cobra eg. *Bungarus* (Fig. 12.5 C).

There are many harmless and non-poisonous snakes. Such as *Ptyas* (Rat Snake), *Dryophis* (Grass snake), *Eryx* (Double headed snake), and racers which neither possess poison glands

nor constricting habit. They are useful as destroyers of rodents and small animals which damage the field crops. unit No 15 deals in detail about the poisonous and non- poisonous snakes.

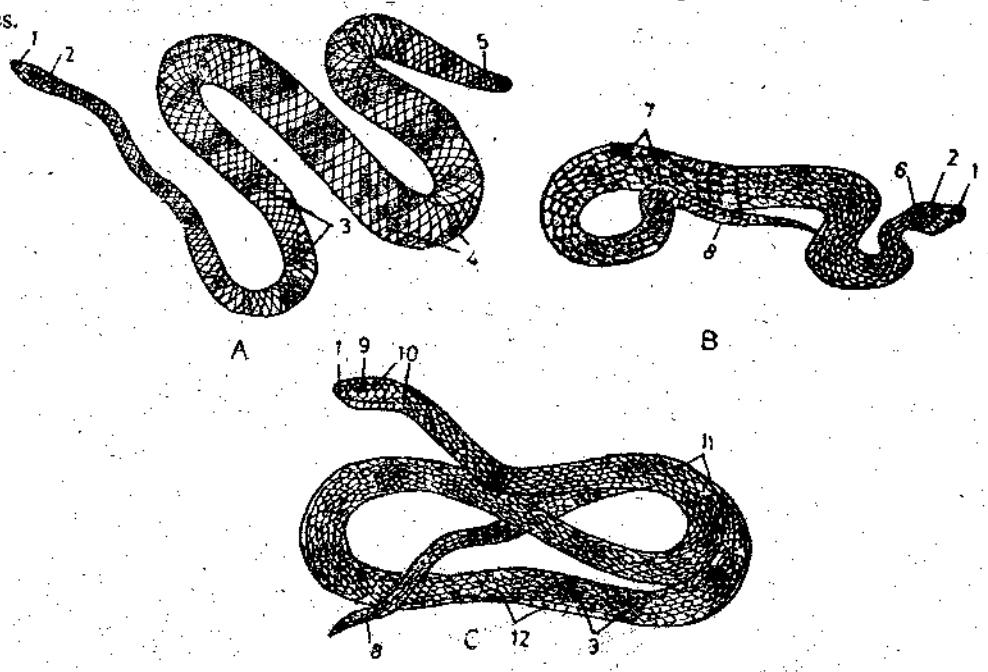


Fig 12.5 Snakes. A. *Hydrophis* B. *Vipera ruselli* C. Krait *(Bungarus).* 1. Nostril 2. Head 3. Dark bands 4. Light bands 5. Laterally compressed tail 6. Small scales 7. Black spots 8. Tail 9. Eye 10. Large head shields 11. Dorsal hexagonal scales 12. Broad ventral plates.

12.4.5 Sub class Archosauria

In reptiles which comprise the sub class Archosauria, the skull is typically diapsid. The interparietal, tabular bones and parietal foramen are absent. The hind-legs were much longer than the fore limbs. Some forms became toothless almost with horny beaks and their distal tarsals fuse with metatarsals. As in birds, digits are reduced. There was a fossa on the outside of the lower jaw between dentary subangular and angular. An antorbital fenestra is almost always present in front of the orbit. The sub-class consists of 5 orders.

Order Thecodontia inlcudes small aquatic, carnivorous reptiles which developed such notable characters as are found in crocodiles today but their external nares were placed posteriorly near the eyes. Possibly with the rise and success of Crocodiles these were exterminated eg. *Phytosaurus.*

Crocodiles, alligators and their allies are the largest reptilia living today are placed in **order Crocodilia.** The skin is covered with bony scutes and epidermal scales. The nostrils are at the tip of the snout from where air passes back into a long tube made by maxillae, palatines and pterygoids all form a secondary palate (Mammals). The nostrils are closed completely when submerged. There is a complicated pressure-equalising eustaschian system. Parts of the skull have pneumatic extensions from the cavity of middle ear (Bird). The teeth are thecodont.

The internal nares open into the throat, protected by a fleshy valve. This mechanism allows to keep open the jaws under water without any inturruption to breathing if the tip of nose is exposed.

All the four limbs are used in walking but the front once are shorter than hind, indicating the bipedal ancestry.

Laterally compressed tail and webbed feet are used in swimming.

The lungs are well developed, having trachea and alveoles. A transverse partition separates off the thoracic from the main abdominal cavity. This is somewhat similar to mammalian diaphragm but differs in not being muscular.

The heart shows complete division of the ventricles by interventricular septum. There are two aortic arches. Although these two aortae cross each other at foramen of Panizza, the higher pressure in the ventricles does not allow the blood to mix up.

Among living forms there are the crocodiles, gharials, alligators and caimans. The *Crocodylus* (Fig. 12.6) is most wide spread genus except in Europe. It has a narrow snout. Fourth lower tooth is visible when mouth is closed. *Alligator* with its 4th lower tooth fits into a pit of maxilla, and a blunt snout is found in North America and China. *Caiman* of Central and South America is related to Alligator. Extremely long and slender snout is present in *Gavialis*, the fish eating Indian gharial and *Tomistoma* of the Indo-China (Borneo,Sumatra).

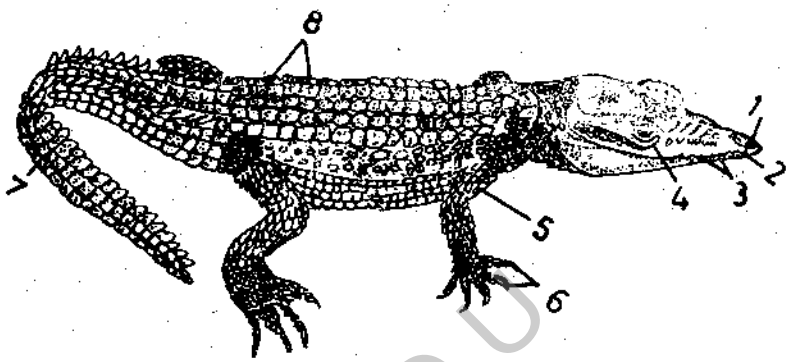


Fig. 12.6 Crocodylus. 1. Nostril 2. Snout 3. Teeth. 4 Eye 5. Fore limb 6. Clawed digits 7. Laterally compressed tail 8. Dorsal scales.

Members of the order **Pterosauria** were flying reptiles in which the skeleton was light, thin and pneumatic. The forelimb modified into a wing in which the fourth finger was greatly elongated to support the patagium. The hind limbs were pentadactyle but weak, fibula being reduced or absent. The skull was pointed with a projection and there were two tempora' fossae, a superior and inferior. No member of this group is living. eg. *Pteranodon.*

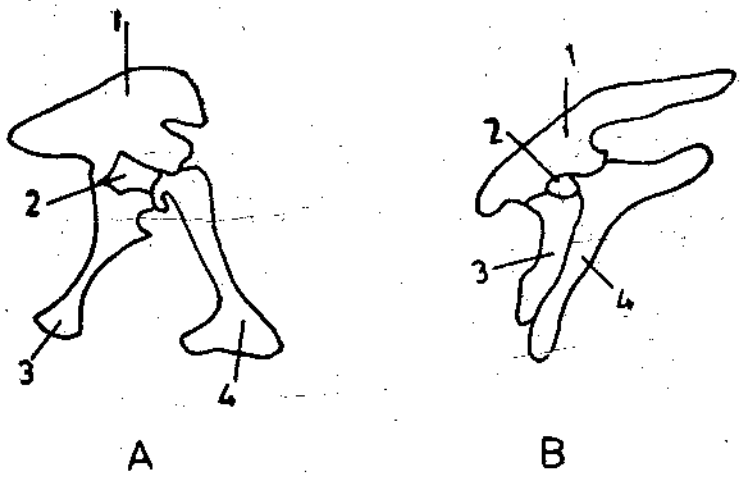


Fig 12.7 Pelvic girdle in extinct Dinosaurs. A. Saurischian pelvic girdle. 1. Ilium 2. Acetabulum 3. Ischium 4. Pubis
B. Omithischian pelvic gridle 1. Ilium 2. Acetabulum 3. Ischium 4. Pubis.

Order Saurischia comprises extinct carnivorous or herbivorous Dinosauras. The pelvic girdle is on usual triadiate reptilian plan, each half is made of 3 bones the ischium, pubis and ilium in triangle (Fig. 12. 7 A). These reptiles had massive bodies with bipedal gait. *Tyrranosaurus* was the largest carnivorous animal. Its hind limbs were very large armed with powerful claws. *Brontosaurus* was herbivorous type distinguished by a very long tail and neck.

Order Ornithischia, the vegeratian extict Dinosaurs had beak - like jaws. The pelvic girdle is bird like, tetra-radiate. The publis lies parallel with an extended ischium (Fig. 12.7 B). The lower jaw possesses a 'predentary' bone that may have supported a horny beak. *Iguanodon* grew to about 30 feet long. *Triceratops* developed paired horns and huge size.

Unit 16 deals with the Dinosaurs in further details.

12.4.6 Sub Class Synapsida

These were mammal like reptiles which became totally extinct. They had single temporal fossa on the lateral side of the skull and large dentary bearing heterodont dentition. Their fossils were excavated in India, North America, Africa and Russia. This sub class includes two orders: The **Pelycosauria** were large lizard like reptiles, with a peculiar web of skin projecting on the back as a sail which is supported by internal skeleton consisting of enormously long neural spines. eg. *Dimetrodon.*

Order **Therapsida** consists of extinct reptiles with mammalian characters in their skull, limbs and dentition. eg. *Cynognathus.*

12.5 SUMMARY

Class Reptilia is defined. The class Reptilia is divided into 6 sub classes based upon the presence or absence and position of the temporal vacuities of skull. Orders **Chelonia** (sub class **Anapsida**),**Rhyncocephalia, Squamata** (Sub class. Lepidosauria) and **Crocodilia** (Sub class Archosauria) are only represented by living members. All the living members except chelonians bear diapsid skull.

12.6 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Enumerate the general characters of class Reptilia.
2. Give an outline classification of reptiles with examples of each group.

II. Answer the following questions in about 10 lines each.

1. Describe the temporal fenestrae in reptiles and explain how the classificaiton of reptiles is based on this character.
2. Write about the subclass Anapsida
3. Describe *Sphenodon.*
4. Describe briefly about snakes.

5. **Differentiate between : A. Chelonia and Crocodilia B. Squamata and Rhynocephalia C. Lacertilia and Ophidia**

6. *Cotylosauria*

7. *Chelonia*

8. *Icthyosaurus*

9. *Rhyncocephali*

10. *Ophidia*

11. *Hemidactylus*

12. *Chamaeleon*

13. *Python*

14. *Hydrophis*

15. *Bangarus*

16. *Pterosauria*

Unit – 13 CALOTES - MORPHOLOGY AND ANATOMY

Contents

13.1 OBJECTIVES

This lesson deals with the organisation of a reptile representative in detail so as to understand its biology.

13.2 INTRODUCTION

Calotes represents the group of garden lizazrds found widely distribued in temperate zones, like Indian sub-constinent, Malayasia and Southern China. In North India it is popularly known as 'girgit' and is quite common in Andhra Pradesh locally called as 'Thonda'.

Calotes lives on trees and shrubs in gardens and jungles. It runs fast and climbs the trees very swiftly. It is active during day time feeding on the insects. When excited or threatened it's head and neck turn red and hence it is also called the 'Blood Sucker', a misnomer. Thus lizards exhibit colour changing machanisam .

13.3 MORPHOLOGY

The body of the *Calotes,* reaching to a length of 35 to 40 cm, is coloured olive green or greyish dorsally and white ventrally. It is divisible into head, neck, trunk and tail (Fig 13.1)

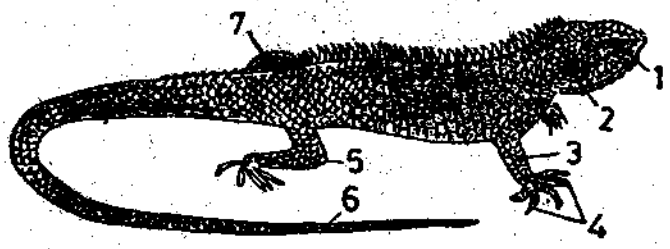


Fig 13.1 Calotes 1. Eye 2. Ear Opening 3. Fore limb 4. Claws 5. Hind limb 6. Tail 7. Body scales.

The head is roughly triangular in shape and bears a pair of relatively small eyes protected by upper and lower movable eyelids and a nictitating membrane which is normally kept folded in anterior corner of the eye. The external nares at the tip of the head (snout) are very minute. The mouth is quite wide. Behind the eyes a pair of external auditory apertures lie having a tympanum at their bottom. The neck region and abdominal regions are distinguishable. On the ventral side a cloacal aperture opens as a transverse slit at the junction of trunk and tail. One pair of fore limbs, short in size, comprise branchium (upper arm), antebrachium (fore arm) and manus (hand) ending on five clawed digits. Each hind limb which is relatively longer than fore-limbs, consists of a femur (thigh), crus (shank), and pes (foot;). Each foot terminates on five thin toes ending on sharp claws. Behind the trunk a very logn cylindrical tail tapers posteriorly.

13.3.1 Ihtegument

The body of the lizard is covered by horny, epidermal scales completely which form an exoskeleton. The scale size, and shape differs according to the requirement of the body. On the trunk, they are large and keeled whereas on the head the scales are small. On the mid-dorsal line of trunk and head the scales are modified to form spiny crests. the skin of lizards is characteristically dry without any galnds. Scales, produced by the Malphigian layer of epiderms are periodically shed in flakes. The colour change of the skin is brought about by the pigment cells, the melanophores,. scattered in the skin.

13.4 ANATOMY

The body wall encloses a spacious coelom in the trunk which is surrounded on all sides by peritoneum. the coelom is disposed into a small pericardial cavity, enclosing the heart and a posterior very large perivisceral cavity containing other viseral organs except the kidneys. These

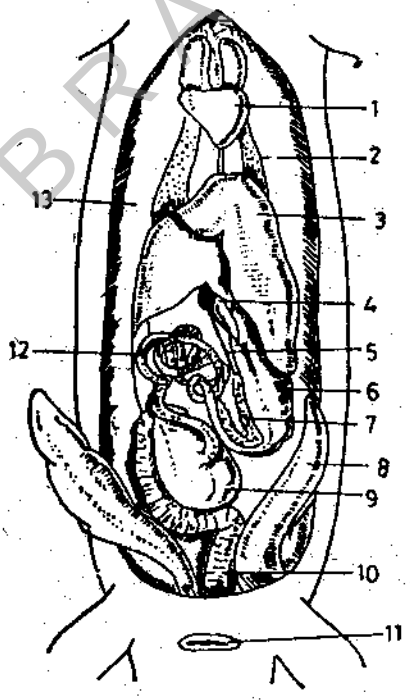


Fig. 13.2 Viscera of *Calotes* 1. Heart 2. Left lung 3. Left liver lobe 4. Gall bladder 5. Bile duct 6. Stomach 7. Pancreas 8. Fat body 9. Large intestine 10. Cloaca 11. Cloacal opening 12. Small intestine 13. Coelomic cavity.

two cavities are completely disconnected. They contain a watery coelomic fluid. There are paired masses of (Fig. 13.2) fat bodies (corpora adiposa) in the posterior region which serve as source of food for lizards during their wintersleep (Hibernation).

13.4.1 Alimentary Canal

The mouth is fringed by labial scales and is supported by the bones of the upper and lower jaw. It leads into a large bucco- pharyngeal cavity. The teeth are pleurodont i.e. attached on the outer margins of the jaws, and are present on both the jaws. A fleshy tongue in the cavity has fine papillae containing taste buds. Labial glands in the mouth secrete mucous which helps in swallowing the prey which is not masticated by the teeth. In the posterior part of the roof at the angles of the jaws a pair of Eustachian tubes open as usual in most vertebrates (Fig. 13.3).

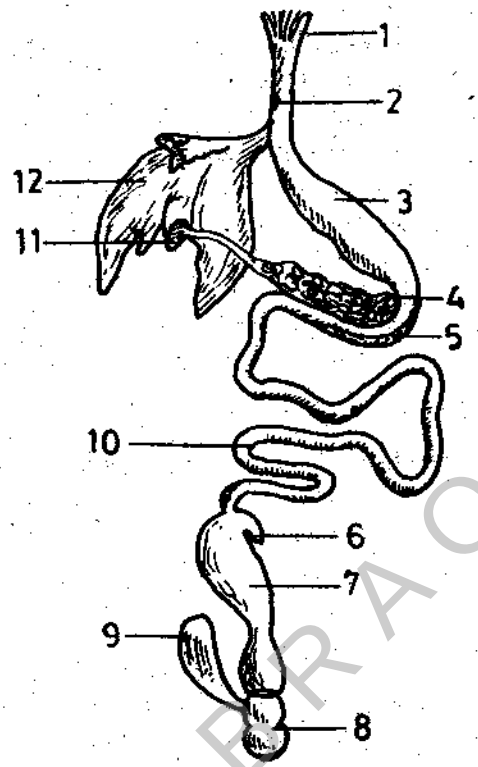


Fig. 13.3 Alimentary canal with associated glands of *Calotes*, 1. Pharynx 2. Oesophagus 3. Stomach 4. Pancreas 5. Duodenum 6. Caecum 7. Rectum 8. Cloaca 9. Urinary baldder 10. Ileum 11. Gall badder

The pharynx leads postoriorly into a narrow short oesophagus which dilates behind to form the stomach. The latter is a tubular sac on the left side of body cavity without any well-marked regions like **cardiac** or **pyloric.** At the end of the stomach, there is a pyloric valve to control the passage of food into the succeeding part, the small intestine. It is a long coiled tube divisible into anterior duodenum which receives at its beginning bile duct from liver and pancreatic ducts. The duodenum abruptly passes into ileum, the longest part of the system which is much coiled.

The ileum opens through an ileo-rectal valve into the large intestine which is a wide thick walled straight tube. It forms on its upper left side a small blind pouch, the caecum of unknown function. The large intestine functions like the rectum of higher vertebrates. It opens into cloaca which differentiates into three regions, namely, the middle **urodaeum** which receives urino-genital ducts dorsally and gives off urinary baldder ventrally and the posterior **proctodaeum** which is the common chamber leading to the cloacal aperture, the common outlet. It is situated at the junciton of trunk and tail.

Digestive glands

There are two digestive glands in *Calotes,* the liver and pancreas. The liver is a large bilobed brownish gland situated in betweeen the lungs. It has a gall baldder embedded in the right lobe. A bile-duct carries the bile from the gall-blader to the duodenum.

The pancreas, situated in the loop of duodenum, is a whitish gland which supplies pancreatic juice to the duodenum through its duct. *Calotes* appears to possess intestinal and gastric glands also pouring intestinal juice and gastric juice in to the respective parts of the alimentary canal. These secretions act on the food of *Calotes* which mainly consists of insects.

13.4.2 Respiration

The external nares lead into olfactory sacs which open anteriorly on a pair of internal nares inside the buccal cavity. Behind the root of the tongue there is glottis, a median longitudinal slit. The glottis leads into the muscular larynx. The walls of which are suppported by a cricoid and a pair of arytenoid cartilages. The larynx opens behind into a cylindrical tube, the tranchea (wide pipe) which extends back upto thorax. Its wall is supported by complete cartilagenous rings. Behind, the trachea bifurcates to form two bronchi, each entering the lung of its own side. Each bronchus is also supported by cartilagenous rings.

The lungs are paired elastic, saclike structures, situated one on each side of the heart. Their inner lining is raised into a network of septa. In between these septa depressions, the alveoli are formed. Since wall of the lung and alveoli are supplied with numerous capillaries, gaseous exchange takes place.

For inspiration, the ribs and outer inter-costal muscles in between the ribs play an important role. When the muscles contract the ribs move outwards and forwards. thus enlarging the body cavity. This in turn expands the lungs when their air pressure falls. The atmosphreic air with high pressure falls. The atmospheric air with high pressure rushes into the lungs by way of external nares.

Contraction of inner intercostals reduce the cavity, muscles of lungs contract so that pressure on the air rises up. Consequently expiration of foul air takes place. Thus ringed trachea, expanded lung surface by septa and rib movements are some of the singnificant features in the respiration of *Calotes.*

13.4.3 Blood Circulation

Heart

The heart of *calotes* comprises of (i) two auricles and (ii) partially divided ventricle. In general it resembles to that of Lacertia (Fig. 13.4). (i) The right and left auricles are formed by an interauricular septum. The right auricle is larger than the left. The right auricle receives deoxygenated blood from the sinus venosus which lies dorsally. Two precaval and a postcaval veins empty their blood into the sinus venosus which opens into the right auricle through sinuauricular aperture guarded by a pair of sinuaricular valves.

The left auricle receives oxygenated blood from a pair of pulmonary veins which open into it through a common aperture in the dorsasl wall. This aperture has no value.

Both auricles open into the ventricle independently through their respective auriculoventricular apertures guarded by valves (Fig. 13.5).

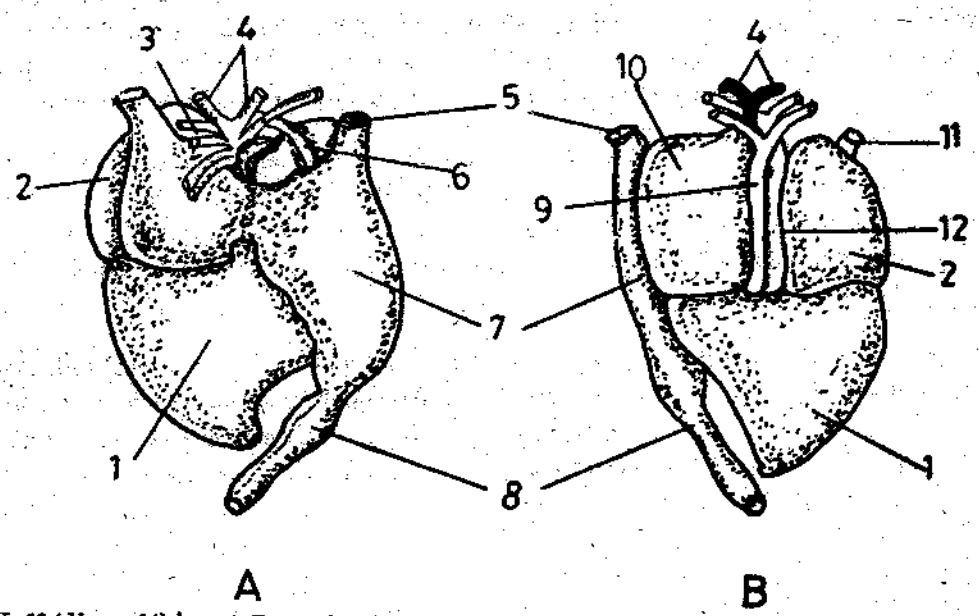


Fig 13.4 Heart of *Calotes*. A. Dorsal view. B. Ventral view. 1. Ventricle 2. Left auricle 3. Right systemic arch 4. Carotid arteries 5. Precaval 6. Pulmonary artery 7. Sinus venosus 8. Posterior venacava 9. Left systemic arch 10. Right auricle 11. Left precaval 12. Pulmonary arch, 13. Forame paniza.

(ii) The ventricle has a thick and spongy wall. Internally it is partially divided into two unequal chambers by an oblique interventricualr septum which is almost horizontal. Its free edge comes in contact with ventral wall so as to divide the interior of the ventricle into two functional chambers a dorsal chamber, the cavum dorsale and a ventral chamber, the cavum ventrale. The (Pulmonale)

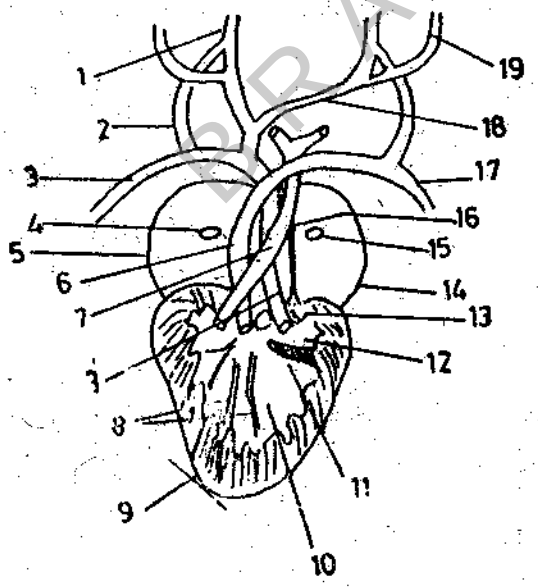


Fig. 13.5 Calotes-Internal structure of the heart and arches 1. Internal carotid 2. Ductus caroticus 3. Right systemic 4. Sinu- auricular aperture 5. Right auricle 6. Left systemic 7. Pulmonary arch 8. Chordae tendinae 9. Ventricle 10. Cavum ventrale 11. Interventricular septum 12. Cavum dorsale 13. Auriculo ventricular valves 14. Left auricle 15. Pulmonary vein aperture 16. Inter auricular septum 17. Left systemic 18. Left carotid artery 19. External carotid.

Three aortic arches arise from the ventricle: the pulmonary and left systemic arches from the cavum ventrale and the right systemic arch from the cavum dorsale. All these arches are provided with a part of semilunar valves at their bases and are bound together by connective tissue. The two systemic arches cross and twist while passing forward from the heart.

The right auricle is filled with venous blood supplied by the sinus venosus. Simultaneously the left auricle is filled with oxygenated blood received from pulmonary veins. Both auricles contract at a time forcing the deoxygented blood into the cavum ventricle contracts, deoxygeneted blood goes into the pulmonary and left systemic arches. The oxgenated blood enters the right systemic arch.

In reptilia some mixture of arterial and venous blood is unavoidable. Most recent work suggests that oxgenated blood received by the cavum dorsale mainly goes into right systemic and carotid arches. Some of the right systemic blood, carrying more oxygen is added to the internal carotid via ductus caroticus, a connecting artery between systemic arch and internal carotid artery going to the brain (Uromastix).

Arteries

The pulmonary arch is divied into the right and left pulmonary arteries just in front of the heart which curve backwards and enter their respective lungs.

The right and left systemic arches cross one another at the anterior end of the heart, extend outwardly, loop backwards and unite in the middorsal region to form the dorsal aorta.

The right systemic gives off a short branch, the common carotid which divides immediately in front of the heart into a right and left carotid arteries. Each carotid further divides into internal and external carotids which supply blood to the head region. Each carotid artery connects with the systemic arch of that side by means of an artery, the ductus caroticus.

A common subclavian artery arises from the right systemic just before the union of the systemics. It divides into the right and left subclavian arteries which extend into their respective forelimbs.

The dorsal aorta proceeds backwards on the midorsal line beneath the vertebral column and gives off the following branches:

(i) Several paired parietals to dorsal muscles and vertebral column;

(ii) An anterior mesenteric which crosses the coeliac, supplies to small intestine;

(iii) A coeliac to stomach, liver, pancreas, and spleen

(iv) A posterior mesenteric to the rectum;

(v) Paired gonadials (spermatic or ovarian) to the reproductive organs;

(vi) Pair of iliac to the hind limbs;

(vii) Few paired renals to the kidneys;

(viii) Median caudal, the terminal portion of dorsal aorta enters the tail.

Veins

The sinus venosus collects deoxygenated blood from two precaval veins situated at its anterolateral angles and a post caval vein at the posterior angle.

Each precaval is formed by the union of internal and external jugular veins that bring blood from the head. A subclavian vein returns the blood from the forelimbs and joins the precaval vein of that side.

The postcaval vein joins the sinus at the posterior angle. It is formed by the union of right and left efferent renal veins into wihch open right and left gonadial veins respectively. At the upper end the post caval which ascends through the mass of liver receives a pair of hepatic veins.

There are two portal systems in *Calotes* like in frog the **hepatic** and **renal**. . the hepatic portal vein is formed by the union of veins coming from the alimentary canal namely the duodenum, spleen, intestine and stomach. It enters the liver and breaks up in to capillaries.

The renal portal system consists of a caudal vein which bifurcates to form two pelvic veins. In to each pelvic vein the afferent renal, femoral and sciatic veins of the that side empty their blood. Both pelvics unite to form and anterior abdominal vein which ramifies into capillaries in the liver.

13.4.4 Brain and Nerves

The brain has olfactory bulbs anteriorly which are stalked. Each bulb contains a cavity, the **rhinocoel**. the cerebral hemispheres are large (Fig 13.6). A longitudinal fissure separates them. Each hemisphere encloses a **lateral ventricle**, the roof of which is very thin (**epallium**) but lateral and ventral walls are thick. These walls form the **corpus striatum**. Both corpora striata are interconnected by anterior commissure. They receive efferent fibres from the **thalami**. This indicates that the brain is functionally advanced. The cerebral cortex also shows improvement over amphibians.

The diencephalon encloses the **third ventricle**, the **diacoel** which is continuous with lateral ventricles through **foramen of Monro**. . Its vascular part of **anterior choroid plexus**. Dorsally diencephalon has **pineal apparatus** consisting of an anterior **parietal body (pineal eye)**) and a posterior **pineal body** The pineal eye in some reptiles appears to be sensitive to light. e.g. *Varanus*. Behind this occur posterior and Habenular **commissures**. Side walls and floor of the third ventricle are thick and are known as **optic thalami** and **hypothalamus** respectively. Hypothalamus produces a downward growth, the **infundibulum**, at the tip of which the hypophysis is attached. The hypophysis (**Rathke's pouch**) is an out growth of the stomodaeum. Together the latter two form the pituitary body. The optic chiasma lies in front of this body.

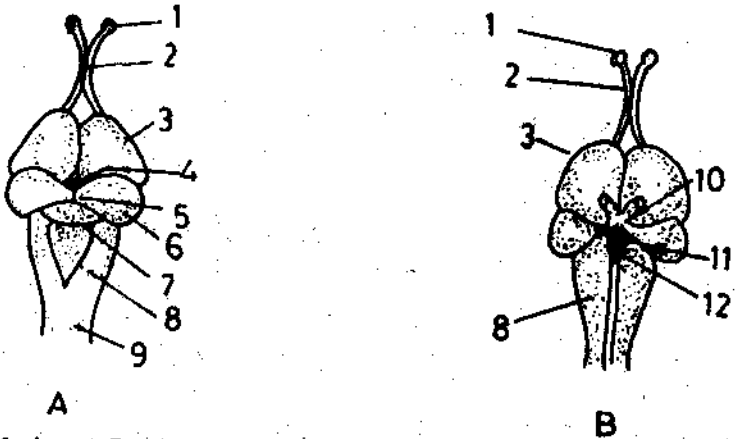


Fig. 13.6. Brain of *calotes*. A. Dorsal view B. Ventral view. 1. Olfactory lobe 2. Olfactory peduncle 3. Cerebral hemisphere 4. Pineal body 5. Diencephalon 6. Optic lobe 7. Cerebellum 8. Medulla oblongata 9. Sp. al cord 10 Optic chiasma 11. Infundibulum 12. Pituitary body.

Two optic lobes are placed dorsally just touching the hemispheres. Their cavities, the **optocoels**, mutually communicate through **iter** which is connected to fourth **ventricle behind.** The **crura cerebri** situated below the optic lobes are longitudinal fibres bands which connect diencephalon to medulla oblongata.

The cerebellum is feebly developad behind the optic lobes as a thin band on the dorsal side.

The medulla oblongata has a ventral flexure from, where the spinal cord begins. The medulla has a cavity, the **fourth ventricle** its roof forms **posterior choroid plexus,** the vascular fold.

The cerebrospinal fluid fills the ventricular interior of cavities of the brain which is secreted by the choroid plexuses.

13.4.5 Spinal Cord

The spinal cord of Calotes is formed on a typical vetebrate plan and very closely resembles to that of frog. In general it is slightly dorsoventrally compressed extending from the medulla to the caudal region within the neural canal. Enlargements of the cord, are found in the forelimb region forming **branchial plexus** and in the hind limb region, the **limbo-sacral plexus.** It encloses a narrow cavity, the **central canal** which contains **cerebrospinal fluid.**

The cranial nerves are 12 pairs. Out of which 10 pairs correspond to those of frog, remaining two the hypoglossal and spinal accessory arise from hinder part of the medulla and innervate the muscles of tongue and larynx respectively

Noteworthy sense organs of *calotes* are a pair of **Jacobson's organs.** These are located in the roof of bucccal cavity in front of the internal nares. They are lined by olfactory epithelium. They smell the food in the buccal cavity through their openings.

13.4.6 Excretory Organs

A pair of metanephric kidneys of dark red colour are placed in the posterior most abdominal region which occupy partly the base of the tail. Each kidney is two lobed (Fig. 13.7) anterior lobes are free but posterior lobes are fused in the middle line. Each kidney midventrally opens into **urinogenital duct** which in turn opens into the urodaeum. A urinary bladder, situated ventrally also opens into urodaeum. the kidneys excrete uric acid along with a little amount of water which is discharged into the urodaeum. It is picked up and stored in the urinary bladder. There entire water is absorbed leaving only solid uric acid to be eliminated.

13.4.7 Reproductive Organs

Sexes are separate. In the male,there is a pair of testes, whitish ovoid bodies, lying in front of kidneys(fig 13.7A).From the inner border of each testis a long convoluted tube, the latter

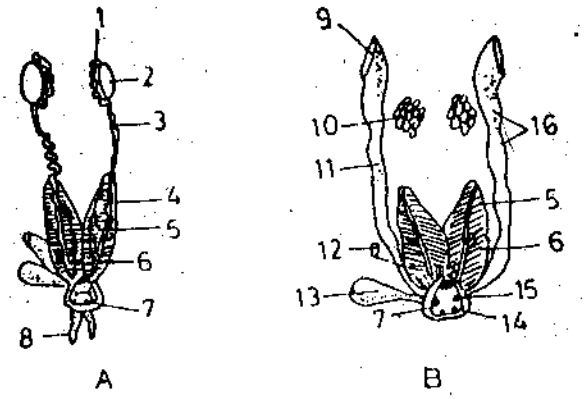


Fig. 13.7 *Calotes*-Urinogenital organs. A. Male B. Female 1. Epididymis 2. Testis 3. Vas deferenns 4. Kidney 5. Ureter 6. Urinogenital duct 7. Cloaca 8. Penis 0. Oviducal funnel 10. Ovary 11. Oviduct 12. Rectum 13. Urinary bladder 14. Opening of ureter 15. Opening of oviduct.

joins the ureter to form a urinogenital duct which opens independently into urodaeum.

Behind the cloacal aperture on either side their is an ever side vascular, grooved and sac-like copulatory organ, the hemipenis. Both hemipenes are everted during copulation as cylindrical bodies, pass sperms along their grooves into the clocal of the female.

In the female here is a pair of ovaries, whitish lobulated bodies. They are attached to the abdominal wall by mesovarium (Fig. 12.7 B). A. Pair of oviducts, one on each side extend in front of the ovary. They are thin walled. The oviducal funnels are directed externally. Each oviduct open into the cloaca separately in front of the ureter:

The fertilization is internal. the female lays about a dozen soft-shelled eggs in shallow, debris covered pit. During the development amnion allantois and chorion are formed.

13.5. SUMMARY

Calotes, the garden lizard is a fast runner, mostly living on trees and shrubs feeding on insects. Body divisible into head, neck, trunk and tail. Trunk with 2 pairs of pentadactyl limbs. Body covered by epidermal scales incontrast to the dermal scales of fishes. Digestive system inlcudes the alimentary canal, liver and pancreas. The lungs are paired, elastic sacs with its inner lining raised into septa which are richly vascularised for gaseous exchange. Verntricle is partly divided by an oblique interventricular septum dividing it into a dorsal and a ventral functional chambers. Brain shows advancement over ammphibian condition. 12 pairs of cranial nerves present. Pineal eye present in *Varanus, Anguis* and *Sphenodon*. Jacobson's organs present in the roof of the buccal cavity. Kidneys are metanephric. Sexes separate males possess a pair of hemipenis. The female lays about a dozen soft shelled egges in shallow debris covered pits. Embryonic membranes protect the developing embryo.

13.6 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each

1. Describe the digestive system of *Calotes.*
2. Give an account of the structure and working of the heart of the garden lizard.
3. Describe the brain of *Calotes* and show how it is advanced than that of *Rana.*

II. Answer the following questions in about 10 lines each

1. Write an account on respiration in *Calotes.*
2. Describe the arterial system of *Calotes.*
3. Describe male and female reproductive organs of *Calotes.*
4. Digestive glands in *Calotes.*
5. Hepatic and renal portal sytems of *Calotes.*
6. Diencephalon of *Calotes*
7. Jacobson's organ.
8. Metanephric kidney.

Unit – 14 SKELETON OF VARANUS

Contents

14.1 OBJECTIVES

- To understand the reptilian organisation of the endoskeleton.

14.2 INTRODUCTION

In vertebrates the bony skeleton, the supporting frame work, lies within the body and hence called as endoskeleton. This develops from mesenchyme or connective tissue. In embryonic stages first the skeleton is formed with cartilage and is later transformed into real bone, after passing through a series of changes. Dermal or membrane bones develop from cranium exteriorly, later incorporate inside the body. The endoskeleton components consist of:

1. The axial skeleton comprising the skull and vertebral column.
2. The appendicular skeleton includes girdles and bones of limbs.

Varanus (common name, monitor) belongs to class **Reptilia,** order **Squamata** and **Lacertilia** forming the group of lizards. The study of its skeleton not only explains the general organization of the skeletal system of a vertebrate but also reveals the peculiarities of reptiles.

14.3 AXIAL SKELETON

Skull

The skull of Varnus is well ossified and contains several more bones which are lacking in amphibian skull. It has four regions (1) Cranium (2) Sense capsules (3) Jaws and (4) Hyoid apparatus.

1. Cranium

The cranium (Fig. 14.1 A and B) consists of 3 regions from behind to front as follows:

(a) The **occipital reigion** is the posterior end of the cranium perforated by **foramen magnum,** which is surrounded by three bones; (i) **supra occipital** forms the arched roof of magnum, ii) **Basioccipital** forms the floor and bears a posterior knob like occipital condyle, and (iii) **Exoccipitals** surrounded magnum laterally, giving out **paroccipital processes.** These three segments unite and form a protective covering over the exit of spinal cord. The single condyle is characteristic of Reptilia.

(b) The **parietal region,** situated in front of the occipital, is made up of (i) an anterior **basisphenoid** and (ii) a pair of dorsally fused **parietals** make up the floor and roof of

the **cranium** respectively. A parietal formen is present. The sides are formed of soft tissue as **alisphenoids** are lacking in this place.

(c) The **frontal region** has 2 components (i) a pair of triangular **frontal** dorsally fused by a **frontal suture** in midline and (ii) a **parasphenoid,** a ventral long, narrow rod-like bone which extends forwards. This also forms an incomplete cranium because of the absence of oribitosphenoids and presphenoids.

Sense Capsules

The following 3 sense capsules enclose and protect the sense organs

(i) **Auditory otic,** (ii) **Optic** and (iii) **Olfactory.**

(i) auditory Capsules: consists of a signle prootic bone in each capsule.

(ii) **The optic capsules** (orbits) are one pair on the sides of cranium. An interorbitral septum divides the two orbits. Each orbit is surrounded by five bones namely, prefrontal, Supra orbital, lacrymal, post frontal and jugal. All these bones arrange themselves around and form the orbit which lodges the eye ball.

(iii) **Olfactory casule** is made up of two triangular flat bones nasals which fuse medially into one piece. A pair of **vomers** form the inner margines of posterior nares.

3. Jaws

(a) The upper jaw is fixed to the cranium. It consists of the following bones.

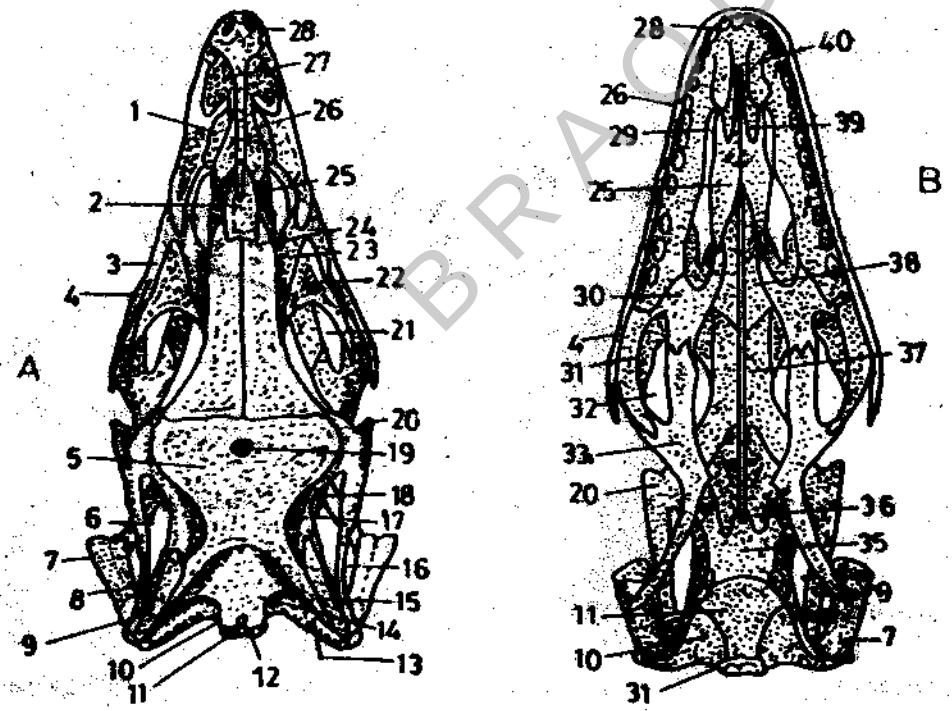


Fig 14.1 Skull of varanus A. Dorsal view B. Ventral view. 1. Septomaxillary 2. Nasal 3. Lacrymal 4. Jugal 5. Parietal 6. Supratemporal fossa 7. Quadrate 8. Supra temporal 9. Squamosal 10. Exoccipital 11. Basioccipital 12. Foramen magnum 13. Paroccipital process of exocicipital 14. Supra occipital 15. Protic 16. Supra temporal arcade 17. Prooltic 18. Epipterygoid 19. Parietal foramen 20. Post orbital 21. Supraorbital fossa 22. Supraorbital 23. Prefrontal 24. Frontal 25. Vomer 26. Maxilla 27. Nasal process of premaxilla 28. Premaxilla 29. Aperture for Jacobson's organ 30. Palatine 31. Transverse 32. Suborbital 33. Pterygoid 34. Occipital condyle 35. Basisphenoid 36. Orbitosphenoid 37. Ventrolateral process of frontal 38. Ventral border of inter orbital septum 39. Vomerine aperture 40. Maxillary process of Premaxilla.

(i) Paired premaxillae are fused in midline to form a single bone on which one pair of dorsal premaxillary, maxillary and foramina are present. Posteriorly a long nasal process and anteriorly a pair of vomeromaxillary processes are prominently seen. They bear 6-8 teeth.

(ii) Maxillae are broad, irregular vertical bones occupying major portion of the upper jaw, just behind the premaxillae. Ventrally between these two bones, an aperture opens into Jacobson's organ. (iii) The Jugal is a slender curved bone which in addition to form the part of the jaw, bounds orbit ventrally.

The above bones form the outer set. The elements of inner set forming the upper jaw consist of (i) the pterygoids a wavy bone ventrally (ii) the transverse or ecotopterygoid, a curved bone on the inner side of the jugal(iii) the epiterygoid is a rod-like bone extending from pteygoid to prootic.

(b) The **lower jaw** is also semioval in shape and consists of the following parts (Fig. 14.2)

(i) The **dentary** is the largest anterior part which bears neural forminae and teeth;

(ii) The **supra angular** is a flat some what rectangualr bone behind the dentary;

(iii) The **angular** is below the dentary and supraangular;

(iv) The **articular** is a slender bone, forms posterior part of the jaw, its free end is tipped with cartilage, it articualtes with the quadrate of the upper jaw;

(v) A **coronoid** with an upward process, is a small conical bone;

(vi) The **splenial** is a flat, thin triangular bone fixed on the inner surface of dentary.

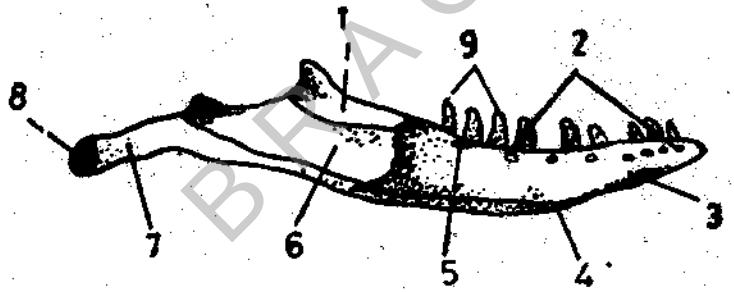


Fig 14.2 Lower jaw of Varanus-outer view. 1. Coracoid 2. Foramen for branches of mandibular nerve 3. Dentary 4. Angular 5. Mental foramen 6.Supra angular 7. Articualr 8. Articualr ridge 9. Teeth.

(C) The suspensorium of lower jaw with upper jaw and cranium is formed by (i) the **quadrate**, a small, stout rod, and (ii) the **squamosal**, a curved bony rod.

4. Hyoid Apparatus

The hyoid apparatus situated in buccopharyngeal cavity consists of a (i) **basihyal cartilage** whose anterior process, os entoglossus supports the tongue, and produces (ii) two pairs of long slender processes, the anterior and posterior horns (Cornua), the anterior part bears a distal limb (Fig 14.3).

The temporl region of the skull has 3 pairs of vacuities. (i) **Supra temporal fossa** on the sides. (ii) the posteriod temporal fossae on the sides of occipital region and (iii) the lateral temporal fossae, large spaces on the sides behind the orbits.

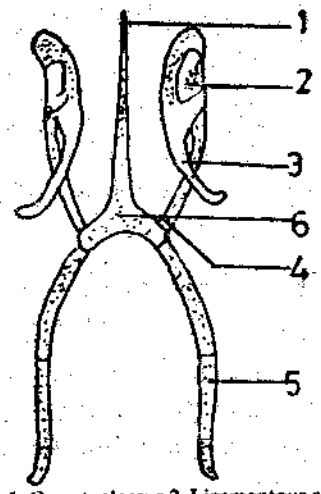


Fig. 14.3 Hyoid appartus of Varanus. 1. Os entoglossus 2. Ligamentous sheet 3. Distal limb of anterior cornua 4. Proximal limb of anterior cornua 5. Posterior cornua 6. Basihyal.

Vertebral Column

The vertebral column has a large number of vertebrae(about 83-85) all with procoelous centra. Forthe passage of the spinl nerves there are inervertebral formina in between the vertebrae.

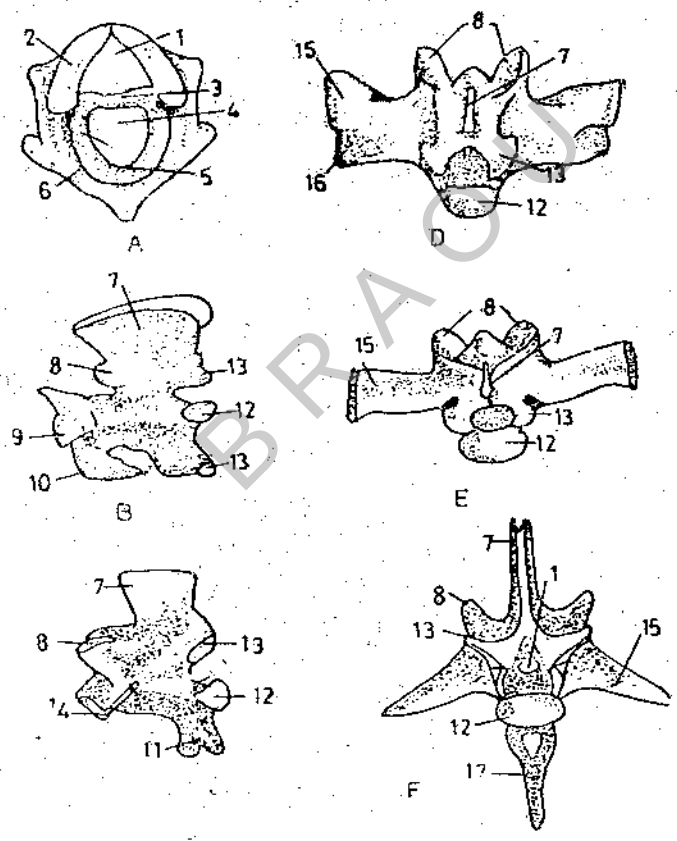


Fig. 14.4 Vertebrae of VaranusA. Atlas vertebra B. Axis Vertebra C.Typical vertebra D. First sacral Vertebra E. Second sacral vertebra. F. Caudal vertebra. 1. Neural canal 2. Dorso lateral piece 3. Ligament 4. Odontoid fossa 5. Cavity for occipital condyle 6. Ventral piece 7. Neural spine 8. Pre zygapophsis 9. Odontoid process 10. Flooked Spine 11. Hypapophysis 12. Centrum 13. Post zygapophsis 14. Facet for cervical rib 15. Transverse process 16. Articular facet for ilium 17. Y-shaped chevron bone.

(i) The Cervicals are 8 (ii) the Thoracolumbar 22, (iii) the Sacrals and (iv) many Caudals. The vertebral formula is $C_8TL_{22}S_2C_{51-53}$.

(i) First of the **cervical verbebrae** is **atlas.** It is ring-shaped with a facet for the single occipital condyle of the skulll. There is a tough ligment which stretches transversely across the neural canal. There is no centrum. The spinal cord passes through the upper neural canal (Fig. 14.4A).

It is formed of a median ventral and two dorsolateral pieces forming upper spinal canal and a lower central canal of atlas and fits into the odontoid canal of atlas.

The **second cervical** is the **axis.** It bears a projection, the odontoid process which is modified centrum (pleurocentrum). Its neural spine is wider and anterior end of centrum has a hoolike spine. Posterior hypapophysis is meant for articulation (Fig 14.4)

Other cervicals are regarded as typical vertebrae in particular, from 4th to 6th. All are similar with a neural arch, neural spine, zygapophyses, a ventral hypaposphysis and articular facet for ribs (Fig. 14.4 C)

(ii) The **thoraco-lumber** vertebrae are large, stout and resemble in all respects to typical cervical vertebrae. The lumbars have no facets for ribs.

(iii) The **sacral vertebrae** have stout transverse processes, a small neural spine, and the first ones bear facets for illia (Fig.. 14.4 D and E).

(iv) The **caudal vertebrae** progressively become smaller in size. Each vertebra has a Y-shaped chevron bone hanging down the centrum, containing the haemal canal (Fig. 14.4 F).

The **sternum** is a thin rhomboidal plate, made of calcified cartilage. An arrow shaped cartilage, the interclavicle, attached to the sterum projects anteriorly (Fig. 14.5). The clavicles are applied to interclavicle.

The ribs articulate with vertebrae starting from 4th cervical to the sacrals. Each rib has a dorsal bony vertebral part and ventral calcified cartilagenous sternal part. Except the first 3 pairs of thorocolumbar ribs which are attached to the sternum, the others are free.

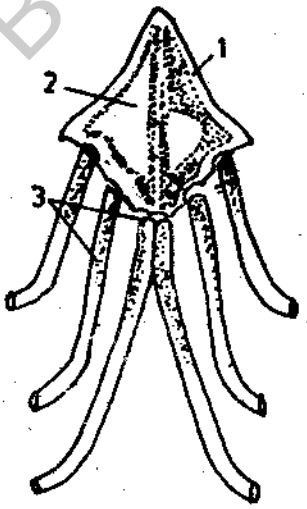


Fig. 14.5 Sternum of Calotes 1. Groove for interclavicle 2. Sternal plate 3. Sternal ribs.

14.4. APPENDICULAR SKELETON

Pectoral girdle

The pectoral girdle consists of two identical halves lying one on either side of the **interclavicle** dorsally and closely connected to the **sterrnum** and **clavicle.** Each half has a bony **scapula,** a **coracoid** and at their junction posteriorly is a **glenoid cavity.** An expanded **supra-scapula** is made up of calcified cartilage. The **procoracoid** and **meso-coracoid** processes of coracoid are bony, but **epicoracoid** at the mid anterior end is cartilagenous. Coracoid region is perforated by three **fenestrae** (Fig. 14.6 A).).

Pelvic girdle

In the pelvic girdle, two similar halves the ossa innominata meet with each other ventrally. Each half is a triradiate, of fused bones consisting of a rod like illium, directed backwards to articulate with sacral vertebrae. It gives off a small projection, the preacetabular process. Both **pubis** and **ischium** meet their counter part to form symphyses of their own. an **epipubic** cartilage and a **hypoischium** cartilage are present at pubic and ischiatic symphyses. A thin cord stretches forward from preischial cartilage and divides the space in the girdle into two **ischiopubic fenestrae** vertically. On each pubis there is an **obturator foramen.** The **acetabulam** is situated at the junction of the three bones ventrlly for articulation of hind limbs (Fig.14.6B).

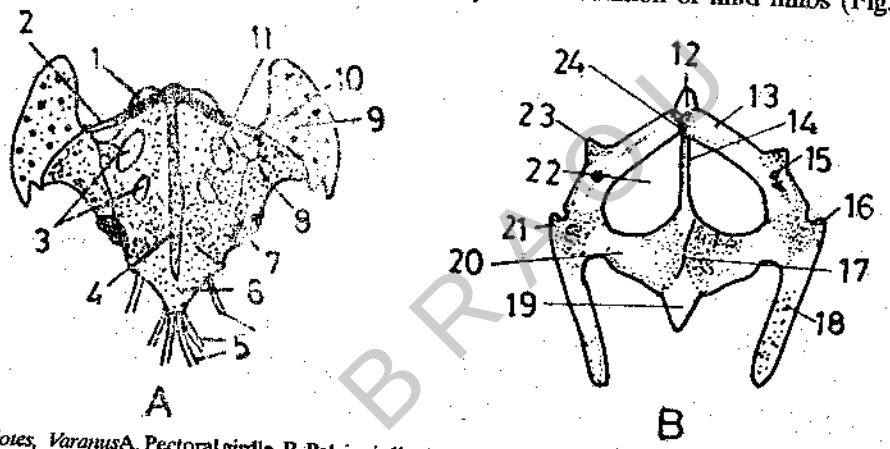


Fig14.6 *Calotes, Varanus*A. Pectoral girdle. B. Pelvic girdle. 1. Epicoracoid 2. Clavicle 3. Fenestra in coracoid 4. Inter clavicle 5. Sternal ribs 6. Sternum 7. Glenoid cavity 8. Scapula 9. Supra scapula 10. Precoracoid 11. Meso coracoid 12. Epipubis 13. Pubis 14. Ligament 15. Obturator foramen for nerve 16. Preacetabular process of ilium 17. Ischiatic symphysis 18. Ilium 19. Hypoischium 20. Ischium 21. Acetabulum 22. Ischiopubic fenestra 23. Prepubis 24. Pubic symphysis

Skeleton of the limbs

The fore limbs and hind limbs of *Varanus* are pentadactley. They have a well developed skeleton stronger than the amphibians.

Bones of the Fore-limb The structural bony elements of the forelimb consist of (i) Humerus (ii) Radius and ulna (iii) Carapals (iv) Metacarpals and phalanges.

(i) The **humerus** is a bone with a stout shaft, flattened at head and trochlear ends, the later has slightly pulley like condyles for articulation with radius and ulna. Just below the head a **deltoid ridge** is prominent to which deltoid muscles attach (Fig. 14.7).

(ii) The **radius and ulna** are separate bones which join each other only at their proximal and distal ends. The ulna bears an **olecranon process** at its proximal end.

(iii) The **carpals** are ten arranged in three rows: The **radiale, intermedium and ulnare** in the proximal row; a **centrale** in the middle; a distal row of 5 distal carpals and a pisciform at distal end of ulna.

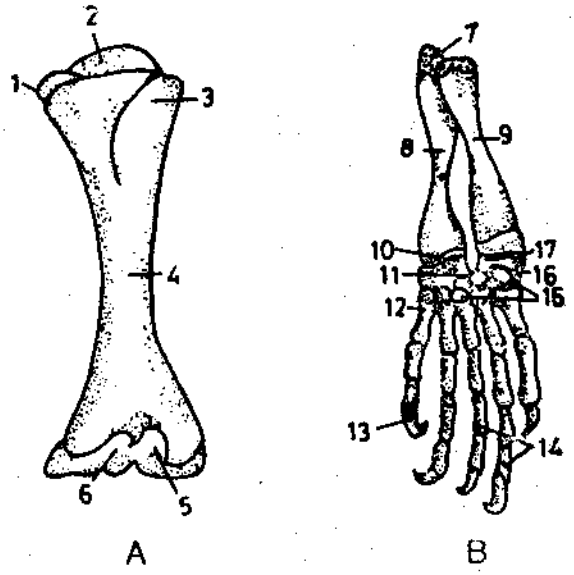


Fig14.7 *Varanus* Fore-limbbones A. Humerus B. Bones of forearm and hand. 1. Medial process 2. Head 3. Deltoid ridge 4. Shaft 5. Radiale epicondyle 6. Ulnare epicondyle 7. Olecranon process 8. Ulna 9. Radius 10. Ulnare 11. Intermedium 12. Meta carpals. 13. Claw 14. Phalanges 15. Distal carpals 16. Radiale 17. Centrale.

(iv) Five slender **matacarpals** of unequal size bear phalanges at their distal ends. The digital formula: pollex (Thumb) has only 2, second 3, third 4, fourth 5, and fifth 3 phalanges. The distal phalanx of each finger carries a curved, sharp pointed, horny claw.

Bones of Hind limb

The skeletal elements in each hind limb are (i) the **femur** (ii) **Tibia** and **Fibula** (iii) **Tarsals** (iv) **Metatarsals** and **phalanges.**

(i) The femur with a stout shaft, bear 8 proximally a round head process to articulate with acetabulum. For insertion of muscles two protrubarances, the lesser and greater trochanters are present. Distally the condyle is grooved (Fig. 14.8).

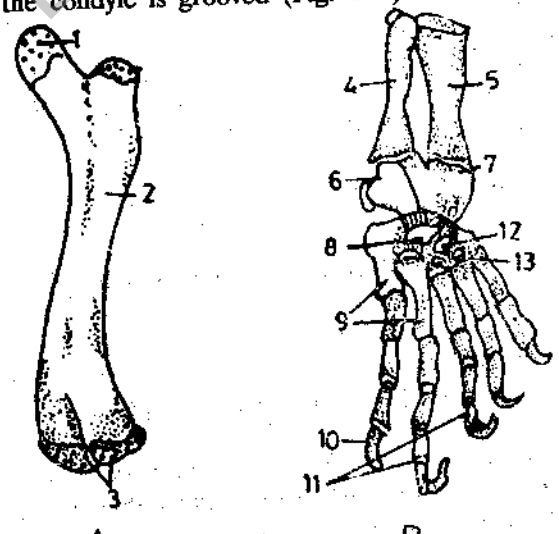


Fig 14.8*Varanus* Tuind LimbBones A. Femur. B. Bones of shank and foot. 1. Head 2. Shaft 3. Condyles 4. Fibula 5. Tibia 6. Fibulare 7. Tibiale 8. tarsals (4+5) 9. Metatarsals 10. Claw 11. Phalanges 12. 3rd distal Tarsals 13. Tarsals (1+2) 14. Lesser trochanter 15. Greater trochanter

(ii) The stout tibia and slender fibular are straight bones which are attached on both ends.

(iii) There are nine tarsals which are reduced to five. Tarsal bone, are arranged in two rows. The tibiale. intermedium and centrale all fused into one. The tibiale in the proximal row; a distal row of only 3 tarsals in which two, the inner and outer, are compound tarsals-each having two tarsals fused.

(iv) Distally five metatarsals of varying size, terminate on phalanges. The digital formula is the same as for the hand-hallux (first toe) has 2, second 3, third 4, fourth 5, and fifth 3. the terminal phalanx of each toe bears a horny pointed claw.

14.5 SUMMARY

The axial skeleton comprises of skull and Vertebral column while the appendicualr skeleton includes girdles and limb bones. Skull consists of cranium, sense capsule, jaws and diapsid. Lower jaw composed of 6 bones. The vertebral column consists of about 85 vertebrae with 8 cervicals and 2 sacrals. The axis bears the odontoid process. The sacral vertebrae have stout transverse processes to articulate with ilia. The caudal vertebrae bear a Y- shaped chevron bone with haemal canal and become progressively smaller posteriosly. The sternum is a rhomboidal plate. The two halves of the pectoral girdle embrace the thoracic region and each half consists of coracoid, scapula and Suprascapula. Interclaviice is a circular anchor shaped structure. The two os- innominata meet ventrally. Both fingers and toes are clawed.

14.6 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Describe the skull of *Varanus.*
2. Describe the appendicular skeleton of *Varanus*. or Describe the, pectoral and pelvic girdles of *Varanus.*

II. Answer the following in about 10 lines each.

1. Cranium of *Varanus.*
2. Hyoid appartus of *Varanus.*
3. Vertebral column of *Varanus.*
4. Bones of the fore limb of *Varanus.*
5. Bones of the hind limb of *Varanus.*
6. Sense capsules of *Varanus.*
7. Lower jaw of *Varanus*
8. Atlas of *Varanus.*
9. Typical vertebra of *Varanus.*
10. Sternum of *Varanus.*
11. Pelvic girdle of *Varanus.*

Unit - 15 POISONOUS AND NON-POISONOUS SNAKES

Contents

15.1 OBJECTIVES

To present an analytical description to distinguish and identify poisonous and non-poisonous snakes.

15.2 INTRODUCTION

India and Africa are rich with snake fauna but a good majority of them are non-poisonous. Out of about 216 species of snakes in India only 52 are poisonous. These include 33 species of terrestrial forms and 19 aquatic. The former comprise mainly the Cobra, the Krait, the pit vipers and vipers and the latter sea snakes.

For the general characters and description of a few common snakes refer unit 12 (squamata). Poisonous snakes possess a pair of poison glands that open into modified grooved teeth on maxillae called fangs. In non-poisionous snakes these are absent. A good number of people die because of snake bite and it was found that a good majority of them died due to sheer fright and unscientific treatment out of ignorance like mantras, plat medicines and magic spells. This method of treatment cannot save a person bitten by a poisonous snake and unnecessary in case of a bite of harmless snake. It is, therefore necessary to have the knowledge of identifying poisonous snakes from non-poisionus ones. The following description for identification is based on the arrangement of scales, plates, shields found over the body and the shape of the head and tail (Fig. 15.1).

15.3 IDENTIFICATION OF POISONOUS SNAKES

If the tail is laterally compressed, the snake is poisonous and is marine snake. Fresh water snakes are non-poisonous. If the tail is cylindrical (round in cross section) and tapers posteriorly is a land snake.

It may be poisonous or non-poisonous. To make sure, the scales on the ventral surface have to be observed.

The presence of small ventral scales resembling those of dorsals or if ventral scaly plates do not extend across belly and are bordered by small scales on both sides, the snake may be recognised as non-poisonous (Fig. 15.1 A and B).

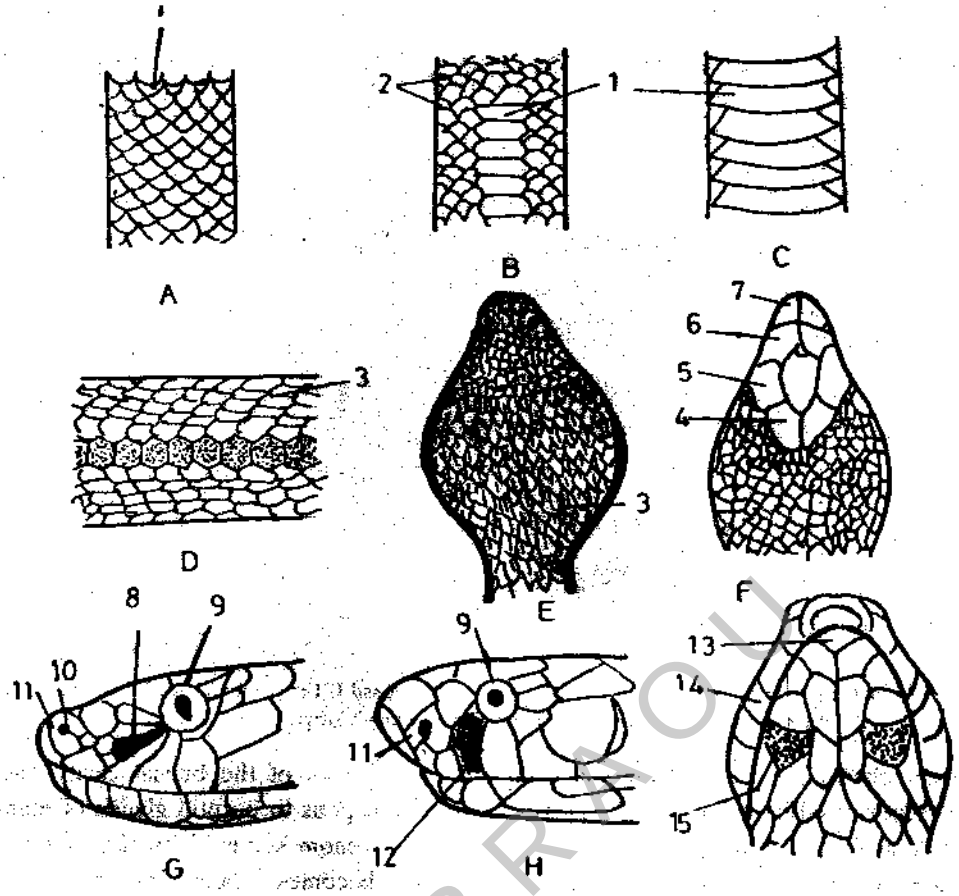


Fig. 15.1 Differences between poisonous and non-poisonous snakes, snakes A& B. Belly of non-poisonous snakes. C. Belly of poisonous or non-poisonous snakes. D. Dorsal body of krait E. Head of pitless viper (dorsal view) F. Head of poisonous or non- poisonous snakes (dorsal view) 1. Head of krait (ventral view) 1. ventrals 2. Small scales (costals) 3. Small scales 4. Shields (parietals) 5. Fronal 6. Prefrontal 7. Rostral 8. Lateral pit 9. Eye 10. Nare 11. Nasal scale 12. 3rd Upper labials 13. Vental 14. Labial 15. Fourth infralabial.

Conversely if the ventral scaly plates extend fully across the belly covering the entire width, without any small scales on the sides, the snake may be poisonous or non-poisonous. Then look for the size of the scales on the head of the snake (Fig. 14.1 C).

Small scales or shields on the head give the clue for poisonous viper snake a pit between the eyes and nostrils is the characteristic of Pit Viper (Fig. 15. 1 G). If only small scales spread in between the eyes and a pit is absent, it is a pitless Viper (Fig.. 15.1 E). In such case with the help of single and double sub-caudal scales, littel Indian Viper and Russell's Viper can be identified respectively. In Cobras and Coral Snakes the 3rd supralabial scale touches the eye and nasal scales. They have large scales or shields on their heads. Cobras have a hood usually with a spectacle marking. When the neck muscles contract, the cervical ribs just behind the head are pulled outwards. They in turn expand the neck laterally forming a hood (Fig. 15. 1 H). Coral snakes have special spots on the belly.

If the vertebral scales in the middorsal region are larger than other, hexagonal in shape and the 4th infra-labial scale is the largest, the snake is a poisonous Krait (Fig. 15. 1 and D).

In the absence of the above said characters of scales, if the snake has large shields on its head. It is non-poisonous. For main points of distinction see table No. 1.

15.4 POISON APPARATUS

All poisonous snakes possess a poison apparatus. It includes a pair of poison glands, a pair of poison ducts and a pair of fangs (Fig. 15. 2).

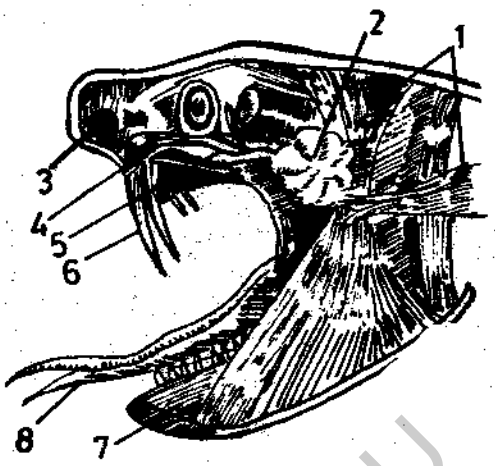


Fig. 15.2 Head of poisonous snake dissected to expose the poisongland 1. Temporal muscles 2. Poison gland 3. Nare 4. Sensory pit 5. Duct of poision gland 6. Fang 7. Lower jaw 8. Tongue.

The poison glands are situated one on each side in the roof of the buccal cavity. they are modified superior labial galnds (salivary) which are homologous to parotid glands of mammals. From each gland a posion duct arises and carries the venom secreted by the gland to the fang. Each fang is a specialised maxillary tooth which becomes tubular and grooved. Some snakes have a pair of reserve fangs behind the funcitonal one. In cobras the fangs are fixed, whereas in vipers they are retracted into a membranous sheath when not in operation.

5.5 BITING MECHANISM

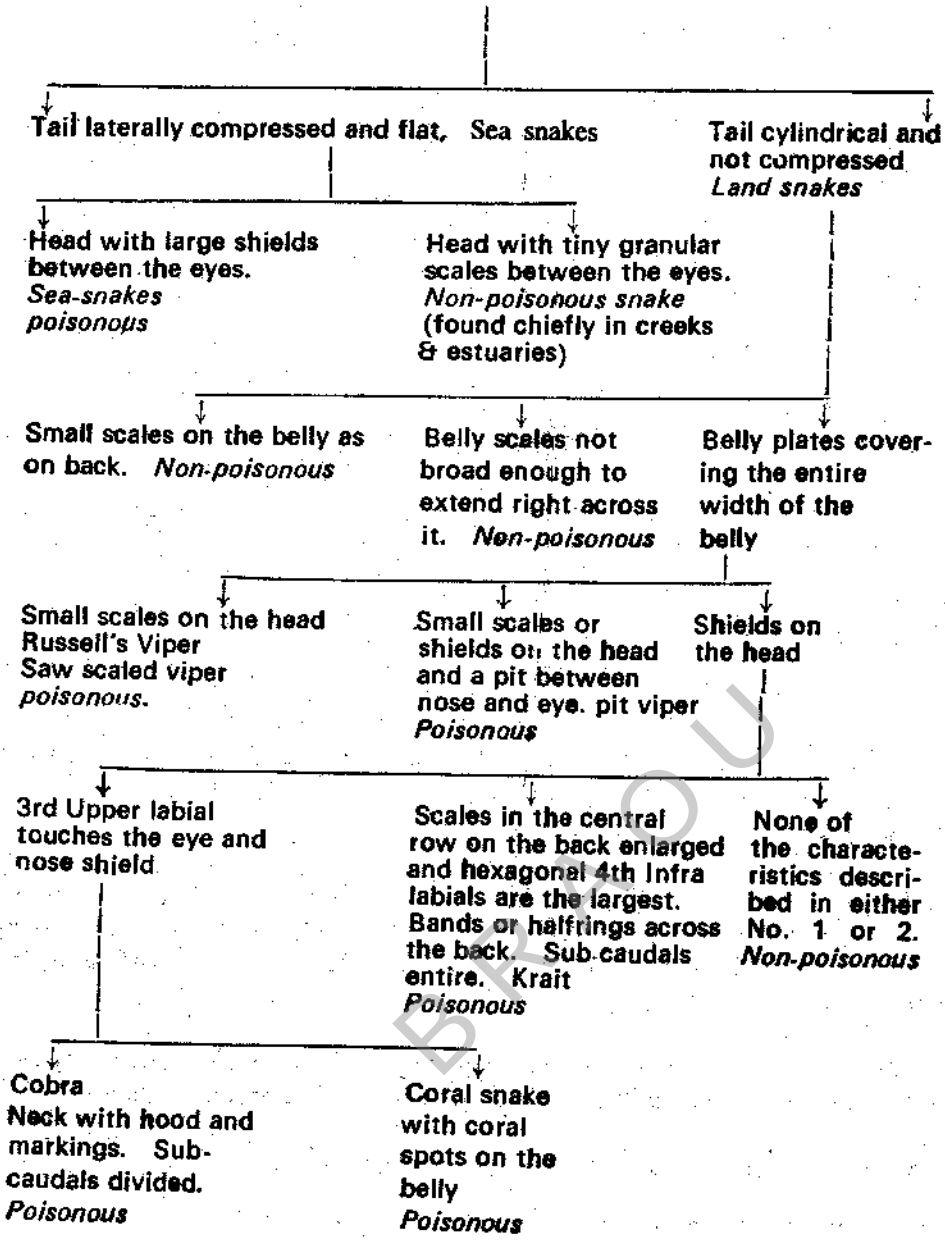
The skull bones of a poisonous snake involved in biting mechanism have greatly modifed. Chiefly the quadrate and pterygoid bones work as levers. The other skull bones are manipulated by these two bones along with squamosal. as a result of their movement the mouth is opend widely. The head is raised a little above the rest of the body (Fig. 15.3).

The next step is the forward thrust of the body. this is brought about by contracting the musles on the bendings of the upper part of the body of the snake. When straightened abruptly the anterior part of the body thursts directly forwards.

The opening of mouth and forward thrust the body are accompanied by the contraction of sphenopterygoid muscles. Articulation of these muscles with the maxillae drag the fangs to an erect position in order to strike the prey.

Table-I

SNAKES



On striking, the fangs drive deep into the flesh, sphenophterygoid muscles relax which is immediately followed by a contracton of the pterygoid externus muscle and palatine. This action moves the fangs backwards violently and penetrates them deep into the wound. Then the lower jaw is closed by the contractions of three temporal muscles-the anterior, the middle and the posterior. During this the anterior temporal, located around the poison gland compresses the later along with its duct so as to eject the poison through the fang into the wound. The entire process is carried on in a moment.

The fangs are released in the following manner. The muscles of the neck relax so that they leave the head inactive. At the same time the continued traction of the body muscles act upon the head and disentangle the fangs when snake quickly runs away.

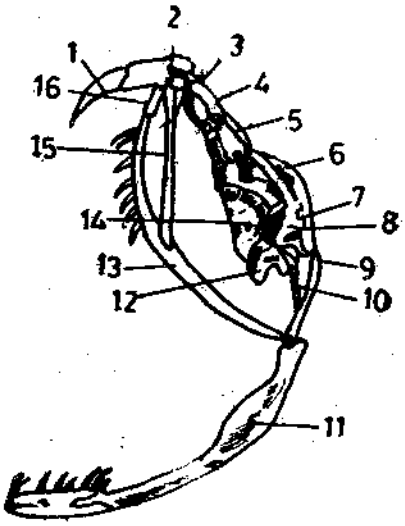


Fig. 15.3 Skull of poisonous snake with jaws open 1. Fang 2. Maxilla 3. Nasal 4. Prefrontal 5. Frontal 6. Parietal 7. Squamosal 8. Prootic 9. Quadrate 10. Stapes 11. Mandible 12. Basiocciptial 3. Pterygoid 14. Basisphenoid 15. Ectopterygoid 16. Palatine.

15.6 SNAKE POISON

The posion, secreted by the glands of a snake is a complex organic compound. Its colour is yellow. It has no taste or smell. It contains 30% poisonous proteins dissolved in organic acid. Its dried powder is soluble in water or saline. The solution is poisonous. Venom secreted by various poisonous snakes have their own characteristic toxicity.

As far the effects are concerned, the poison is of two types: **neurotoxic** and **haemotoxic.** Poison of cobra and krait is neurotoxic. It effects the respiratory system acting on the nervous system, both optic and phrenic nerves are affected leading to blindness and asphyxiation or respiratory paralysis.

Vipers venom is haemotoxic. It effects the heart, breaks down the red blood corpuscles and dissolves the endothelium of capillaries, causing haemorrhage and coagulation.

Antivenon sera injections are given to a victim of snake bite.

15.7 SUMMARY

India and Africa are rich in snake fauna. A majority of them are non-poisonous. Newzealand and ireland are free of snake fauna. Out of 216 species of snakes, only 52 are poisonous, of which 19 are aquatic (sea snakes). Among the 33 terrestrial forms are the cobras, Kraits and Vipers. Kraits and cobras are neurotoxic while the vipers are haemotoxic. The snake venom contains 30% poisonous proteins dissolved in organic acid. It is yellowish in colour and without taste or smell. Many people die of snake bite due to psychological shock and unscientific treatment. Snake antivenom is a life saviour. Doctor should be given a good description of the snake to select specific antivenin. The poisonous snakes can be easily distinguished from non-poisonous ones by colouration and by the structure, size and position of the scales.

15.8 MODEL EXAMIATION QUESTIONS

I. Answer the follwoing questions in about 30 lines each.

1. How do you differentiate poisonous snakes from that of non- poisonous snakes.
2. Explain the structue of poison apparatus and mechanism of biting of a poisonous snake. Add a note on snake poison.

II. Answer the follwoing questions in about 10 lines each.

1. Describe the commonly occurring poisonous snakes of India.
2. Describe the nature of snake poison and explain how it affects the patient.
3. Describe the poison apparatus of a snake.

Unit - 16 DINOSAURS

Contents

16.1 OBJECTIVES

To discuss the dominance of Dinosaurs on land and their extinction.

16.2 INTRODUCTION

In the Mesozoic era (about 225,000,000 years ago) the earth was dominated by several groups of reptiles. During this period for a time there evolved a group of reptiles of gigantic size of ferocious character which adapted themselves to different types of environment. They were diapsids and were known as Dinosaurs (terrible reptiles). They made a great advance over the reptilian locomotion on land. They had strong limbs to support and keep the body a little distance above the ground level just like a mammal. This arrangement naturally increased their speed and range of vision.

A notable common tendency among Dinosaurs is the disproportionate development of hind limbs and a counter balancing tail. These characters contributed more to their speed and vision. Long slim neck has further added to find out choice food. Because of these evolutionary advancements, the reptiles became very abundant and spread into all the habitats, from semideserts through swamps to the open oceans. They varied widely in size and appearance and came to dominate the animal life practically everywhere. Consequently the Mesozoic era is considered as the **golden age** of reptiles.

The Dinosaurs include two distinct orders; one with a reptilian pelvis, **Saurischia,** the other with a birdlike pelvis, the **Ornithischia.** In unit 12 under sub class Archosauria, diagnostic characters of these orders have been described in detail.

16.3 ORDER-SAURISCHIA

The Saurischia first evolved in Triassic and remained in existence until the Cretaceous. On the basis of their feeding and living habitats Saurischians are divided into two sub-orders. The **Theropoda** and **Sauropoda.**

These Dinosaurs lived from upper Triassic through Cretaceous. These were of small size, slender and hollow boned reptiles which reached to a maximum length of 10 feet. Along with such small-sized ones evolved collaterally the great dinosaurs which were big headed, carnivorous with wide jaws, equipped with long stabbing and tearing teeth. They reached a length of 50 feet and stood 14 feet high. They were feeding on small dinosaurs. The skull though disproportionate was remarkable in providing anchorage for the powerful masticatory muscles of the jaws. Hind legs were massive and were able to support several tons of huge body weight. These animals vanished at the end of Cretaceous, possibly due to lack of food. Eg. *Tyrannosaurus* (Fig. 16.1 A).

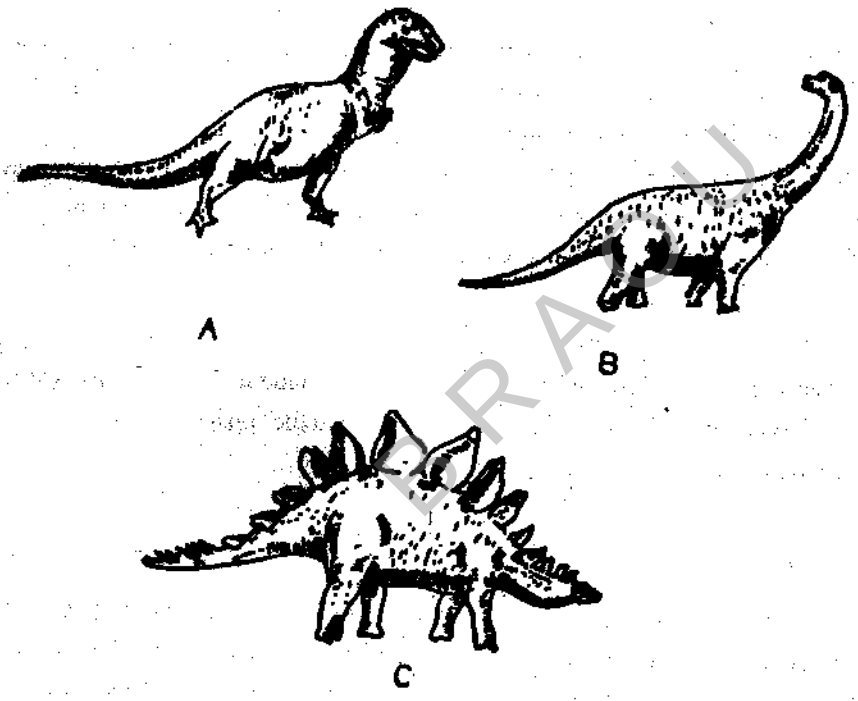


Fig 16.1 Dinosaurs A. Tyrannosaurus B. Brachiosaurus C. Stegosaurus

Sub-order Sauropoda

These Dinosaurs reached their largest and heaviest size of all land animals. They attained a maximum length of 80 feet and weight probably 50 tons or more. They lived from Jurasic to Cretaceous. They were amphibious, vegetarian and noted for their immense length of neck and tail. Limb bones were non-pneumatic. Due to their huge, bulky bodies they preferred to live in waters. *Brachiosaurus* is the best example (Fig 16.1 B).

16.4 ORDER-ORNITHISHIA

These Dinosaurs appeared in late Triassic and became extinct during upper Cretaceous. In them the public bone of the pelvis had rotaled becakward so that it occupiecl a position parallel to the ischium. In fact this condition is retained in modern birds- the bird-like pelvis. Due to anterior prolongation of ilium the pelvis, as seen from the side, was tetraradiate in contrast to triradiate pelvis in **Saurischia.** In majority there was a single new bony element on the front of lower jaw, the predentary, that formed the lower part of the horny beak. The teeth were limited to the sides of the jaws only. All the Ornithischia were vegetarians which fall into four suborders as following:

Sub-order : Ornithopoda

These Jurassic ornithischians were of moderate size when compared with Saurischia. All were bipedal with a reduced antorbital fenestra. The primitive forms which were medium-sized had strong hind limbs. They gave rise to far more specialised types.

The *Hadrosaurs* or duck-billed dinosaurs' whose well preserved fossils spell out many peculiarities. Their long beaks and jaws contained a large number of small teeth arranged in parallel rows. Besides were several distinguished by unusual adaptations in the nasal region of the skull. The premaxillary and nasal bones were pulled over the skull to form a hollow crest as in *Parasaurolophus,* through which internal nares traversed in a loop. These adaptations suggest that they had some functional importance either concerned to food-procuring or grovel under water.

The other specialised forms, **Troodonts,** were of dryland habitat. Their skulls were made of a solid dome of bone with knobs and spikes. This structue possibly was used in defence against their contemporary hunting Dinosaurs.

Sub-order : Stegosauria

These Jurassic Dinosaurs grew large to a length of 25 feet and adapted four footed mode of locomotion. They developed peculiar flattened, bony plates of triangular shape on their back, neck, body and tail in two rows. These monsters tails were armed with four long bony spikes eg. *Stegosaurus* (Fig. 16.1 C).

Sub-order : Ankylosauria

The ankylosaurs were armoured Dinosaurs of Cretaceous age. *Ankylosauria* was a bulky quadruped reptile, about 20 feet in length. Its hind limbs were longer than fore limbs. The dorsal surface of head and entire back were protected by heavy polygonal bony secutes which gave a mosaic touch. The tail covered dorsally by scutes teminated in a formidable clublike organ, Close resemblance to first world war tank the *Ankylosaurs* can be called **'living Mesozoic tanks'.**

Sub-order : Ceratopsia

The Ceratopsia were horned Dinosaurs which evolved during the waning perod of reptilian age. They were like rhinoceroses among modern mammlas. they were large quadrupedals with huge skulls provided with long, sharp horns for protection. *Triceratops* fossil happens to be one of the completely known dinosaur whcih grew to a length of about 20 feet. They had a very brief histoyr which appeared and died out in Cretaceous (Fig. 16.2).

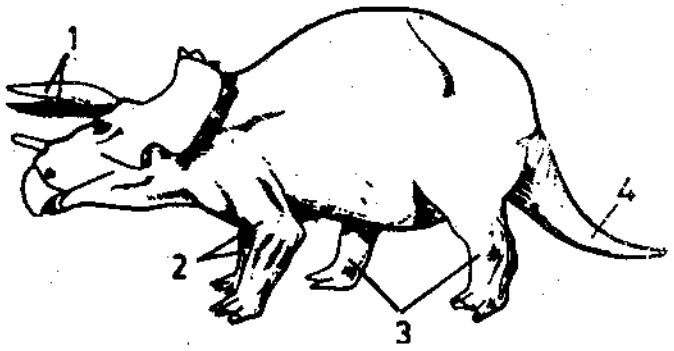


Fig 16.2 Triceratops. 1. Horns 2. Fore limbs 3. Hind limbs 4. Tail

16.5 EXTINCTION

The mighty race of Dinosaurs met with dramatic extinction by the end of Mesozoic era itself. Several reasons have been ascribed for their sudden down fall. Primarily the dinosaurs failed to respond positively to the changing and conditions of the mesozoic era. Further, the appearance of the blood thirsty warm blooded mammals another prime reason for their extinction. Besides, Valcanoes, infighting, evolution of alkaloid angiosperms upon which they were to graze indiscriminately were some of the potent reasons for their sudden disappearance. However, we must note that nature should have had realised treat the dinosaurs were ill-designed with very disproportionate brain.

16.6 SUMMARY

Dinosaurs were the giant reptiles large sized but very ill-designed animals with a very disproportionately developed brain. Quadrupedes with a long neck occupied all the different habitats dominating the animal life practically, hence golden age of the reptiles. The pelvis with triradiate on Suerischea while it is tetraradiate in ornithischia as in birds. This mighty race suddenly disappeared from earth by the end of mesozoic era owing to a cumulative effect.

16.7 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines.

1. "Mesozoic era is the golden age of reptiles". Discuss.

II. Answer the following in about 10 lines each.

1. Pelvic girdle of dinosaurs.
2. Mesozoic reptiles.

Unit - 17 AVES – GENERAL CHARACTERS AND CLASSIFICATION

Contents

17.1 OBJECTIVES

To understand the characteristic peculiarities of birds, suitable for aerial life and their broad classification

17.2 INTRODUCTION

The class Aves includes birds. Dinosaurs and birds have many resemblances. Therefore, birds are described as **"Glorified reptiles"**. Birds arose in Jurassic period (about 130 million years ago) from reptilian ancestor. All birds possess feathers as their exoskeleton which is their unique feature. The forelimbs are modified into wings which enable them to fly. The shoulder girdle is modified for the attachment of muscles of flight. The hip girdle and hind limbs are modified in such a manner as to support the entire body weight. The respiratory system is geared up to a high metabolic activity and high body temperature. This is possible because of fuller utilisation of oxygen by the lungs.

Birds possess certain unique characters such as the absence of teeth, left aortic aorta and right ovary and oviduct. The olfactory lobes are usually degenerate due to poorly developed organs of smell. Birds show some remarkable changes such as a higher constant body temperature, formation of pneumatic bones, fusion of skull bones, fusion of some vertebrae and supression of tail. Birds by and large are more or less a homogenous group. There is less diversity of structure than in fishes, amphibians or other calsses. Birds are well known for courtship and nest building. The migration of birds is a fascinating aspect of bird life. Birds travel thousands of Kms, across continents. The migration could be seasonal in response to climatic conditions or to the physiological state of gonad.

Birds are feathered and warm blooded bipeds. Exoskeleton and endoskeleton of birds exhibit a number of features of aerial adaptations. Lungs are compact and non-distensible. Air sacs maintain a continuous supply of fresh air during inspiration and expiration. Heart is 4 chambered, only right systemic arch is found. Nervous system is well developed with large optic lobes, cerebral hemispheres and cerebellum. However, olfactory lobes are poorly developed. Eye with pecten and ear with organ of corti. Birds are classified into two sub classes: a) Archaeornithes b) Neornithes.

17.3 GENERAL CHARACTERS OF BIRDS

Birds outnumber all other vertebrates except fishes. They are widely distributed all over the world. They are found virtually every where from the edges of the polar ice caps to the highest Himalayas and Indian slopes to the roughest seas.

1) The birds are craniates characterised by the presence of epidermal exoskeleton in the form of feathers which cover greater part of the body. The claws and beak are covered by hormy sheath. The feathers provide a light insulating covering to prevent the loss of body heat.

2) The fore limbs are modified into wings and provided with large feathers. The hind limbs alone support the body weight when the bird is walking or in standing position. For this purpose the articualtion of the hind limbs is pushed forwards.

3) Endoskeleton is usually spongy with air cavities. The bones of the skull have become ankylosed early in the life. There is a single occipital condyle. The premaxilla forms almost the whole of the upper jaw. The lower jaw consists of 5 or 6 bones. Teeth are totally absent.

4) The cervical and free thoracic vertebrae usually have a heterocoelous centrum. The ribs are double headed, provided with uncinate processes. The vertebrae in the sacral and lumbar regions fuse with some posterior thoracic and anterior caudal vertebrae. All such fused vertebrae form a synsacrum which supports the weight of the body when the bird is walking. The posterior caudal vertebrae are fused to form a pygostyle or 'plough-share bone'.

5) The pectoral girdle has a number of adaptive modifications. The stemum is broad and ventrally poduced into a keel called carina in flying birds. The muscles of flight are attached to it. The coracoid is stout and pillar shaped. The scapula is flat and sabre-shaped. The clavicles and the inter-clavicles unite to form a **'furcula'** also known as **'Merry thought'** or **wish bone.**

6) In the fore limbs carpals and metacarpals are united to form a carpometacarpus. Only three digits are present.

7) The pelvic girdle consists of large iliac bones. Ischia and pubes are directed backwards and do not form sysmphyses. Acetabulum is perforated

8) The tibia is fused with the proximal tarsals to form tibiotarsus. The distal tarsals fuse with metatarsals to form tarsometatarsus fuse with metatarsals to form tarsometatarsus. Only four digits are present.

9) The digestive system has some unique features. the oesophagus is generally enlarged into a crop. The stomach is usually divided into a gladular pro-ventriculus and a muscular gizzard. The latter is highly muscular and grinds the food particles. A pair of caeca are found at the junction of small and large intestine.

10) Lungs are spongy and non-distensible and attached to ribs. Lungs are connected to a number of thin walled air says, which maintain a constant supply of fresh air both during inspiration and expiration. Some air sacs usually communicate with the pneumatic cavities of the bones. At the junction of the trachea and bronchi, the syrinx is found, which produces the sound.

11) Heart consists of four chambers, two auricles and two ventricles. Only the right aortic arch is present. The right auriculo-ventricular valve is large and muscular. the renal portal system is poorly developed. the sinus venosus and truncus arteriosus are absent the sinovenosus is absorbed into the right auricle. The red corpuscles are biconved, oval and each with a well developed nucleus. The temperature of the blood is maintained constantly higher than other animals (42^0 45^0C).

12) The nervous system is characterised by the great development of cerebral hemispheres and cerebellum. The enoromus size of the cerebral hemisphere is due to the presence of thick corpora striata of its on the ventral and lateral walls.

13) The olfactory lobes are poorly developed, since the birds do not need them while flying high in air. The spinal cord has a wide cavity in the lumbar region which is called sinus rhomboidalis.

14) Eyes are usually large, needed for a clear vison over a considerable distance. The sclerotic has bony plates. At the entrance of the optic nerve a pleated and strongly pigmented membrane, the pecten is found. It is highly vascular and probably supplies oxygen to the interior of the eye ball. It also protects retina from sun rays particularly when birds are flying. Ear has large and usually curved cochlea with the organ of corti for hearing.

15) The kidneys are three lobed and metanephric. Ureters open into the cloaca. The urinary bladder is absent. Urine consists of uric acid in a semi solid state.

16) Sexes are separate. Testes and vasa deferentia are paired and found one on either side. But the ovary and the oviduct of the right side are atrophied. Gonoducts lead into cloaca, which is usually three chambered. Fertilization is internal. Males generally lack the copulatory organ.

17) Birds are oviparous. the eggs contain a large amount of yolk enclosed in shell membranes and a calcareous shell. The embryo has special extraembryonic membranes such as amnion, allantois. Yolk sac and chorion. These membranes are very useful to the embryo. the newly hatched young may be precocial i.e., ale to walk, run or swim and feed or they may be altricial i.e., naked (no feathery covering) and dependent for the food supply upon the parent.

17.4 CLASSIFICATION OF BIRDS

The class Aves is divided into two sub classes.

1. Archaeornithes II. Neornithes

17.4.1 Sub Class Archaeornithes (Gr. Archios - ancient; Ornithos - bird)

The sub class includes some primitive extinct birds from upper Jursaic period. these birds show some reptilian and some avain features. Only two perfectly preserved fossil specimens are found *Archacopteryx lithographica* (Fig. 16.1) and *Archaeornis simensi.* These were about the size of a crow. Both the jaws bear enamel crowned teeth. They had a long tail with many vertebrae and tail feathers arranged on either sides and is without pygostyle. Bones were solid with no air cavities. Vertebrae were having amphicoelus centra unlike the heterococlous condition found in present day birds. Sternum was flat without a keel for the attachment of flight muscles. Skull and the large eyes were avian in character.

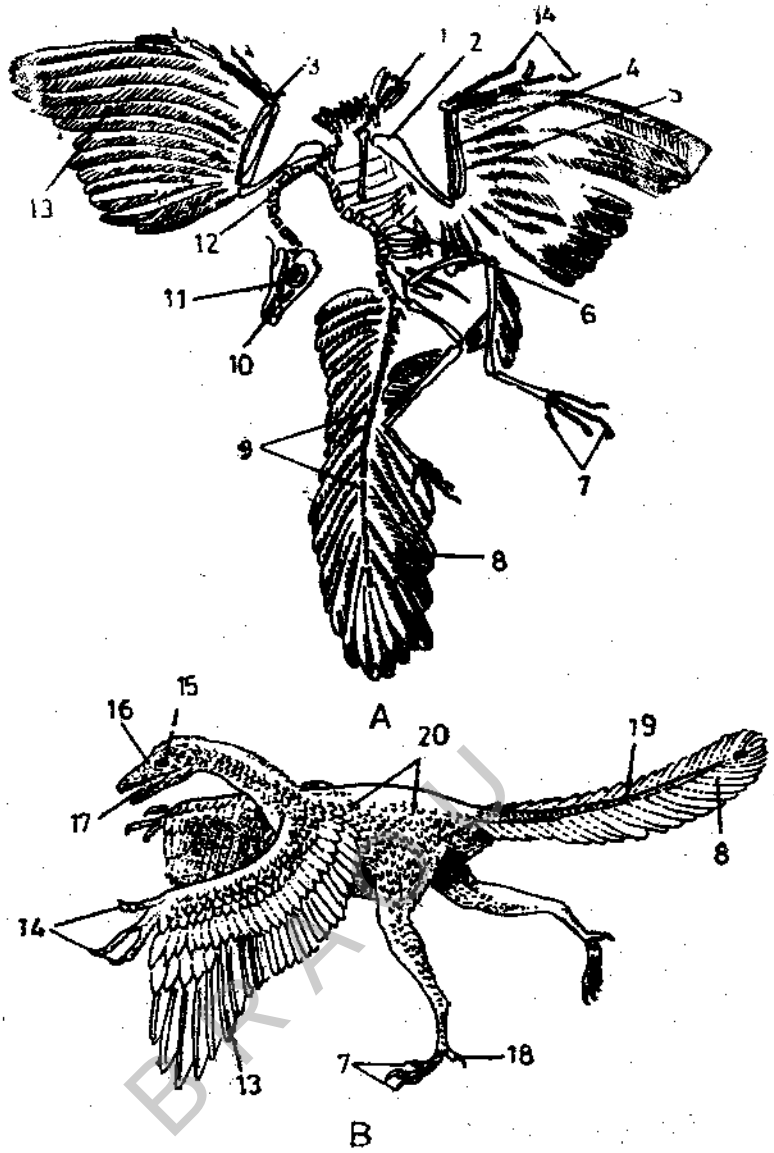


Fig 17.1 Archaeopteryx A. Sketch of fossil impression showing skeleton and feathers. B. Reconstruction of Archaeopteryx. 1. Coracoid 2. Humerus 3. Free metacarpals 4. Radius 5. Ulna 6. Ribs 7. Clawed toes 8. Tail feathers 9. Free caudal vertebrae in lizard-like tail 10. Teeth in beak 11. Sclerotic bones in orbit 12. Scapula 13. Wing feathers 14. Free clawed fingers 15. Eye

These birds were not capable of successful flight. The small sternum, the small wing spread and a long tail gave a clear indication that these birds could only hop from one branch to another. Studies of the cast of endocranium revealed that the brain had smooth cerebral hemispheres and small cerebellum. The cerebellum occupied a positon behind the optic lobes instead of overlapping them. The smaller size of the cerebellum is a further evidence of the limited power of flight of these birds. The brain of *Archaeopteryx* was predominantly reptilian. Thus it is clear that the birds arose from bipedal, arboreal, reptile like ancestors, which had limited powers of flight.

17.4.2 Sub Class Neornithes (Gr. Neos : New; Ornithos: bird)

This sub class includes all living birds and the some extinct birds. Birds belonging to this sub class have an extremely short tail usually ending in a pygostyle. Teeth are absent in all the living birds. Carpals and metacarpals are fused to form carpometacarpus. Fore limbs have

three digits without claws. The pectoral girdle is characterised by a well developed sternum with a keel for the attachement of muscles of flight. The birds belonging to Neornithes first arose in the cretaceous period and were mostly water birds.

Sub class Neornithes inlcudes:

A. Group of extinct birds belonging to super order: **Odontognathae.** These are flightless aquatic birds. eg., *Hesperornis.*

B. The living birds are included in three super orders.

1. **Paleognathae:** Flightless birds, decended from flying birds. eg., *Struthio Rehea* and *Apteryx* (Kiwi) (Fig. 17.2 A-C).
2. **Impennae** : These are also flightlessbirds decended from flying birds. They have become adapted for swimming and diving eg., *Penguins* (Fig. 17.2. D).
3. **Neognathae** : They include the flying birds having most of the avian characteristic features. They show a great variety in the details of structure and habit. There are more than 20 orders belonging to Neognathae. Few of the important orders with examples are quoted below:

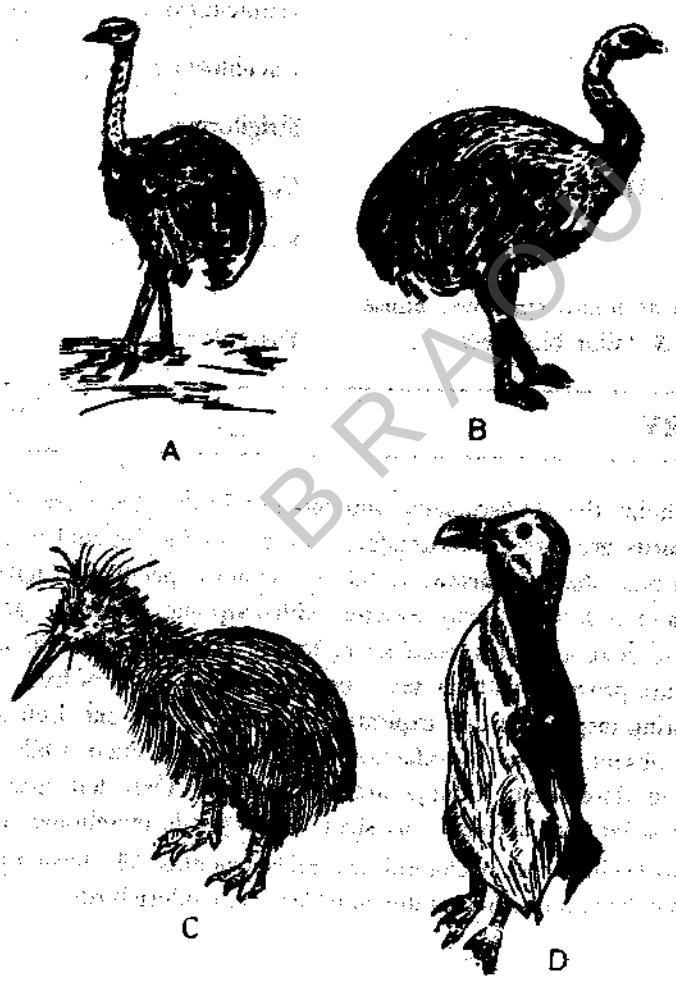


Fig. 17.2 A. Struthio B. Rhea C. Pateyx D. Penguins

Bird	Order
Albatross, Storm Petrel and Diving petral etc.	Procellariiformes
Pelicans, Cormorants etc.	Pelicaniformes
Herons, Storks, egrets & Flammingoes etc	Ciconiformes
Duck,Gees & Swans etc.	Anseriformes
Valtures, eagles, Kites etc. (birds of prey)	Falconiformes
Fowls, pheasants, patridges (Game birds)	Galliformes
Cranes & bustards	Gruiformes
Gulls, terns, lapwigs, plovers etc.	Chardriformes
Pigeons and doves	Columbiformes
Parrots	Psittaciformes
Cuckoos	Cuculiformes
Owls	Strigiformes
King fishers, Rollers, Hoopoes, Hombills etc.	Coraciformes
puffbirds etc,	Piciformes
Perching birds such as house sparrows, house crow, weaver birds & tailor birds etc.	Passeriformes

17.5 SUMMARY

The class Aves includes the *Archeapteryx* and modern birds. They are often described as **glorified reptiles.** Birds are large homogeneous, warm blooded bipedal vertebrates. Skeleton is pneumatic with a boat shaped Carina. Vertebral column is peculiar in having heterocoelous centra, synsacrum and pygostyle. Limb skeleton with carpometacarpous, tarsometatarsus and tibiotarsus. Degestive system is also peculiar in having crop and gizzard. Lungs spongy but not distensible and are provided with air sacs. *Airsacs* are the source of fresh air for continuous respiration both during inspiration and expiration. A syrinx is present. Left systemic arch and sinus venosus are absent. Sense of olfaction is poorly developed while optic lobes and cerebelleum are well developed. Kidneys are metanephric. Only left ovary with oviduct is present. Eggs large sized with a calcareous shell. Embryonic membranes present. The class Aves is classified into 2 subclasses: Archaornithes and Neornittes. The former includes lizard-like arboreal formes while the latter includes ratite and Carinate modern birds.

17.6 MODEL EXAMINATION QUESTIONS

I. **Answer the following questions in about 30 lines each.**

1. Give an account of the general characters of the Class Aves.
2. Classify Aves upto sub classes and give general characters along with examples.

II. **Answer the following in about 10 lines each**

1. Archaeornithes
2. Neornithes

Unit - 18 : PIGEON - MORPHOLOGY AND EXOSKELETON

Contents

18.1 OBJECTIVES

- To explain the morphological details and their significance. To describe the structure of feather and different kinds of feathers.

18.2 INTRODUCTION

The pigeon or the common 'Indian wild rock pigeon' is scientifically known as *Columba livia.* A number of varieties of pigeons are found with slight variations in size, colour, feathers and other details. However, the following description will generally apply to all varieties.

18.3 HABITAT

It is a common ancestral rock bird found in mediterraian in Europe and Asia. But now a number of domestic varieties are distributed all over the world. They are commonly found in grain market, warehouse, old tall buildings and in other such places.

18.4 HABITS

Pigeon is a gregarious bird and feeds on grains, seeds, fruits and young green shoots. These birds are monogamous i.e., one male bird and one female bird keep company. The courtship is very common. Eggs are laid in the nest. Both the parents incubate the eggs. The young birds are fed by the parents by a fluid which is secreted by the crop during breeding season and known as "pigeons mils". The pigeon flies swiftly, but cannot walk rapidly on the ground.

External Characters

The body of pigeon is divided into head, neck, trunk and tail. The colour of the bird is blue-grey. The entire body is covered with feathers except at the feet and beak. The body is stream lined and offers minimum resistance to wind.

The head is small with a round cranium. There is a prominent beak. The beak is formed by the upper and the lower jaw and covered by horny sheath, the rhamphotheca. The mouth has a wide gap extending along the border of the beak. At the base of the upper beak on each side, threre is a patch of naked, swollen and soft skin. This area is known as cere (Fig. 18.1). It is suggested that the cere may be a receptor organ, but there are no experimental evidences to this effect. The external nostrils are oblique slits. They are situated close to the anterior margin of cere, and remarkably backward in position. The eyes are very large and round. Each eye has an upper and a lower eyelid. In addition each eye has a transparent nictitating membrane, which can be pulled over the eye ball. A little distance behind each eye is the auditory opening or ear, which is concealed by auriculr feathers.

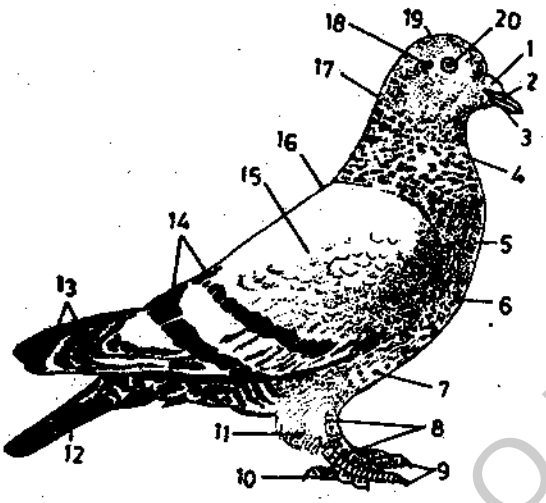


Fig. 18.1 Pigeon *(Clolumba livia)* - External features. 1. Cere 2. Nostril 3. Beak 4. Throat 5. Thorax 6. Breast 7. Abdomen 8. Scales (or corueoscutes) 9. Clawed toes 10. Hind toe 11. Leg 12. Tail feathers (or pectrices) 13. Wing feathers (or regines) 14. Black barbs 15. Wing 16. Back 17. Neck 18. External ear opening 19. Head 20. Eye.

Neck is very long cylindrical and mobile and distinct from head and trunk. The trunk is boat shaped due to the presence of a mid ventral ridge, the keel or carina of the sternum. At the posterior end, the body is drawn out into a short conical projection, the **uropygium** or

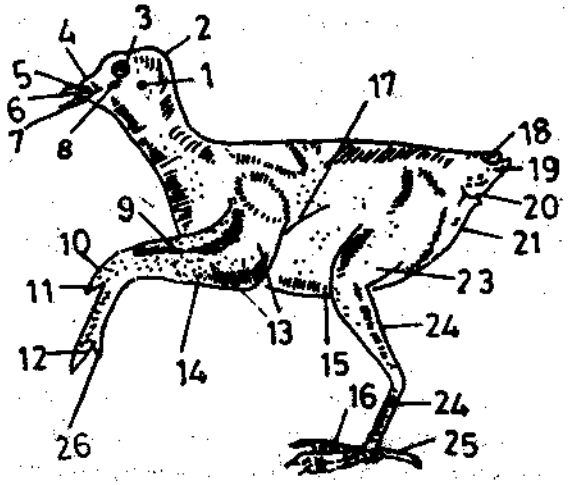


Fig 18.2 Pigeon - Feathers removed. 1. Auditory aperture 2. Head 3. Eye 4. Cere 5. External naris 6. Upper beak 7. Lower beak 8. Nictitating membrane 9. Prepatagium 10. Manus 11. Pollex (1st digit) 12. 2nd digit 13. Brachim 14. Ante-brachim 15. Thorax 16. Scales (carneoscutes) 17. Post patagium 18. Uropygial gland 19. Uropygium 20. Cloacal aperture 21. Abdomen 22. Thigh 23. Shank 24. Tarsometatarsus 25. Hallux 26. 3rd digit.

tail. A number of large tail feathers or retrices are found attached to the tail. On the dorsal side of uropygium is a small papilla, which bears the opening of a preengland or oil gland. The skin of the bird is dry and lacks any gland. Preen gland is the only skin gland found in pigeon. The cloacal aperture is a large transverse slit found on the ventral surface at the junction of the trunk and uropygium.

The fore limbs are modified into wings. Each fore limb consists of an upper arm, a fore arm and a hand. The forelimbs bear long quill feathers. Only three digits, the first, second and the third, are found. The second digit is much longer than the other two. The three parts of the wings are bent upon one another in the form a 'Z' during resting position. During the flight, the entire wing is fully extended and held at right angles to the trunk. A fold of skin stretches between the upper arm and fore arm, which is known as alar membrane or 'prechpatagium'. Similarly a smaller fold of skin is found extending between the proximal part of the upper arm and trunk, which is knwon as 'post patagium'.

The **hind limbs** are used for balancing and walking. Each hind limb is made up of the thigh, shank and foot. It is not directed outwards as in reptiles, but downwards and forwards. the femur is turned under the body and articulates with the acetabulum, at a forward position. Thus the movement is almost restricted to antero-posterior direction. There are four digits. All of them end in hornv claws. the first digit (hallux) is direected backwards and all others are forwardly directed. The feet are covered by horny epidermal scales the carneoscutes while the rest of the hind limb is covered by feathers. The whole of the hind limb is parallel with the sagittal plane of the trunk. .

18.6 EXOSKELETON

The exoskeleton of birds consists of scales feathers, claws and rhamphotheca.

Scales are horny and epidermal in nature and found covering the tarso-metatarsus and the four digits of the foot. Claws are also of horny epidermal nature. They are found at the end of each digit of the foot. Rhamphotheca, the horny sheath on the beak is also epidermal in origin.

Feathers are also horny and epidermal in nature. They do not originate uniformly form the entire surface of the body. There are certain well defined areas - the feather tracts or **pterylae**, from where the feathers develop. In between, the feather tracts are areas known as featherless tracts or **apteria**. Only a few small feathers the filoplumes arise in these apteria. However, the feathers (found in pterylae) are long enough to cover the apteria also and thus the entire body is covered by feathers.

Kinds of feathers

The feathers of the birds are of several kinds such as quill feathers, contours, filoplumes coverts or down feathers (Fig. 18.4).

18.6.1 Quill Feathers

These are the largest of all the types of feathers. They are found on the wings and tail. The quill feather possesses a typical structure. Each feather consists of a stiff long central axis called shaft or stem. The proximal part of the them is hollow, cylindrical and short which is known as **calamus** or **quill** (Fig. 18.4 A). A small aperture is found at its base which is called **inferior umbilicus**. A small conical projection of the skin, the feather papilla fits into

the inferior umbilicus. The distal part of the shaft is solid and known as **rachis**, which bears on either side an expanded membrane consisting of delicate thread like strucutres the **barbs.** The expanded memberanous part of the feather is known as **vexillum** or vane. At the upper end of the calamus on the ventral surface there is another smaller aperture, the **superior umbilicus** A small tuft of barbs is found near the superior umbilicus, almost covering the latter. This tuft is known as after shaft or **hyporachis.**

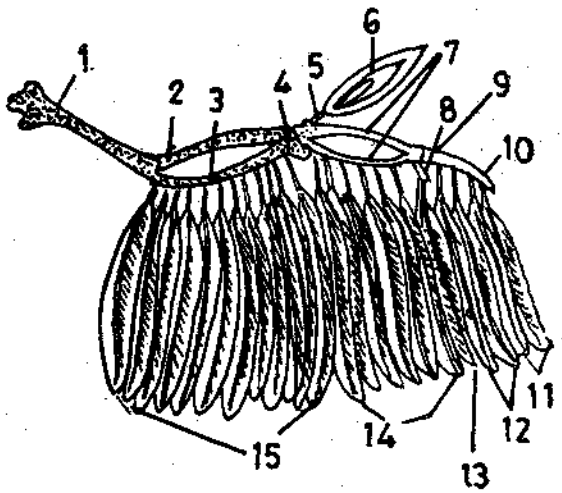


Fig. 18.3 Pigeon-Wing bones showing fixation of feathers. 1. Humerus 2. Radius 3. Ulna 4. Carpals 5. First digit 6. Ala spuria 7. Carpometacarpus 8. 3rd digit 9. Proximal phalanx of 2nd digit 10. Distal phalanx of 2nd digit 11. Pre-digitals (2) 12. Mid digitals (2) 13. Ad-digitals (1) 14. Meta carpals (6) 15. Secondaries (12).

The barbs extend outwards from the rachis. All the barbs are finely connected to each other to form a continuous membrane. However, a little amount of gentle pressure can separate them. each barb is a thin long structure arising from the rachis. The microscopic examination of the feathers will reveal the structure of the barbs so that we can understand the mechanism of interlocking of barbs. The barbules arise on both sides of the barbs. Thus there are two sets of barbules arising from each barb. A proximal set of barbules, directed towards the base of the feather, bear grooves or flanges. A distal set of barbules, directed towards the feather-tip, bear minute hooklet or **barbicels** or **hamuli.** The hooklets of each distal barbule fit into the groove of each proximal barbule situated on the bar to in front of it. In this manner all the barbs are firmly connected to each other and form a continuous surface to withstand the resistance to air (Fig.18.4 D).

The feathers found on the wing are known as remiges. There are 23 such feathers in each wing. Of these eleven are attached to the bones of the hand or manus and known as primary quills. The other twelve are attached to the ulna and these ere called secondaries or cubitals. Six of the primary quills are attached to the metacarpals and hence called **metacarpal quills.** The remaining five primary quills are known as digitals. These are further distinguished into ad-digital the feather attached to the only plalanx of the third digit; two mid digital attached to the proximal phalanx of the second digit; two predigitalis, attached to distal phalanx of the second digit.

The quill feathers found in the tail region are known as rectrices. there are twelve such feathers, arranged in a semicircle around the uropygium.

The first digit of the hand i.e., pollex bears a tuft of small feathers which is called **ala spuria** or false wing or bastard wing.

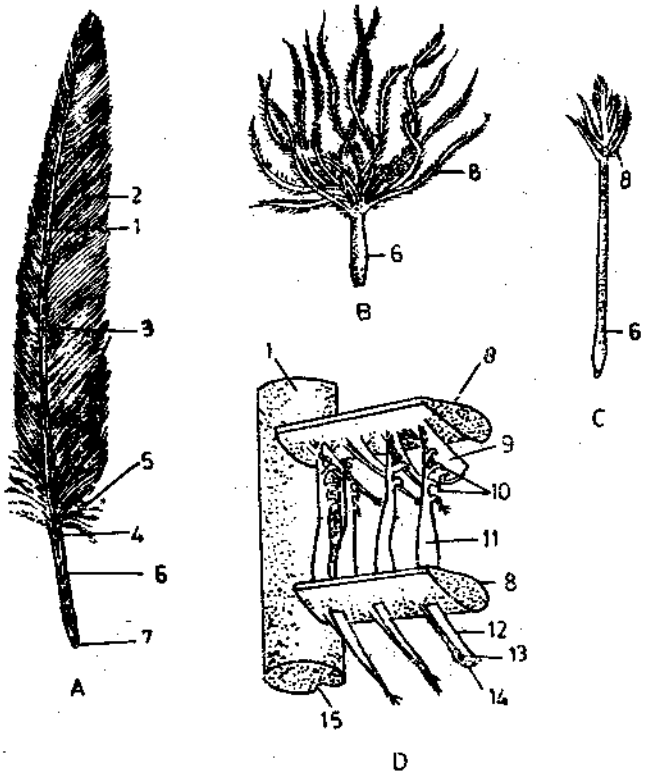


Fig. 18.4 Pigeon-Different kinds of feathers. A. Quill B. Down C. FiloplumeD. A part of rachis magnified to show barbs, barbules and hooklets 1. Rachis 2. Vexillum, 3. Umbilical groove 4. Superior umbilcus 5. After shaft 6. Calamus 7. Inferior umbilicus 8. Barb 9. Proximal barbule 10. Hooklets 11. Distal barbule 12. Proximal barbule 13. Flange or groove 14. Umbilical groove.

18.6.2 Coverts

These are like the quill feathers except that they are smaller in size. They cover the gaps between the bases of the quills. They are found amidst the remiges and rectrices.

18.6.3 Filoplumes

These feathers are found scattered on the body surface and can be seen after the body feathers are removed. Filoplumes are very delicate with a long slender calamus, bearing barbs at the tip. There is no interlocking arrangement in the barbs (Fig. 18.4 C).

18.6.4 Down Feathers

These are very small and without a shaft. The calamus is very short. The barbs have no interlocking arrangement. These feathers are found covering the body of nestling birds (Fig. 18.4 B).

Feathers arise from the papillae in the skin with an epidermal covering very much like the scale of a reptile. The feather papilla grows into cylindrical tube and sinks into feather follicle. The core of the feather papillae is dermal and vascular and forms the **feather pulp.** The outer layer of the feather papilla becomes cornified and thickened. The malpighian layer of the feather papilla proliferates and forms a number of vertical ridges. Of these the two central ridges unite to form the rachis and the remaining ridges form the barbs, with their barbules forming the vane.

The feathers have two important functions to perform. They provide an insulating covering and thus prevent the loss of the body heat. They also serve as organs of flight by constituting

the wings in the fore limbs. Protective colouration is yet another function of the feathers. They also play an important role in sexual display.

18.7 SUMMARY

The pigeon or the common Indian wild rock pigeon is a gregareous bird feeding on grains, seeds and young green shorts. It dips entire beak under water and drinks like a horse unlike other birds. The pigeon is monogamous, It lays usually 2 eggs, incubated by both the parents for 14-18 days. Young are fed by pigeon's milk secreted by crop.

The body and wings are covered by feathers: Wings and tail covered by quills. The barbules of the quills joined by barbicles or hamuli. Eyes are with 3 eye lids. There are 3 figures and 4 clowed toes. A fold of skin stretches between the fore arm and upper arm is called the prepatagium (alar Membrane)and a post patagium between the upper arm and the trunk, The hallux is directed backwards. The urepygiuru (tail) with the love preem gland.

The quill feathers arise as epidermal feather papillae, grow into 'feather germ' embedded in feather follicle much as the reptilian scales. Flight muscles are well developed.

18.8 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines:

1. Describe the external features of pigeon.
2. Describe the exoskeleton of birds.

II. Answer the following in about 10 lines:

1. Explain the structure of Quill feather.
2. Feathers development and functions.

Unit - 19 ENDOSKELETON OF PIGEON

Contents

19.1 OBJECTIVES

In this lesson the endoskeletal features are discussed. There are two main divisions of endoskeleton (i) Axial skeleton (ii) Appendicular skeleton.

19.2 INTRODUCTION

The endoskeleton of the pigeon like that of any other bird is highly specialised and unique in structure. The skull, vertebral column, the bnones of the girdles and limbs are so highly modified that they can be easily distinguised from the corresponding bones of any other vertebrate. Many of the bones are pneumatic, containing air spaces. The bones are light without any marrow in them. Some of the air cavities of the bones communicate with the air sacs and ultimately with the lungs. The endoskeleton consists of:

i. Axial skeleton comprising of skull and vertebral column.

ii. ppendicular skeleton consisting of girdles and the limb bones

19.3 AXIAL SKELETON

19.3.1 Skull Structure

Skull of the pigeon is characterised by large size made of light and spongy bones: a complete fusion of bones; very large orbits, a long and pointed beak; a single occipital condyle; lower jaw having two movable joints with the freely movable quadrate.

The Skull of the *Gallus* (Fig. 19.1) the fowl is generally used for the study in place of the skull of pigeon, because of its larger size which makes the study convinient in the laboratory. The skull of *Gallus* is built on the basic reptilian patttern, although there are a number of unique features as mentioned in the earlier paragraph.

The occipital region consists of four bones:

(i) **Supra-occipital** (ii) **Two ex-occipitals** (iii) a lower **basi-occipital.** All these four bones surround the **foramen magnum,** a large opening which is directed backwards and downwards and visible from ventral side. There is a single **occipital condyle.** On the ventral side below the basi-occipital is a large basi temporal plate and little anteriorly, the basisphenoid is found which is continued into a slender rostrum as in lizards.

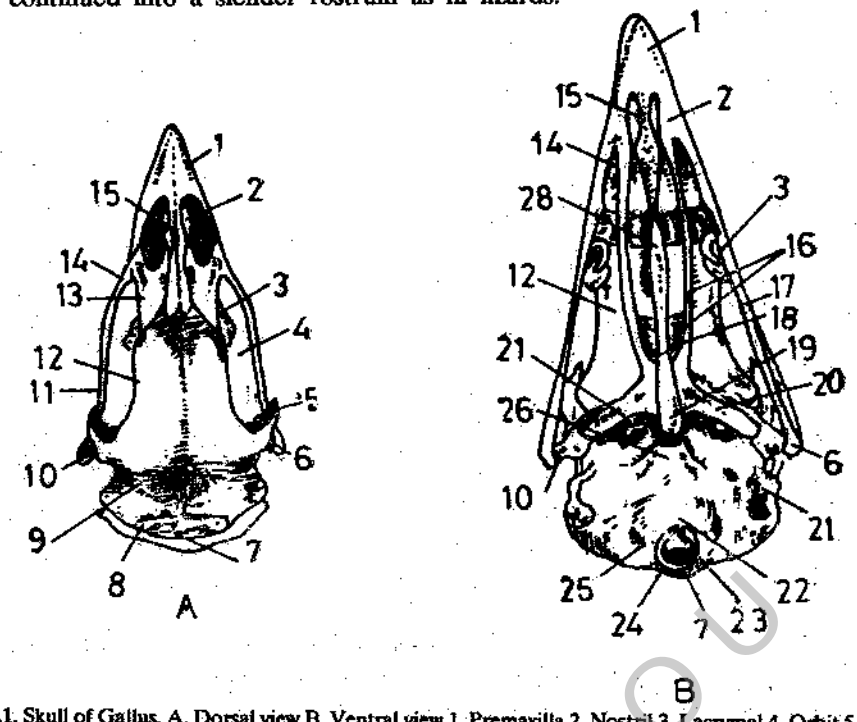


Fig. 19.1. Skull of Gallus. A. Dorsal view B. Ventral view 1. Premaxilla 2. Nostril 3. Lacrymal 4. Orbit 5. Zygomatic process of frontal 6. Quadrato-jugal 7. Supra-occipital 8. Lamboidal ridge 9. Parietal 10. Quadrate 11. Jugal 12. Frontal 13. Nasal 14. Maxilla 15. Nasal process of premaxilla 16. Palatine 17. Jugal 18. Rostrum 19. Basisphenoid 20. Pterygoid 21. Tympanic cavity 22. Basioccipital 23. Occipital condyle 24. Foramen magnum 25. Exoccipital 26. Basitemporal 27. Eustachian opening.

On the dorsal surface of the skull large paired parietals and frontals are found. The parietal and the supra occipetal are demarcated by a prominent ridge, the **lamboidal ridge.** The tympanic cavity is bound by the squamosal. The auditory capsule is supported by prootic bone. The orbits are large and separated by **interorbital septum,** which is formed by the **mesethmoid** and **orbitosphenoid.** The interorbital septum is a partition partly bony and partly cartilagenous, It stands vertically between the two optic capsules. Anteriorly each orbit is covered by a lacrimal bone.

The olfactory capsule has a pair of **nasals** and **vomer** infont of each **palatine.** The nasals are long narrow bones, on the dorsal surface and vomer is a slender bone on the ventral side and is the continuation of rostrum. The upper jaw has premaxilla and maxilla. The two premaxillae are very prominent and united to form practically the whole of the upper beak. The maxilla is a slender bone and produced on the inner side into palatine. Alongwith the premaxilla and maxilla, there are two other bones, jugal and quadratojugal which form the arcade on the ventral side of the skull. The quadrato-jugal is a bony rod and articulates with the quadrate. The quadrate is a stout, triradiate freely movable bone. It articulates with the mandibles by two otic processes, so that the former bone has double movable joints as in lizards and snakes, pterygoid is a stout bone on the inner side of the upper jaw, which articulates with the quadrate.

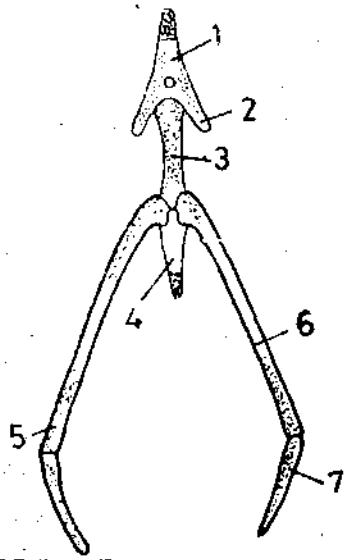


Fig. 19.2 Hyoid apparatus of Gallus. 1. Entoglossal ceratohyal2. Anterior cornua 3. Basihyal 4. Urohyal 5. Posterior cornua 6. Ceratobranchial 7. Epibranchial.

The lower jaws of the two sides are fused anteriorly, but free throughtout and leave a wide gap. Each lower jaw consists of five bones, all of which are fused together. The four bones are 1) a large dentary (the two dentaries are united anteriorly), 2) splenial, 3) supraangular, 4) angular. These four are investing bones. There is a replacing bone, the articular, which forms the posterior expanded part having concave articular facet for the quadrate.

The hyoid apparatus lies in the floor of the buccal cavity and supports the tongue. There are three bones in the median axis. 1) Entoglossal 2) Basihyal 3) Urohyal (Fig. 19.2). Entoglossal has a cartilage infront. A. pair of short anterior cornua project backwards from the entoglossal. A. pair of long posterior cornua airse from the junction of the basihyal and urohyal, which are directed backwards. The posterior cornua consists ceratobrachials and epibranchials.

18.3.2 Vertebral Column

The vertebral column of birds is characterised by its rigidity because of fusion of vertebrae in some regions. It is further characterised by the extreme mobility of the neck and shortness of tail. The vertebral column of the fowl is divisible into 1) Cervical region 2)Thoracic region 3) Sacral region 4) Caudal region.

1. **Cervical region:** There are 16 cervical vertebrae found in neck region. The last one or two vertebrae bear large ribs which are double headed and movably articulated ribs. The cervical region passes into the thoracic region. it is not easy to recognise the transition from the cervical region to the thoracic region. However, the first vertebra having its rib articualting with the sternum is regarded as the first thoracic vertebra. Starting from the third cervical upto 10th cervical vertebra, the structure is more of less alike and these are described as typical cervical vertebra.

Structure of a typical cervical vertebra: The typical cervical vertebra is a slightly an elongated bone (Fig. 18.3 A). A wide cavity or canal is enclosed in its entire length. This canal is called the neural canal, through which the spinal cord passes. The main body of the vertebra is the **centrum** which is found at the floor of the neural canal. The centrum is very unique in having saddle shapped surfaces. The anterior face of the centrum is concave from side to side and convex dorso-ventrally. The posterior face is convex from side to side and concave dorso-ventrally. Such a centrum is described as **heterococlus**. Such articular surfaces of the

centra allow greater mobility of neck. The sides and roof of the neural canal are thinner and constitute the neural arch. There is a small mid dorsal projection from the neural arch, which is called as **neural spine.** The transverse processes are short, outwardly directed projections on both sides of the centrum.. Ventrally the centrum sends out, a short process known as **hypapophysis.** At the base of each transverse processes, an aperture is found through which the vertebral artery passes. This aperture is called **vertebrarterial foramen.** A backwardly directed process is given out from the transverse process. This is known as the rib. Generally from the margins of the neural arch articular surfaces are found extending, which are called zygapophyses. The anterior articular surface faces upwords and is known as **prezygapophysis.** In Gallus however, the prezygopophys occur on the upper side of the transverse processes. The posterior articular surfaces arising from the neural arch which face downwards are the **prezygapophysis.** The postzygopophyses of each vertebra articulates and overlaps with prezygapophysis of the succeeding vertebra. The first two cervical vertebrae are modified to form the atlas and axis.

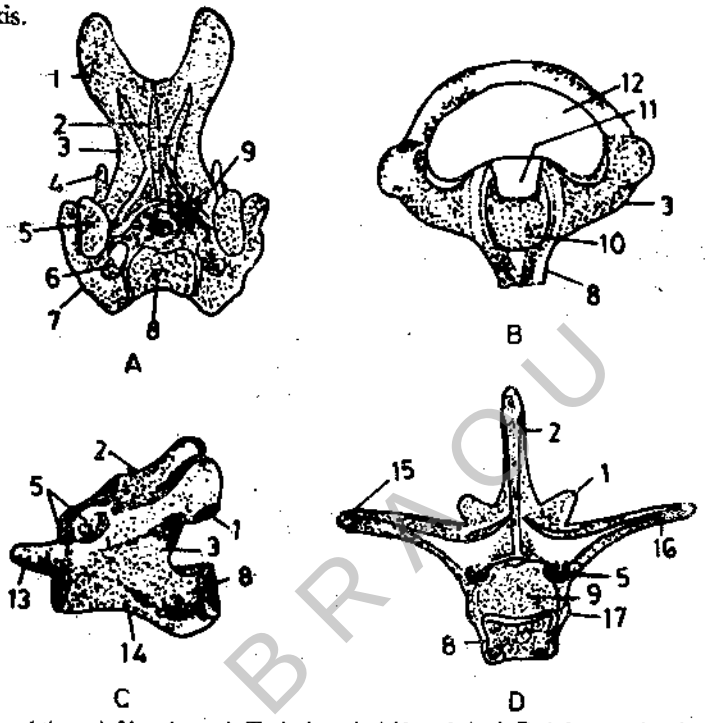


Fig. 19.3 Pigeon-Cervical and thoracic Vertebrae. A. Typical cervical (dorsal view). B. Atlas vertebra (anterior view) C. Axis vertebra D. Free thoracic vertebra 1. Post zygapophysis 2. Neural spine 3. Neural arch 4. Cervical rib 5. Prezygapophysis 6. Vertebraterial canal 7. Transverse prrocess 8. Centrum 9. Neural canal 10. Facet for occipital

Atlas or First cervical vertebra: It is very small and ring like in apperance. The centrum is poorly developed. The neural spine and the postzygapophysis is rudimentary. The neural canal is large and is divided by a ligament into two parts. The upper, the spinal canal for the spinal cord and the lower odontoid canal for the odontoid process of the second vertebra. The anterior end of the centrum has an articular surface for occipital condyle of the skull. Transverse processes and prezyapophyses are absent (Fig. 19.3 B).

Axis or second cervical vertebra: This is also a small bone but larger than the atlas. It has no transverse processes. Ribs are also absent. The centrum is produced anteriorly into a slender process known as odontoid process which fits into the odontoid canal of the first vertebra. The odontoid process is considered to be the centrum of the atlas. This neural spine is small and blunt. The anterior and the posterior zygapophyses are found (Fig.19.3 C).

2. **Thoracic region:** This region is characterised by its rigidity as a result of the fusion of vertebrae. There are five vertebrae in all. The first fourth are fused, the three is free and the last one is fused with the sacral and the first five caudal vertebrae to form the **synsacrum**. The first three or four thoracic vertebrae are fused with the last cervical vertebra to form a rigid girder. The transverse processes of these fused vertebrae unite forming horizontal bony plates. Their neural spine forming a continuous ridge in the mid-dorsal region. The hypopyses are fused midventrally to form a compressed plate for the attachment of the neck muscles.

All the thoracic vertebrae bear ribs each consisting of a vertebral and a Sternal portion and articulates with the vertebra by a double head. From the vertebral part of the rib arises a small bony out growth, the **uncinate** process.

Lumbar vertebrae are 6 in number and situated next to thoracic vertebrae. They do not have free ribs and hence regarded as lumbar verterae. However, some authors consider them as sacral vertebrae only.

3. **Sacral region:** There are 14-15 sacral vertebrae (Fig. 19.4) 14th. It is by the fusion of the following bones the synasacrum if formed 1) Last thoracic verterae 2) the sacral vertebrae 3) The first five caudal vertebrae. The synsacrum provides surface for attachment to the heavily built ilia of the pelvic girdle.

4. **Caudal region:** The first five caudal vertebrae are fused to participate in the formation of the synsacrum. The next five or six caudal vertebrae are small and free. The last four caudal vertebrae are fused and form a compressed upturned bone, the 'pygostyle' or the **'plough shape bone'.**

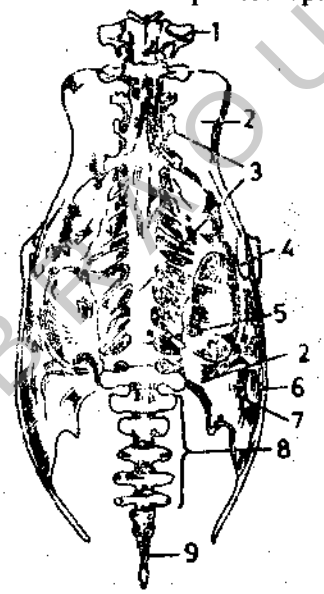


Fig. 19.4 Pigeon-Synsacrum 1. Last thoracic vertebra 2. Ilium 3. Synsacrum 4. Acetabulum 5. Caudal sacrum 6. Pubis 7. ischium 8. Caudal vertebrae 9. Pygostyle.

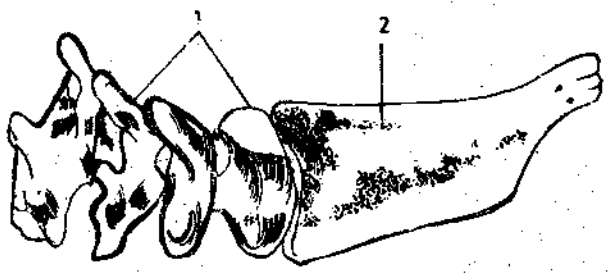


Fig 19.5 Pigeon-caudal vertebrae 1. Free caudals 2. Pygostyle.

19.3.3 Sternum

Sternum is a very characteristic and highly modified bone. It is a broad triangular bone extending far posteriorly below the abdomen. The mid ventral part of the sternum is produced into a vertical ridge, the keel or carina. The large muscles of flight are attached to the keel of the sternum. On this broad ventral girder, much of the body weight of the bird is carried during flight. The anterior end of the sternum projects upwards as the **manubrium.** From the anterior dorsal side of the sternum, a little posterior to the manubrium are two flat processes known as **xiphod process.** The shorter one is the **external xiphoid process** and the longer one is the **internal xiphoid process.** The distal end of these processes are expanded and plate like. Anterior to the external xiphoid process, dorsally there is a costal process having notches for the attachment of sternal part of the ribs. Between the manubrium and the costal process there is a deep groove, the coracoid groove for the articulation of the lower end of the coracoid (Fig. 19.6).

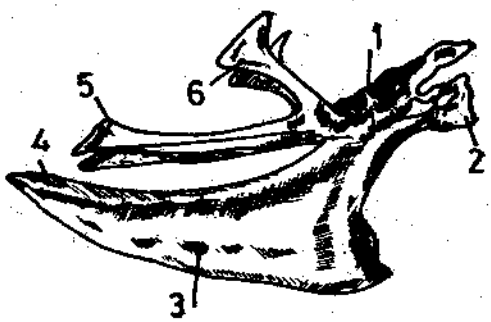


Fig. 19.6. Sternum of Gallus. 1. Costal facets 2. Manubrium 3. Carina (keel) 4. Sternum 5. Lower xiphoid process 6. Oblique xiphoid

19.4 APPENDICULAR SKELETON

19.4.1 Pectoral Girdle

The shoulder or the pectoral girdle is very distinctive in birds. It consists of a scapula, coracoid and clavicles. Scapula is a long, flat, sword like bone. It lies over the ribs bracing them. The scapula is produced internally into an acromion process. It is joined to the coracoid at its anterior end at an acute angel by a ligament. The corcoid is a stout, broad, straight, pillar like bone. The dorsal end of each coracoid is produced into an acrocoracoid. It articulates with the sternum at the coracoid groove. On the outerside of the coracoid where it is connected to the scapula, there is a cup shaped depression, the glenoid cavity. The head of the humerus (bone of the upper arm) fits into the glenoid cavity. A pair of slender long bones, the clavicles are attached to the coracoid. The two clavicles are joined ventrally to a small flat interclavicle forming a V-shaped **'furculum'** or **'wich bone'** or **'merry thought'.** The apex of the furcula nearly reaches the sternum. Each of its extermities is attached by ligament to the acromion and acrocoracoid processes of the corresponding side in such a manner that a large aperture, foramen triossum is left, between the three bones of the girdle. Through this foramen the tendon of the pectoralis minor passes through and attachs to the humerus (Fig. 19.7 A).

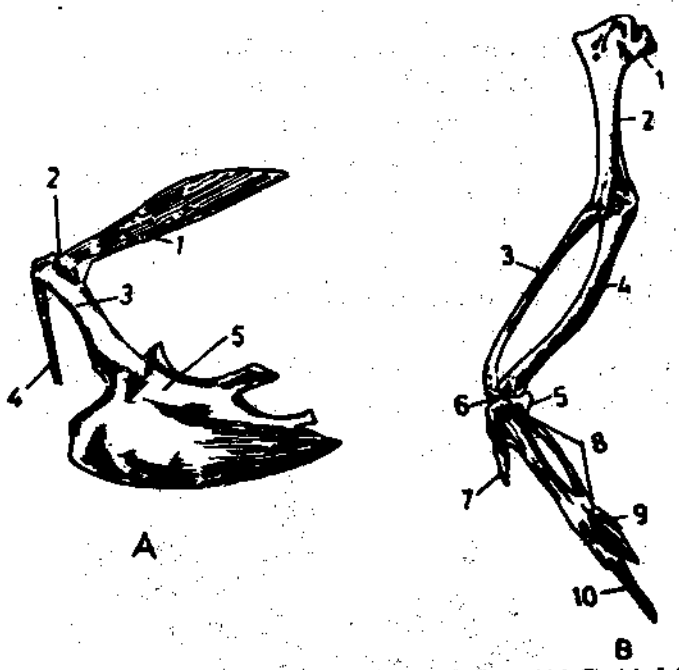


Fig. 19.7 Pigeon A. Pectoral girdle 1. Scapula 2. Foramen triosseum 3. Coracoid 4. Clavicle 5. Sternum
B. Fore limb 1. Pneumatic foramen 2. Humerus 3. Radius 4. Ulna 5. Ulnare 6. Radiale
7. Phalanx of digit 1st 8. Carpometacarpus 9. Phalanx of 3rd digit 10. Phalanx of 2nd digit.

19.4.2 Fore limbs

The fore limb of the bird is modified into a wing. It consists of an upper arm, foreasm and hand. The bone of the upper arm is humerus. At its proximal end is the head, which is slightly swollen and knob like. The head of the humerus articulates with the glenoid cavity. There are two projections one on either side of the head of the humerus, a small lesser tuberosity on the preaxial side and a greater tuberosity on the post axial side. The greater tuberosity has a pneumatic foramen, through which the air sac enters, making the bone spongy and light. In line with the lesser tuberosity the humerus has a deltoid ridge for the insertion of pectoral muscles. The posterior end of the humerus bears an articular surface, the trochlea for the radius and ulna. The forearm consists of two separate bones, the radius and ulna. The radius is relatively slender and more or less staright. Its proximal end articulates with the trochlea of humerous. The distal end articulates with radiale. the ulna is longer, stouter and slightly curved. At its proximal end it articulates with the trochlea. The distal end articulates with radiale. The ulna is longer, stouter and slightly curved. at its proximal end it articulates with the rochlea. It is continued as a short process beyond the articulation, which is known as olecranon process. The distal end of ulna articulates with ulnare (Fig. 19.7 B).

There are two large free carpls in the proximal row of radiale and **ulnare**. The distal row of carpals and the three metacarpals are fused to form a compound structure, the corpometacarpus. Of the three metacarpals the first is much reduced. The second is elongated and stout bone. The third metacarpal is slender and slightly curved and joined to the second metacarpal at both the ends but free in between. the first digit has a single phalanx, the second digit has two phalanges and the third has a single phalanx. The fourth and fifth digits are absent. The digital formula is 1:2:1:0:0

19.4.3 Pelvic girdle

The pelvic girdle is a massive bony structure. It is united to the synsacrum of the verbetral chumn dorsally. The pelvic girdle consists of two similar and equal halves. Each half consists

of three bones. 1) **Ilium** 2) **Ischium** 3) **Pubis.** All the three bones are united to form innominate bone. At the junction of the three bones a cup like depression is found, which is known as **acetabulum.** The head of the femur articualtes with the acetabulum. A large foramen is found at the bottom of the acetabulum, the **acetabular foramen** which is covered by a thin membrane (Fig. 19.8 A).

The ilium and ischium have become elongated and wider in order to distribute the body weight evenly during locomotion on land. The ilium is a large, expanded bone consisting of a pre-acetabular and a post acetabular portion of more or less equal size. The pre- acetabular part has a concave outer surface while the post-acetabular, part, is convex on the outer surface. On the posterior edge of the acetabulum, the illium is produced into a process, the **anti- trochanter** which works against the trochanter of the femur bone. The ilium is a broad bone fused posteriorly with the postacelabula ilium. there is a foramen known as ilio ischiatic foremen, which seperates ischium from ilium. The pubis is a long slender, curved rod like bone. It turns parallel to the ventral broader of the ischium. the pubis is separated from the ischium behind the acetabulum by a slit like opening the obturator foramen. The pubis is extended anterior to the acetabulum as pre-acetabular or pre-pubic process. The pubes and ischia do not form symphyses. The two innominate bones are united dorsally with the synsacrum. Ventrally the two halves lie apart from each other. In all other vertebrates the two halves are fused ventrally.

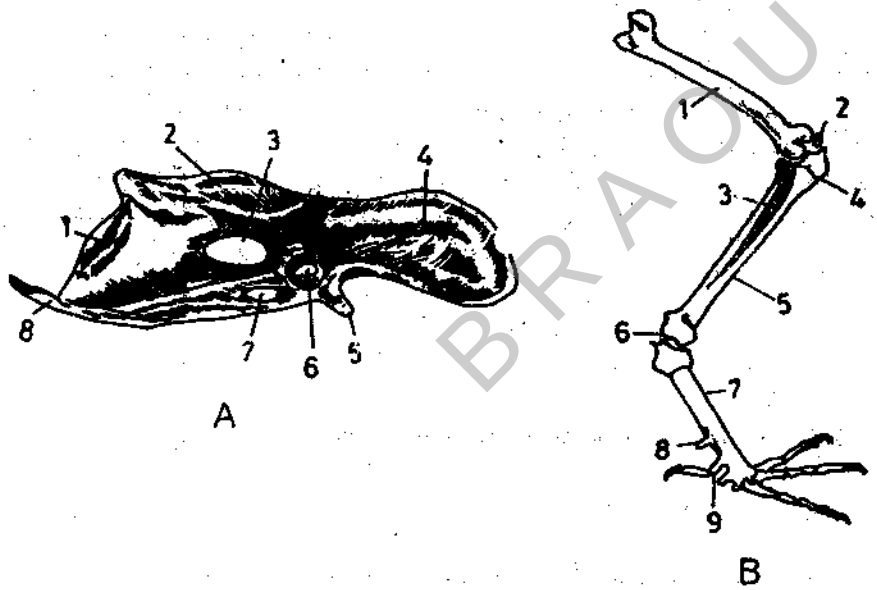


Fig.19.8 Pigeon A. Pelvic girdle. 1. Ischium 2. Post-acetabular illium 3. Ischiatic foramen 4. Preacetabular ilium 5. Prepubic process 6. Acetabulum 7. Obturator foramen 8. Pubis B. Hind limb 1. Femur 2. Patella 3. Fibula 4. Cnemial crest 5. Tibio-tarsus 6. Tarsals 7. Tarso-metatarsus 8. Spur 9. 1st metatarsal.

19.4.4 Hind limbs

The bones of the hind limb consist of a femur, a tibio-tarsus fibula tarsometatarus and phalanges. Femur is a stout bone. The anteroir end is differentiated into a smooth rounded head and trochanter. The distal end of the femur is produced into pulley like condyles. The two condyled enclose between them an inter condylar groove. A small sesamoid bone, the patella is found in the intercondylar groove, on the extensor side of the knee joint. The

shank consists of tibio-tarsus and fibula. The former articulates with the femur. Tibio-tarsus is a long bone formed by the fusion of tibia with the proximal row of tarsal bones. The proximal end of the tibiotarsus is projected into two large ridges the **cnemial crests.** The proximal end of the tibio-tarsus also bears two articular surfaces for the condyles of the femur. The fibula is slender, smaller and tapering bone. It is closely applied to the tibio-tarsus. The next part of the hind limb is the foot consisting of tarso- metatarsus. It is formed by the fusion of distal row of tarsals with the second, third and foruth metatarsal. The proximal end of the tarso-metarsus bears articular surfaces for the tibio-tarsus. The distal end of the tarso-metatarsus bears three pulley like surfaces corresponding to the three metatarsals. The ankle joint ie., connecting the tibiotarsus and tarso-metatarsus is formed between the two rows of tarsal bones and hence it is described as intertarsal joint. At the lower preaxial side of the tarso- metatarsus the first metatarsal is found. The first digit or hallux is directed backwards and contain two phalanges. The second, third and fourth digits are all directed forwards and contain 3,4 and 5 phalanges respectively. The last phalanx of each digit has a pointed and curved claw. The digital formula is 2:3:4:5:0

19.5 SUMMARY

Endoskeleton of pigeon comprises of axial and appendicular skeletal system. Axial skeleton includes skull and vertebral column while the appendicular skeleton embodies the girdles and the limb skeletons. Skull includes cranium, jaws, sense capsules and hyoid apparates. Bird skeleton is unique among vertebrates being pneumatic and ankylosed (fused). Almsot every part of skeletal system is unique. Skull monocondylic and rounded posterierly with edentate and pointed beak. lower jaw greatly reptilion. Sternum with carina (keel). Coracoid stout and pillar like. Pelvic girdle is tetra radiate as in ornithischian dinosours. Synsacrum, pygostyle, Carpometacarpus, tibiotarsus, tarsometlatarsus, are some peculiarities of the system.

19.6 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each:

1. Describe the skull of pigeon.
2. Describe the vertebral column of pigeon with an emphasis on the various modifications found in its structure.
3. Describe the appendicular skeleton of pigeon.

II. Answer the following questions in about 10 lines each:

1. Describe the structure of a typical cervical vertebra of pigeon.
2. Describe the structure of sternum of pigeon.
3. Describe the structure of pectoral girdle of pigeon.
4. Describe the structure of pelvic girdle of pigeon.

Unit – 20 ANATOMY OF PIGEON

Contents

20.1 OBJECTIVES

This lesson describes the various important organs like heart, lungs and those forming part of viscera.

20.2 INTRODUCTION

When we begin to dissect the bird, first of all we come across the skin, then the muscles of the abdomen, thorax and the broad sternum. Internally we find the body cavity or coelom, which is lined by peritoneum. Various organs of the body are found suspended in the body cavity by membranous folds known as 'mesenteries'.

20.3 VISCERA

In the neck region we find the long cylindrical **gullet** or oesophagus running dorsally and parallel to the **trachea** or wind pipe. Mouth is bound above and below by horny beak. The buccal cavity is narrow anteriorly but becomes wide posteriorly. It contains a large tongue which is pointed at the tip. The buccal cavity is followed by a narrow short pharynx which in turn is followed by the gullet or oesophagus mentioned earlier. At the base of the neck, the gullet dilates into a thin walled, large, bilobed sac, the **crop.** It serves to store hurriedly swallowed large granules of food which undergo masceration and digested later. The epithelium of the crop secretes during breeding season a highly nutritive fluid **"the pigeons milk"** which is regurgitated and fed to the young bird. Both the parants secrete this milk. The crop is continued into the stomach which consists of two parts (i) an anterior **proventriculus** (ii) a posterior **gizzard.** The proventriculus is slightly wider than gullet and contains a number of gastric glands in its mucous membrane. The gizzard is large, hard biconvex structure. Its walls are highly muscular. The inner lining is made of a horny epithelial layer. A number of small pieces of stones which are swallowed along with grains are to be found in the inner cavity of the gizzard. These small pieces of stones help in crushing the food particles. There is a mesentery attached to the gizzard. The mesentery extends from the gizzard to the ventral body wall towards the left of the median line. This is known as **ventral ligament,** which is continued anteriorly to form the ligament of the liver known as falciform ligament which extends down from the mid ventral part of the liver to the mid ventral line of the body. These two ligaments are continuous with each other. They constitute a partition or septum, which divides the peritoneal cavity into a larger right cavity and a smaller left cavity. Such a septum is not found in other vertebrates.

The gizzard is followed by a long small intestine, consisting of a proximal **duodenum** and a distal part, the **ileum.** The duodenum is 'u' shaped and receives two bile ducts and three pancreatic ducts. The duodenum passes into the ileum without nay demarcation. The ileum is coiled, very long tubular structure. The next part of the alimentary canal is the large **intestine** or **rectum.** This is a very short chamber and more or less of the same diameter as that of ileum. At the junction of the ileum and rectum there is a pair of small **Colic caecae,** which also aid in digestion. The last part of the alimentary canal is the **cloaca** which opens by the cloacal aperture. The cloaca consists of three chambers, the anterior large **coprodaeum** (receiving the rectum), the middle **urodaeum** (receiving renal and genital ducts) and the posterior **proctodacum** which opens by cloacal oepning. Cloaca reabsorbs water from the urine and faecal matter.

The liver and the **pancreas** are the two glands associated with the alimentary canal. The liver is bilobed large, dark red coloured organ found behind the heart. The right lobe is larger than the left. Each lobe has its own bile duct. there is no gall baldder. There is a small **spleen** found near the liver. **Pancreas** is found in the loop of duodenum. It is a pinkish coloured gland of great significance. These ducts arise from the pancreas which carry the pancreatic juice to the duodenum.

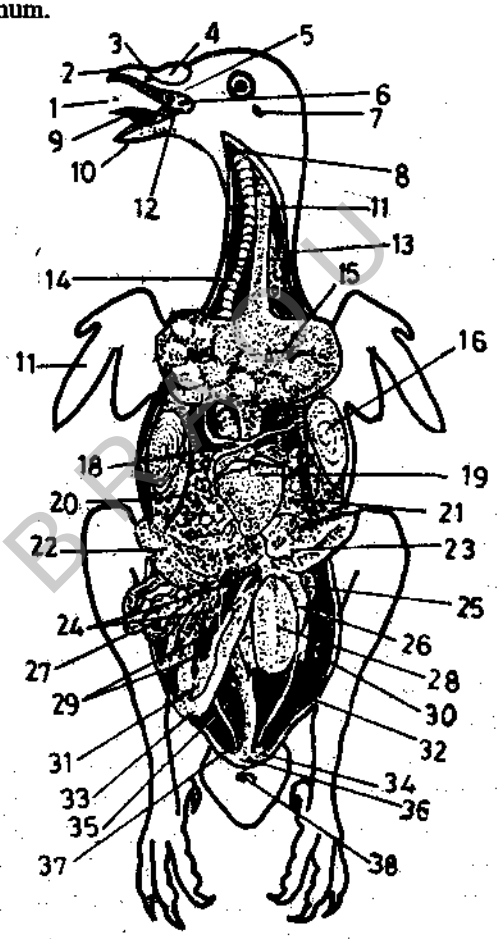


Fig 20.1 Soft Anatomy of pigeon 1. Mouth 2. Upper beak 3. External nostril 4. Cere 5. Common eustachian opening 6. Gullet 7. External ear opening 8. Upper larynx 9. Tongue 10. Lower beak 11. Oesophagus 12. Opening of trachea 13. Thymus gland 14. Trachea 15. Crop 16. Pectoralis major muscle 17. Right wing 18. Dorsal aorta 19. Heart 20. Right lung 21. Left lung 22. Right lobe of liver 23. Left lobe of liver 24. Bile ducts 25. Spleen 26. Proventriculus 27. ileum 28. Gizzard 29. Peaumatic ducts 30. Left kideny 31. Pancreas 32. Ureter 33. Duodenum 34. Bursa fabrici 35. Rectal caeca 36. Cloaca 37. Rectum 38. Cloacal aperture.

The heart of the pigeon is very large in proportion to the size of the body and consists of four chambers. The heart is found in a delicate pericardial sac lying dorsal to the sternum. The auricles are thin walled chambers, situated on the anterior side. They are much smaller compared to ventricles. The two ventricles form the major part of the heart which together consitute a muscular thick walled cone with the apex directed down wards posteriorly. There is an aorta on the right side starting from the left ventricle. The sinus venosus is absent. (Since it is absorbed in the right auricle). From the right ventricle a pulmonary trunk originates, which soon divides into two large pulmanary arteries. There is a complete separation of oxygenated and deoxygenated blood in the heart of birds. The venous blood is received by the right auricle, conveyed to the right ventricle and pumped to the lungs. The oxygenated blood is returned to the left auricle by two pulmonary veins and the left ventricle pumps the same into right aorta, then to all parts of the body. In birds, the left systemic artery continues as the left subclavian artery.

The trachea or wind pipe is found ventral to the gullet running in the neck region. The trachea is displaced to the left by the crop. It soon divides into two **bronchi** as it enters the body cavity. There are bony rings supporting the trachea. The bony rings completely surround the trachea. On the other hand the bronchi are supported by cartilagenous rings which do not surround completely. At the junction of the trachea with the paired bronchi, a swollen structure is found which is known as syrinx. This is a highly characterstic sound producing organ of birds. Lungs are very small compared to their body size and lie in pleural civities. The lungs are non-saculars spongy lobes and only slightly distensible unlike in frog and lizards. On the dorsal surface the lungs closely fit into spaces between the ribs. The ventral surface of the lungs is covered by peritoneum or pleura.

A number of air sacs are found connected to the lungs. Air sacs are expansions of the mucous membrane of the bronchi. The air sacs are very thin and transparent. Of the nine air sacs, four paired and one **extra clavicular** median unpaired. The **interclavicular air sac** is median and connected to the bronchi of both the lungs. An **auxillary air sac** from the interclavicular air sac enters the humerus (Fig. 20.3) on each side. From the anterior side of each lung arises a **cervical air sac**, which gives out small branches to the neck. **The anterior thoracic air sacs** arise from the anterior lateral side of each lung. Similarly the **posterior thoracic air sacs** arise from the posterior side of each lung. A pair of large **aabdominal air sacs** are found lying amidst the coils of intestine. The ventral surface of the **thoracis air sacs** are covered upto the pericardium. The oblique septa of both sides are united middorsally. The oblique septum divides the coelom into two chambers. The anterior chamber containing lungs, interclavicular and throacic air sacs. The lower chamber contains abdominal air sacs, heart, liver, stomach, intestine etc. Air sacs do not have any rolc in the gaseous exchange as they are least vascularised. They increase the efficiency of the lungs by providing them fresh air during expiration. The air sacs also cool the body by internal evaproation of the body fluids from their surface.

A pair of kidneys (metanephric) are found fitted in the hollows of the pelvis. Each kidney is three lobed, flattened and dark red coloured. They are covered by peritoneum only on the ventral side. The ureters are narrow ducts arising ventrally between the anterior and the middle lobe of the kidney. They run straight posteriorly and open directly into the urodaeum, the middle compartment of the cloaca. The urinary baldder is absent.

A pair of testes are found. They are attached by the peritoneum to the ventral surface of the anterior part of the kidney. The fold of peritoneum is called mesorchium. The size of the testes vary considerably according to the season. They are ovoid in shape. Narrow convoluted ducts arise from the inner side of the posterior part of the testes. These ducts

are called **vasa deferentia,** which run backwards parallel to the ureters. The anterior part of each vas deferens becomes more densely convoluted to form the **epididymis.** Before opening into urodaeum each vas deferens becomes enlarged to form a **seminal vesicle.** The seminal vesicle serves the purpose of storing the sperms. The copulatoyr organ is absent in pigeon.

In the female reproductive organs, the **ovary** is found only on the **left side.** The one on the right side is atrophied. The oviduct of the right side also atrophies and only a remnant of the oviduct is found near the cloaca. The ovary is considerably increased in size during the breeding season. The ovary is quite large and irregular in shape. It is attached to the kidney at the anterior part on the ventral surface by the peritoneum which is known as **mesovarium.** A large number of round **follicles** of different sizes are found studded within the surface of the ovary. Each follicle contains an ovum. The left oviduct is long, convoluted and muscular. The anterior part of the oviduct is enlarged to form a wide oviducal funnel, with large median opening, having fimbriated margin. The next part of the oviduct is provided with glandular epithlium where albumen is secreted for the egges. Then follows the uterus, which secretes the shell of the egges. The terminal part of the oviduct is a small vagina, which secretes mucus. The **vagina** opens into urodaeum.

Adrenal glands or supra renal glands are found as prominent, yellow coloured bodies of irregular shape situated anterior to the kidneys, near the gonads. The secretion of adrenals is known as adrenaline which is a hormone that controls the involuntary muscles. Thyroids are paired bodies found on either side of the trachea, where it branches into brochi. The secretion of the gland is thyroxin which regulates the general metabolism.

20.4 SUMMARY

The soft anatomy of pigeon includes the various organ systems viz., digestive, respiratory, circulatory, nervous and urinogenital. The digestive system shows peculiarities in possessing crop, proventriculus and gizzard. The respiratory system too shows unique structures like air sacs and syrinx (sound producing organ). Lung is a very small, non-distensible lobe. Air sacs pump fresh air into the lungs during expiration. Heart is 4 chambered. There is only right aorta. Sinus venosus is absorbod into right auricle. Kidney is 3 lobed and metanephric. There is only left ovary with its oviduct which not only passes the egg down to vagina but also secretes albumen and shell to the egg.

20.5 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines.

1. Give a general account on the internal structure of the pigeon.

II. Answer the following in about 10 lines:

1. Describe the digestive system of pigeon.
2. Describe lungs and air sacs of pigeon. Add a note on the significance of air sacs.
3. Describe the genital system of pigeon.
4. Describe the heart of pigeon.

Unit – 21 FLIGHT ADAPTATIONS AND MIGRATION IN BIRDS

Contents

21.1 OBJECTIVES

This unit gives an account of adaptations in the structure of various organs in response to aerial mode of life and the significance of seasonal movements.

21.2 INTRODUCTION

We have noted the birds show very interesting structureal modifications. This is particularly true, to lift and maintain the body in the air. Every part of the body accordingly modified. In addition, the birds also show habit of migration from its home to another part of the world and back scasonally for purposes of feeding and for breeding. Now we shall discuss the flight mechanisms and mighty habits of these aerial bipeds.

21.3 FLIGHT ADAPTATIONS

Birds are the most successful animals in adapting themselves to the aerial mode of life. Adaptations could be found practically in every organ of a bird. Some of the major adaptations are as follows:

The body of the bird is **streamlined** so as to offer minimum resistance to air during flight. The body is **boat shaped** and all the feathers are backwardly directed and lie flat over the body. Such an arrangement of **feathers** would ensure minimum resistence to air. Another remarkable adaptation to flight is found in the modification of the forelimbs into **wings**. The wings are covered by long feathers, the quills. The primary feathers provide the greater part of the forward thrust, acting as propellers, while the secondaries are mainly responsible for the lift. The **air space** that occurs between the feathers especially towards the tip of the wings, serve as slots. The slots allow the air to escape thereby reducing the turbulence and results in the smooth flight of bird in the air. Slots are conspicuous in slow fliers and mostly in such birds which soar on thermal up currents. Slots are also found in the wings of large birds such as pheasants, which are fast fliers. The alaspuria or bastard wing also asppears to act as a slotting device.

The muscles of flight are enormously developed in fllying birds. A massive and powerful muscle, the **pectoralis major**, which is about 1/5 of the total body weight is found. It arises from the whole of the keel of the sternum and from the clavicles, filling up the entire wedge shaped space between the body and the keel. This muscle is richly supplied with blood vessels and it is the chief motive force during the powerful down stroke of the wings. The elevation of the wings is performed by the **supra coracoids** (pectoralis minor also called sub clavius) which arises from the anterior part of the sternum, dorsal to the pectoralis major. The dorsal **supra-humerals** or **scapulo-humeral** and **coraco-humeral** muscles cause the rotational movement of the wings. These muscles extend from the pectoral girdle to humerus (Fig. 21.1).

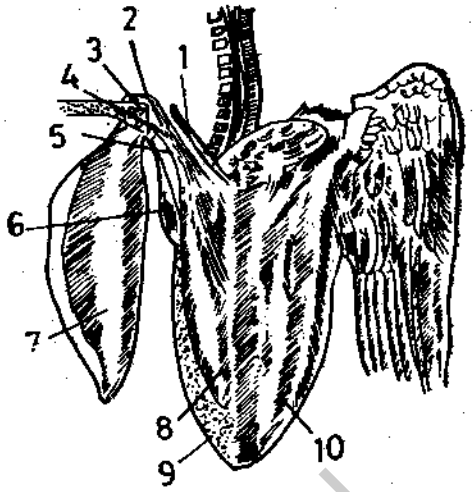


Fig 21.1. Pectoral muscles of pigeon. 1. Clavicle 2. Tendon of the subclavius 3. Humerus 4. Foramen triosseum 5. Coracoid 6. Coracobranchialis 7. Pectoralis major 8. Subclavius 9. Sternum 10. Pectoralis major.

Endoskeleton is well adapted to the aerial mode fo life. Various parts of the skeleton such as vertebral column, skull, girdles and limb bones are highly modified to suit the aerial mode of life. Many of the bones of the bird are light and do not have marrow. They are **pneumatic** filled with air and communicate with the air sacs. the long pneumatic bones are provided with struts, without sacrificing the strength (Fig. 21.2). This principle is often used in the wings of the aeroplane. the vertebral column has undergone remarkable changes, such as the great mobility in the neck region, the shorteness of the tail and rigidity of the trunk region. The cervicle and free thoracic vertebrae have heterocoelus centra, which provide free mobility to the neck region. The rigidity of the vertebral column is due to the fusion of vertebrae to form two girders. The first girder is formed by the fusion of the anterior thoracic vertebrae. The second girder, the synsacrum, is formed by the fusion of last one or two thoracic, lumbar, sacral and anterior caudal vertebrae. This rigidity of vertebral column is of great advantage to the bird for withstanding the pressure of air during flight.

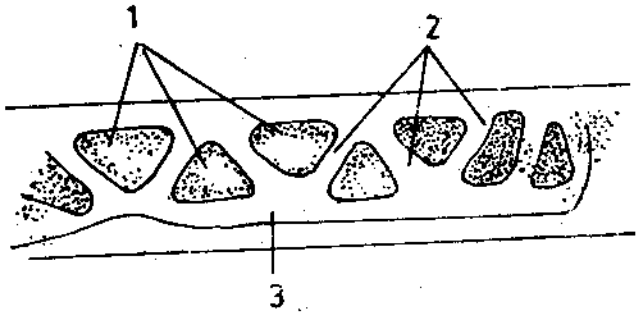


Fig. 21.2. L.S. of long bone of vulture showing structs. 1. Air spaces 2. Struts 3. Base

Sternum is very characteristic part of the skeleton of bird. The ventral part of the sternum is produced into a **keel** of **carina**.. The massive muscles of flignt are attached to the sternum and keel. During flight much of the body weight is carried by the sternum and keel.

The respiratory and circulatory systems are very efficiently organised to meet the high energy needs of the flight muscles. The most characteristic feature of the circulatory system is unusually large size of the heart, beating rapidly. The oxygenated and the deoxygenated blood is kept well separated. Further the birds are warm blooded and maintain comparatively a higher constant temperature. This can be correlated to a very high metabolic activity of birds. All these are the adaptation to aerial mode of life. The lungs are connected to the air sacs which make the respiratory system most efficient (Fig 20.3). The air sacs act like bellows thereby allowing an efficient flow of air in and out of the lungs. Birds are only vertebrates where there is no dead space (containing unused air) in the lungs.

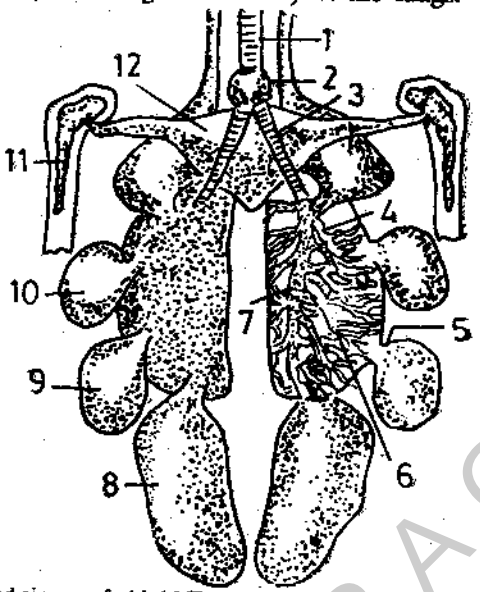


Fig 21.3. The lungs and air sacs of a bird 1.Trachea 2.Syrinx 3.Bronchus 4. External branches 5. Recurrent Bronchus 6. Parabronchus.8. Abdominal air sac 9.Posterior thoracic air sac 10. Anterior thoracic air sac 11.Air sac extending in to humerus 12. Interclavicular air sac.

The maintainance of equilibrium is of great importance for the birds during flight. The even distribution of weight is ensured by the position of wings, which are articulated at a much anterior point. The muscle of flight which are very massive are borne on the keel of the sternum and the sternum in turn is attached to the ribs.

The nervous system is very well developed. The cerebellum is unusually large consisting of a median lobe and lateral flocculi. Transverse convolutions are found on the cerebellum, so as to increase the grey matter. The great development of cerebellum is obviously in response to the active flying habit of the birds (fig.21.4). Cerebellum co-ordinates the coplex movements of the wings by regulating the equillibrium. The sense organs, particularly the eye is very well developed. It is very large and reaches a high level of efficiency (Fig. 21.5). The muscles of the iris and ciliary muscles are striated and concerned with the power of accommodation by changing the curvature of lens. These muscles are very fast in operation, which is of great advantage to the birds while flying. Thus the birds have vision which is described as telescopic vision. The birds are very poor in olfactory sense. The olfactory lobes in the brain are poorly developed, because of the fact that the birds flying in air do not depend on smell.

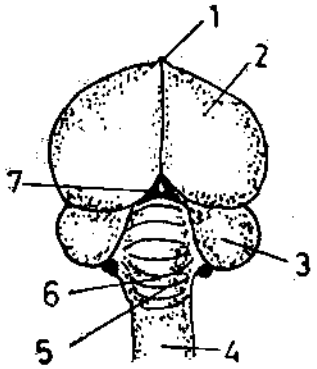


Fig. 21.4 Pigeon briain-Dorsal view. 1. Olfactory lobe 2. Cerebral hemisphere 3. Optic lobe 4. Medulla Oblongata 5. Flocculus 6. Cerebellum 7. Pineal body

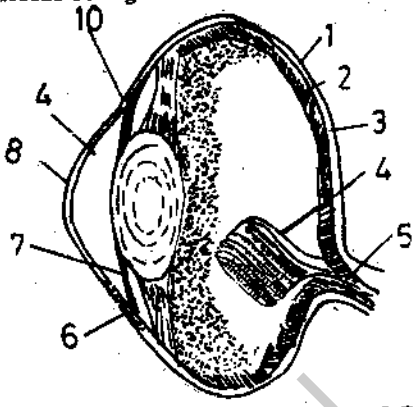


Fig. 21.5 The eye of pigeon 1. Sclerotic coat 2. Choroid coat 3. Retina 4. Pecten 5. Optic nerve 6. Ciliary process 7. Iris 8. Cornea 9. Aqueous chamber. 10. Sclerotic plate.

The spongy bones with air cavities, the rigidity of vertebral column, fusion of a number of bones in vertebral coloumn, skull and also in limbs, make the body of the bird lighter which are of great advantage during flight. Besides the covering feathers, the muscles of flight and structure of brain and eye are of basic adaptive value. Further the efficient types of respiratory and circulatory systems are in conformity with the high metabolic rates of the birds. Thus we find that birds have a number of adaptive features in response to aerial mode of life.

21.4. MIGRATION OF BIRDS

The migration of birds is a very fascinating aspect of bird life. It has attracted the attention of mankind for centruries. However, extensive experimental study has been carried out only in the present century. Migration referes to seasonal movement of birds from one region to another to obtain the advantages of favourable conditions of life. Migration also implies a return to the original place. The most common migrations are those of north to south and back. Such migrations are described as **latitudinal**. During summer northern regions offer more favourable conditions of life and so the birds migrate from south to north. In winter they return to south. Birds living in mountainous regions migrate to plains in winter (for feeding) and in summer they return to mountains (for breeding). Such migrations are referred to as **altitudinal**.

In India, there are about 350 forms of birds which migrate to palaearctic regions i.e., north of Himalayas in Central and Northern Asia, for breeding during summer. The most abundant and regular migrants are the ducks and geese, swallows, flycatches etc. A number of birds migrate to northern places such as Ladakh, Gilgit, Bhutan, Sikkim etc., for breeding during

summer. Most birds leave for northern places before hot weather commences in March/April in our country. They return in the early autumn between September and November when there would be severe cold in the northern parts.

The direction and course of movement during migration is not fully understood. Most migrating birds follow prominent land marks, such as rivers, coast lines, mountain ranges etc. Soaring birds migrate with the help of up currents and tend to use short sea crossings. Birds seem to possess some sense of general direction. They do not learn the routes of migration from their elders. Young birds without any previous experience of route of destination, complete the migratory journey with regularity and accuracy without any mishap. Evidently birds are guided by instinct impressed upon their individual memory, so that it has become hereditary.

Birds flying over the sea during the migration, do not go much higher, since they do not meet with any obstacle. Generally birds fly at a height ranging between 400-900 meters. Birds which have to cross high mountain barriers fly at a very high altitude. Many migratory birds such as Geese, Waders and passerine birds have been observed over the Himalayan altitude. Many climbers have observed the remains of migratory birds such as ducks, cranes, waders, eagles etc., strewn in the Himalayan glaciers.

The Arctic Tern (*Sterna paradisea*) is a champion long distance migrant. These birds nest in Northern Europe, Asia, and Alaska. The migratory flight towards south starts between September and November. They reach Antarctica in southern hemisphere where they stay from December to March. They return to north between April and May. During these migration flights the Terns cover nearly 9000 miles each way (Fig. 20.6). The wood cock (*Scolopax rusticola*) is capable of non-stop flight of 2,400 kms from Nilgiri, its feeding place to Himalays, its breeding place. Storks and plovers are also examples of long distance migrants.

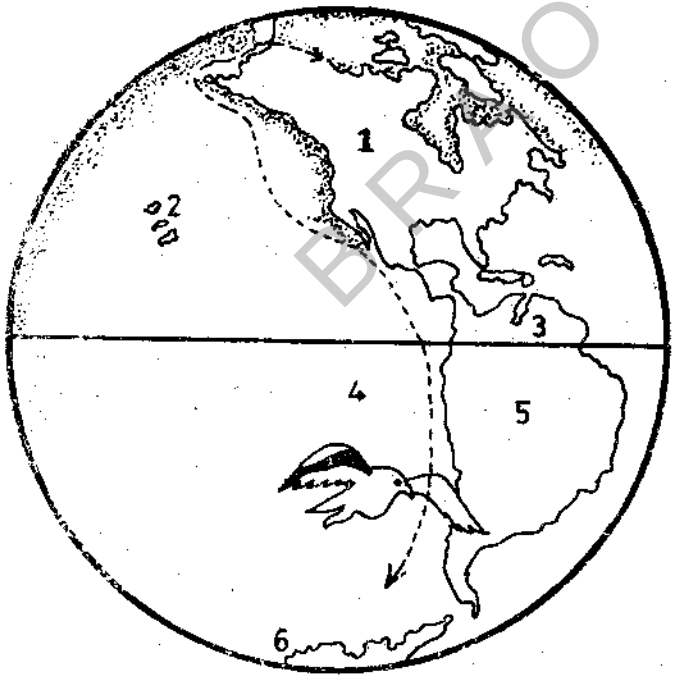


Fig. 21.6. Map showing the route and distance of migration of Arctic Tern. 1. Alaska 2. Hawaii 3. 7455 miles (distance between 1 and 3) 4. 9319 miles (distance between 1 and 4) 5. South America 6. Antarctica.

21.4.1 Causes

The migration of birds is in response to some stimuli, which could be provided by the physiological conditions of the gonads. The amount of day light or the **photoperiod** has a direct influence on the physiological conditions of the gonad. It has been observed that in birds which are caged in autumn and exposed to illumination to make up the loss of day light, the gonads do not regress. Such birds when released, move away northwards where the conditions are more appropriate for breeding. On the other hand the control birds which were not provided with extra illumination, did not show any urge to move away towards north, when released. Obviously this was due to regression of gonads. These experiments by **Rowan** suggest that seasonal changes in illumination may be an important factor in migration.

A bird enters a physiological state that triggers the migratory instinct prior to the actual migration. In this phase the day light which reaches the eyes of the bird, induces nerve impulses. These nerve impulses reach the hypothalamus, which in turn induced the anterior pituitary to secrete gonadotrophic hormones. The physiological state of the gonad of the bird is changed because of the action of the gonadotrophic hormone, which provide a stimulus for migration.

21.4.2 Significance

Migration confers abvious advantages to the birds. It helps the bird to live in favourable conditions of life all through the year. By migrating from high altitude during winter, they avoid extreme cold conditions such as freezing of water and shortening of length of day. During summer when birds return to northenly regions or high altitude, they get the advantage of longer day light for searching food. They avoid extreme hot climate. Further they get enough food due to luxuriant vegetative growth, and suitable conditions for breeding.

21.5 SUMMARY

The birds are the unique vertebrates showing several adaptations for flight. Almost every (organ) system is affected particularly the skeletal system. Even among the soft organs, right from the digestive tract upto the urinogenital system, we find the modifications. The feathers, flight muscles, pneumatic bones, keel, the air sacs, cerebellum, the absence of right ovary with its duct, all contribute for the aerial mode of life. The origin of the migratory habit of the birds is a disputed fact. Probably, of the several other causes, the day length may influence the gonad condition, through the endocrinal regulations, thereby triggering the migratory instinct. The scarcity of food, weather conditions coupled with hereditary instinct might put the bird on migratory route. Interestingly, the young birds take the migratory routes without receiving any sort of training or guidance for migration from their elders.

Several types of migration viz., altitudinal, lititudinal (arctic term, geese & some passerine birds), seasonal, vertical, diurnal etc, are noted to occur in nature.

21.6 MODEL EXAMINATION QUESTIONS

I. **Answer the following questions in about 30 lines each.**

1. Describe the flight adaptations of birds.

2. What is meant by bird migration? Describe the process of migrations, causes and significance.

II. **Answer the following in about 10 lines each.**

1. Flight muscles
2. Brain of bird
3. Causes of bird migration

21.7. GLOSSARY

Acetabulum	:	The socket for the articulation of femur in the pelvic girdle
Acrodont	:	Teeth fused to the edge of jaw-bone
Air sacs	:	Large bags acting as air reservoirs connected to the lungs
Alar membrane	:	A fold of skin attached between the upper arm and fore arm of the bird, anteriorly.
Ala spuria	:	A tuft of feathers attached to the thumb of a bird
Allantois	:	A sack which grows from the hindgut in the embryo amniotes
Amnion	:	The inner of the two foetal membranes of aniotes; the outer being the chorion
Amniotes	:	Reptiles, birds and mammals
Amphicoelous	:	Biconcave. A term used to describe vertebrae in which the centrum has depressions on both anterior and posterior faces
Antivenin	:	Antipoisonous serum
Apteria	:	Spaces on the surface of a bird's body where the skin is naked or covered with only down feathers.
Arboreal	:	Animal dwelling in or on the trees
Barbicles	:	Small hooked processes by which the barbules of the feather interlock
Carapace	:	Dorsal covering of tortoises and turtles
Centrum	:	A part of the bone which forms the chief part of the vertebra
Cerebellum		Enlargement of the hind brain in a vertebrate. It is lobed and convoluted in birds and mammals. It is concerned with co-ordination of muscclar action
Chorion	:	The outermost of the foetal membranes in reptiles, birds and mammals
Cnemial Crest	:	A ridge on the tibia to which the main tendon of the knee is attached
Cochlea	:	The spiral part of the inner ear containing complex receptor by which various sounds are perceived
Columella	:	A single ossicle connecting the tympanic membrane with the inner ear
Coprodaeum	:	The part of the cloaca of a bird into which the rectum opens.

Coagulation	:	Clotting of blood
Crop	:	A dilation of oesophagus where food may be kept stored for some time before passing on to the gizzard
Cretaceous	:	In pigeon it secretes nutritive milky fluid. Geological period-lasting approximately from 135 till 70 million years ago
Ciliary muscles	:	A ring of small muscles at the junction of cornea & choroid in the vertebrate eye. This helps in the power accomodation
Desiccation	:	Drying up of embryo due to evaporation
Dermal Bone	:	(Membrane bone)-Bones which do not replace preexisting cartilage but are deposited independently in the lower layer of the skin
Ectothermic	:	(Poikilothermic)-Having a body temperature which changes with that of surrounding
Epidermis	:	The outer layer of the skin derived from the ectoderm
Foramen Magnum	:	The large opening at the hind-end of a vertebrate skull through which the spinal cord passes from the brain
Foramen triosseum	:	An opening enclosed by the scapula, clavicle and corocaid of a bird. The tendon of the pectoralis minor passes through the opening
Falciform ligament:		A short double sheet of mesentery connecting the liver with the ventral wall of the abdomen of pigeon
Fossil	:	Preserved remains of past animals; generally hard parts like bones, teeth etc
Gizzard		A part of the stomach having thick muscular wall often with horny teeth. It breaks up the food into small particles
Glenoid cavity	:	A cup like hollow in the pectoral girdle into which the head of the humerus fits
Gullet	:	Food tract in the neck (oesophags)
Habenular	:	Transverse nerve tract running across the roof of the third ventricle (brain)
Heterocoelous Vertebrae	:	Vertebra having saddle shaped centra. Such articular surfaces of the centra allow great mobility of neck
Hemipenis	:	Paired, muscular male intromittent organs in reptiles
Heterodont	:	Having several different types of tooth i.e., incisors, canines etc]
Hypapophysis	:	A median ventral process on the centrum of a vertebra
Hypothalamus	:	The floor of the third ventricle in the vertebrate brain which is thickened
Infra-labials	:	Scales on the lower jaw of the snake or a reptile
Jugal	:	Membrane bone forming part of the anterior border in the vertebrate skull
Jurrasic	:	Geological period-lasted approximately from 180 till 135 million years ago
Lacrymal	:	Membrane bone in the anterior part of the eye orbit
Marrow	:	Yellow or red pulp in the central cavities of the bone. In this tissue the red blood corpuscles (RBC) are formed
Melanophores	:	Cells containing pigment granules usually of black melanin

Mesozoic Era	:	Geological periods - this era lasted approximately from 225 till 60 millions years ago. The age of great reptiles or "Golden age of reptiles"
Oblique septum	:	A septum which divides the coelome into two chmbers in Birds. The anterior chamber containing lungs, interclavicular and thoracic air sacs. The lower chamber contains abdominal air sacs, heart,liver,stomach etc
Obturator Foramen	:	A large opening between the pubis and the ischium on each side of the pelvic girdle
Occipital condyle	:	Bony knob on the ventral part of skull for articulation with atlas vertebra
Odontoid process	:	A projection of the second vertebra, directed forwards fit into the first vertebra
Oviparous	:	Animals reproducing by laying eggs
Parasphenoid	:	Membrane bone, forming part of the floor of cranium
Parietal Body	:	(Pineal eye)-An outgrowth from the roof of the forebrain. In lampray it is with lens and retina acts as photoreceptor. In other reptiles its function is doubtful
Parietal Foramen	:	A median opening between two parietal bones
Parotid Glands	:	Salivary glands in the check of mammals
Plastorn	:	Ventral covering of tortoises and turtles
Pecten	:	A Vascular comb-like processes from the choroid in the eye of a bird. Its function is not certain. Probably it suypplies oxygen to the inside of the eye
Pectoralis Major	:	A very large muscle which is spread all along the keel of the sternum. The powerful down stroke is due to this muscle.
Pectoralis minor	:	This muscle is responsible for the elevation of the wings. It arises from the anterior part of the sternum dorsal to the pectoralis major.
Pleurodont	:	Teeth attached by their side to the jaw
Prehensile	:	Organ capable of grasping
Procoelous	:	Vertebrae whose centra are concave in front and convex behind
Proctodaeum	:	The posterior chamber of cloaca which opens by cloacal opening
Pteryia	:	These are also known as feather tracts. The contour feathers of a bird are arranged along these tracts
Pygostyle	:	The last four tail vertebrae of a bird which are fused
Quadrate	:	Cartilage bone at the hind end of upper jaw which articulates with lower jaw
Quadruped	:	Animals walking on fore and hind limbs
Rhamphotheca	:	The horney epidermal sheath surrounding the beak of a bird
Synsacrum	:	A number of fused vertebrae supporting pelvic girdle of bird
Struts	:	The long bones in flying birds have cavities inside with a framework of bars of the bones to resist the pressure
Symphysis	:	A junction or union of two bones as for instance the two public bones

Syrinx	:	The sound box of a bird located at the lower end of the trachea where the two bronchi are found
Sclerotic bones	:	Ring of small overlapping bones present around the iris
Scutes	:	Scales or shield-like on the body forming exoskeleton
Supra-labials	:	Scales on the upper jaw of a snake or reptile
Sub-caudals	:	One or two rows of ventral scales behind the cloaca of snakes
Thecodont	:	Having teeth in sockets
Temporal Muscles	:	Muscles connecting the lower jaw with temporal region of the cranium
Triassic	:	Geological period-lasted approximately from 225 till 180 million years ago
Unicinate process	:	A small process projecting backwards from the ribs of the birds each over-lapping the next posterior rib and so helping to strengthen the wall of the thorax
Uropygium	:	The short tail-stump of a bird
Urodaecum	:	The middle chamber or part of the cloaca into which the ureters and genital ducts open
Viviparous	:	Animals, whose young ones develops inside the body of the parent

Unit - 22 : MAMMALIA – GENERAL CHARACTERS AND CLASSIFICATION

Contents

22.1 OBJECTIVE

- To know the distinctive features and also the diversity of mammals.

22.2 INTRODUCTION

Mammals arose from **cotylosaurian reptiles**. They originated in the Jurassic period about 150 million years ago. The transition from primitive repitiles to mammal like forms took place in the upper carboniferous period but in Permian, they had a set back. In the Jurassic period there were only a few mammals but in the Cretaceous, these small forms became abundant and before the Eocene, a variety of different types of mammals evovled and the Tertiary period regarded as the 'age of mammals'.

22.3 GENERAL CHARACTERS

1. Due to the presence of mammary glands unfunctional in males and milk secreting in females the class is named as **mammalia**. Mammary glands are present in females for suckling the young ones. Except a few forms all give milk to young ones; placenta is developed as an organ for the nourishment of embryo from the mother's.
2. The body is usually covered with insulating coat of hairs. The skin is glandular. The body temperature is kept at a constant level. Hence they are **homiothermic** or **endothermic**.
3. The vertebrae and the long bones have terminal ossifications. The centra of vertebrae have generally flat or slightly rounded facets and there are seven cervical vertebrae with the exception of sloths.
4. Skull **dicondylic**. Skull bones firmly united, sutures generally persist. Lower jaw is formed of dentary only. Middle ear with three ossicles viz **stapes, incus** and **malleus.**

5. Nasal part is usually long; teeth on both jaws situated in sockets or alveoli (thecodont) and are differeniated (hetrodent). Teeth are rarely absent. The tongue is usually mobile. Eyes are provided with movable lids, ears with external fleshy pinnae. The senses of sight, smelll and hearing are well developed.

6. Fore limbs and hind limbs are usually present except in few forms pentadactyle, adapted for walking, running, climbing, flying, burrowing, and swimming which are provided with horny claws, nails, digits, hooves or fleshy pads.

7. A muscular partition the **diaphragm** seperates the chest cavity containing the heart and lungs from the abdominal cavity and is of great importance in inspiration.

8. Respiration is only by lungs. Larynx is provided with vocal cords.

9. Heart is four chambered (two auricles) and two ventricles. Only the left aortic arch persists; red blood cells are circular biconcave without nucleus except in Camelidae.

10. Urinary bladder is present for excretion of urine.

11. The brain is highly developed. The cerebrum and the cerebellum are large and complex. There is a high degree of coordination in alll activities including the power of learning and memory. Cranial nerves are 12 pairs.

12. Testis desend in majority into scroctal sacs in the adult. Small ovaries with eggs graafian follicles.

13. The male has a copulatory organ called penis.

14. Fertilization is internal. Eggs are usually small without shells. The females have uterus for development (viviparous). Embryonic membranes are present.

22.4 CLASSIFICATION

The living mammals are divided into two sub classes: Prototheria and Theria

22.4.1 Sub Class : Prototheria

Prototheria is represented by the primitive mammals comprising the order monotremata. Examples *Ornithorhynchus* (Duck-billled platypus) and *Tachyglossus* (Echidna or spiny Ant eater (Fig. 22.1 AB)

Characters

1. They posses temporary pouches in which the young ones are hatched into which they are transfered after hatching.

2. The body is small and is covered with hairs. In Ornithorhynchus, fur is soft. In Tachyglossus along with hair, short but sharp spines are presents.

3. External ear or pinna absent. The inner ear is primitive.

4. Calcified teeth are found. They are very brittle and degenerate. Later on they are shed and replaced by horny plates.

5. Mammary glands are without nipples and are modified sudorific glands.

6. Fore legs are short but powerful. Hind limbs are less specialised.

7. Skull dicondylic.

8. Malleus, incus are well developed. Ribs are not double headed.

9. 'T' Shaped interclavicle and epipubic bones are present as in reptiles. Stomach is globular. Intestine is distinguished into small and large intestine. Lungs are small in size as compared to the body size.

10. Heart is four chambered. Single left aortic arch is present.

11. Kidneys are metanephric, ureters open into urinogential sinus and urine is passesd into the cloaca.

12. Testes are attached to the kidneys and are abdominal.

13. Right ovary is less developed or is some what reduced.

14. Oviparous. egg laying without uterine gestation. Postnatal care of young ones is not found.

Example: *Ornithorhynchus, Tachyglossus* (Fig 22.1 A&B).

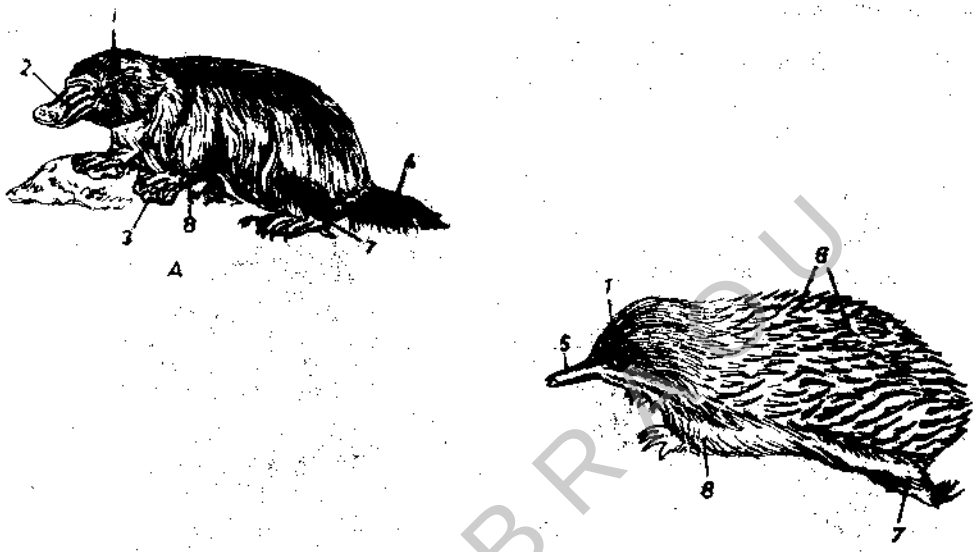


Fig. 22.1 Prototheria A. Ornithorhynchus B. Tachyglossus. 1. Eye 2. Ducklike beak 3. Webbed foot 4. Tail 5. Muzzle long beak like 6. Spines 7. Hind limb 8. Fore limb..

22.4.2 Sub class: Theria

Modern mammals are included in the subclass Theria. This group is split into two infra-classes as: (i) **Metatheria** (ii) **Eutheria**

22.4.2.1 Infra Class: Metatheria

1. Oldest placental mammals. A pouch, the **marsupium**, is on the belly of female into which new born young one is kept and nourished.

2. Hind limbs larger than the fore limbs and are well developed.

3. Metatheria has only one order i.e., **Marsupalia**.

4. The brain case is small, orbit and temporal fossa confluent.

5. Inter clavicle is absent,while clavicle is large.

6. Coracoid is reduced and scapula is enlarged and provided with a spine.
7. Epipubic bones are present in pelvic girdle.
8. The heart possesses membranous auriculo-ventricular valve.
9. The brain is less developed and small.Corpus callosum is absent.
10. Testes are situated in scrotum, in front of the penis and are extra abdominal.
11. Two oviducts remain separate throughout their length and there is a pair of vagina and uteri.
12. Viviparous condition.The young are born imperfectly developed.
13. In some animals a true allantoic placenta with nutritive function formed.
14. Gestation period varies from animal to animal.
15. New born young ones crawl in to the pouch where they become attached to the nipples or teats for sufficiently long time.

Examples:- *Didelphys* (Opossum) *Macropus* (Kangaroo)

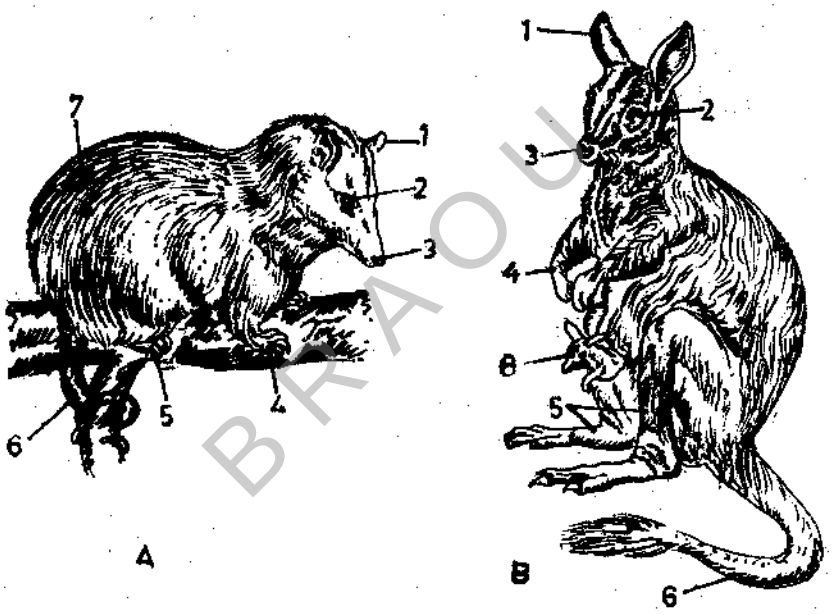


Fig.22.2. Some Metatherians: A. Didelphys.B. Mecropus1.Eye.2. Nostril 3. Fore limb 4. Hind limb 5. Tail 6. Soft fur coat 7. Young one.

22.4.2.2 Infra class : Eutheria

1. Young ones are nourished with in the uterus for a considerable time.
2. Allantoic placenta is formed. There is no marsupium.
3. Epipubic bones are absent.
4. Tympanic bone is either ring like or in the form of a bulla.

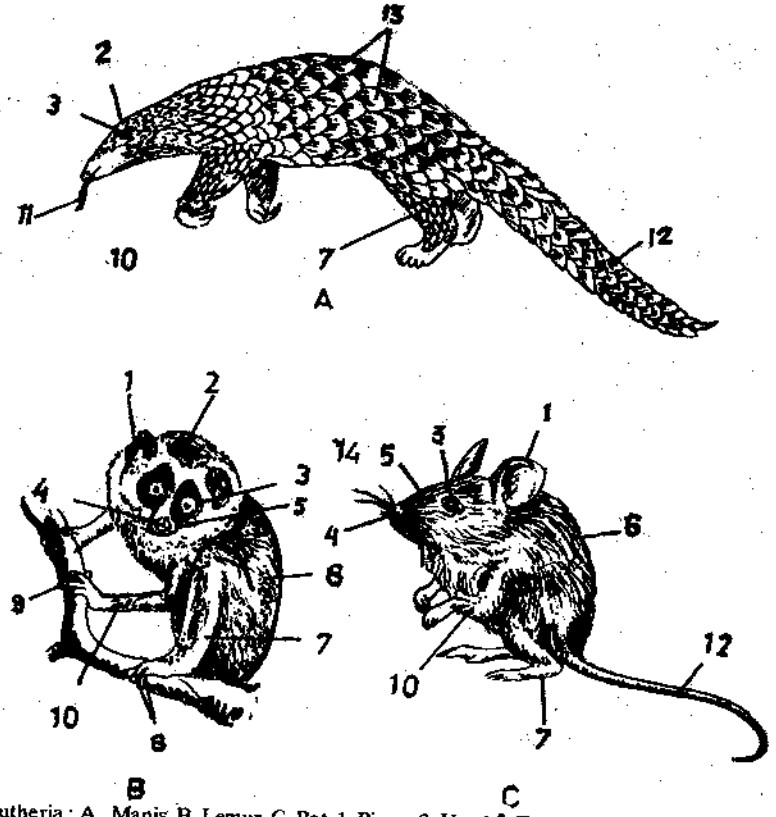


Fig 22.3 Eutheria : A. Manis B. Lemur C. Rat 1. Pinna 2. Head 3. Eye 4. Nostril 5. Snout 6. Trunk 7. Hind limb 8. Digits 9. Nail 10. Fore limb 11. Tongue 12. Tail 13. scales 14. Whiskers

5. Brain is well highly developed, large cerebral hemispheres which are connected by the Corpus callosum.

6. Usually the number of the incisors, canines, premolars and molars in half of each jaw is expressed as dental formula $\frac{3143}{3143}$

7. Uterus becomes a single structure

8. Urinary ducts reach the bladder by passing outside the genital ducts.

9. Cloaca is almost absent and a common sphincter, if present it is only a remnant.

Example:- *Manis, Lemur, Rat* (Fig.22.3 A-C).

22.5 SUMMARY

Mammals are warm blooded, hairy quadreepedes. It is a large heterogeneous group showing adaptations to different habitats. The members of this group are unique in possessing hair, nails, glandular skin, milk, glands to nourish the young, intrauterine development, thecodont and heterodont type of dentition, a muscular diaphragm, well developed larynx with vocal cords, nucleated RBCs, right ariculo-ventricular opening with the tricuspid valve, descended testes and a pendant penis are some other diagnostic features of the mammals.

The class Mammalia is divided into subclasses Prototheria and Theria. The lattter once again divided into 2 infra classes viz., (i)Metatheria (ii) Eutheria. Kangaroo and opposum possess a brood pouch (Marsupialia) while the horse, lion, dog cattle, rat and man are included in the Eutheria.

22.6 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Discuss the general characters of mammals.
2. Classify mammals and mention the characters of Prototheria.

II. Answer the following in about 10 lines:

1. What are Eutherians?
2. Give a brief account of Metatheria.

Unit – 23 RABBIT - EXTERNAL FEATURES

Contents

23.1 OBJECTIVE

- To know the external morphology of rabit *Oryetolagus cuniculus* about the skin and its functions.

23.2 INTRODUCTION

Rabbit can be handled and domesticated easily. Therefore it is used as a laboratory animal to conduct experiments particularly concerning to human physiological aspects. Knowledge on its morphology and anatomy throws light on all aspects of mammalian biology.

23.3 HABITAT

The rabbit is a very widely distributed animal. It is usually found in nature in various fields, grass lands and open wood lands. It leads a fossorial life i.e., digs burrows in the ground. The parental care is shown by female rabbit. It is a fast runner and covers 32 to 40 km in an hour. It is herbivorous and feeding on grasses and a large variety of plants. It is polygamous, one male lives in the company of many females. The rabbit is useful to man as game animal and harmful as it destroys crops.

23.4 MORPHOLOGY

The rabbit is a bilaterally symmetrical animal, can be divided into two equal parts. The body is covered by a hairy coat which keeps the body temperature constant at about 388°C. Thus the rabbit is warm blooded or **homeothermal** animal. The hair posses pigments which are responsible for imparting colour to the animal.

The rabbits are of different colours. The domestic varietites are commonly white and black.

The body of the rabbit is like that of a typical mammalian form and consists of **head, neck, trunk and tail.** The trunk is further subdivided into **thorax** and **abdomen.** There are two paris of limbs i.e. fore and hind limbs. Head is large and extends anteriorly into a blunt snout. The snout is made up of upper and lower jaws. It has a mouth at its lower and anterior end. The mouth is transverse slit and is bounded by two movable lips. From the upper tip of the snout tactile hairs, vibrissae or whiskers project out wards. These hairs are long stiff and tactile or sensory in function. On the sides of head are situated a pair of prominent eyes. Each eye has an upper and a lower eye lid with a small **nictitating membrane** which is movable. On the top of the head is a pair of large movable trumpet shaped external ears called pinnae.

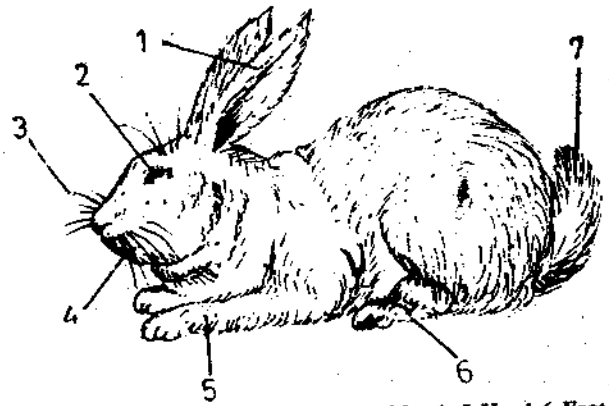


Fig.23.1 Rabbit. 1. Pinna. 2. Eye. 3. Vibrissae. 4. Mouth. 5. Hand. 6. Foot. 7. Tail.

Neck is a short extension of the body between the head and the trunk. The trunk is divided into two parts (1) an antorior thorax which is protected by ribs and sternum and (2) a posterior soft part abdomen. On the ventral side between the thorax and abdomen are situated four or five pairs of teats or nipples or mammae on which mammary glands open out. Teats are also found in males but they are vestigeal i.e., nonfunctional.

At the posterior end of the trunk is situated anus, which is the external opening of alimentary canal. In front of the anus lies a urinogenital aperture which in the male is situated at the tip of the skin covered male genital organ penis while in the female it is situated within a slit known as vulva.

23.5 LIMBS

There are two pairs of pentadactyl limbs in rabbit. The fore limbs are shorter than the hind limbs. Each fore limb is divided into upper arm or **brachium**, the fore arm or **antebrachium** and the hand or manus consisting of wrist or carpus, palm or metacarpus and five fingers or digits. Fore limbs are used for digging.

Hind limbs are much longer and more powerful than fore limbs. Each hind limb consists of proximal **thigh**, the middle **shank** or **crus** and a **distal foot or pes.**

The type of locomotion found in the rabbit is **digitigrade**, i.e. it runs on digits.

Tail lies at the end of the trunk which is every short. The tail is usually turned upwards.

23.6 STRUCTURE OF SKIN

Rabbit is a warm blooded animal. Therefore the skin is modified for regulating the body temperature. In rabbit **sweat** or **sudoriferous** glands are found which secrete sweat on the surface of the skin for regulation of body temperature. The skin of rabbit consists of two parts an outer ectodermal epidermis and an inner mesodermis.

23.6.1 Epidermis

It is made up of epithelial cells arranged in several layers. The outer layer is made up of flat cells and is called **stratum corneum**. This layer is completely **karatinised** i.e., made up of keratin and consists of dead cells and also another layer called **stratum lucidium** is situated below that. The inner layer of the epidermis is **stratum granulosum** which consists of a layer of granular cells. The inner most layer is called **stratum malphigii** or **stratum germinativum.** The cells in this layer contain protoplasm and give rise to new cells on their outer side. As the new cells are formed, older cells are pushed up and at the same time they become gradually flattened and their protoplasm is converted into horny substance called, the keratin. The pigment cells are **chromatophores** or **melanophores** which are found in the basal layer or epidermis and are branched cells with long processes. The colour of the skin is due to the pigments.

The Claws at the ends of the digits are the horny epidermal derivatives.

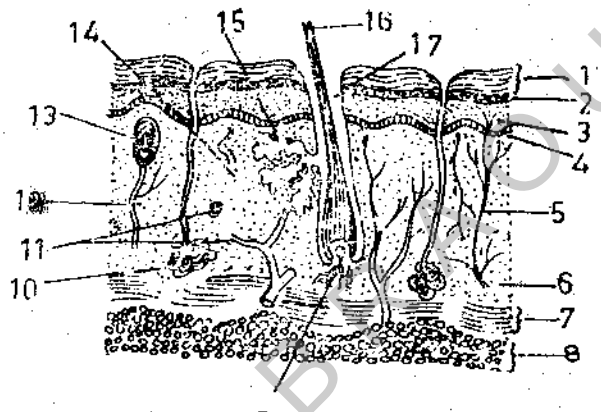


Fig.23.2 Rabbit-Vertical section of the skin. 1. Stratum corneum. 2. Stratum lucidum. 3. Stratum granulosum. 4. Stratum malpighi 5. Nerve fibre. 6. Dermis. 7. Muscles. 8. Fat cells. 9. Hair papilla. 10. Sweat gland. 11. Blood vessels 12. Connective tissue. 13. Tactile corpuscle. 14. Arrector pili. 15. Sebaceous gland. 16. Hair shaft. 17. Hair follicle.

23.6.2 Dermis

It is a layer situated below the epidermis and makes a tough flexible and elastic cover over the whole of the body. Dermis consists of **connective tissue fibres, unstriped muscles, blood capillaries, nerves** and **flat cells.** Dermis also contains, lymph vessels and small finger like projections into the epidermis, which possess loops of blood capillaries and tactile corpuscles having nerve endings. The deeper part consists of subdermal, adipose tissue, which consists of groups of fat cells, serving as a heat insulating layer.

23.6.3 Hair

Hair is epidermal structure, which develop as a thickening of **stratum germinativum.** Hair is enclosed by a tube like invagination of the epidermis formed by **stratum malphigii.** It is called **hair follicle.** Situated at the base of each hair follicle is dermal tissue which forms a

small protruberence called the **hair papilla** which is rich in nerves and blood vessels. The shaft of the hair is covered by a cuticle. On the whole it is distinguished into two parts. The basal part lying in the dermis is called root, and the upper traversing the dermis and projecting from the epidermis is called **shaft.**

23.6.4 Glands

There are two types of glands in the skin called sebaceous and sweat or sudorifous glands.

Sebaceous glands : This gland is also called as saccular gland which consists of small branching or alveolar sac opening by the out pushings of the wall of hair follicle. The function of sebaceous gland is to produce an oily secretion, the **sebum** for keeping the hair and skin water proof and greasy.

Sweat glands : These are thin long tubes formed as tubular invaginations of the stratum germinativum. Each gland opens with the help of a duct on the surface of the skin. The duct passes upwards through the dermis and epidermis and its opening is in the form of a minute pore. The cells of the gland are large and columnar, while those of the ducts are epithelial. The cells of the sweat glands separate sweat from the blood; this is conducted along the ducts and passed out side onto the general surface of the skin.

Sweat glands are responsible for removing the metabolic waste of the body, in the form of sweat consisting of inorganic salts and excretory products dissolved in water. Sweat glands also serve to regulate the body temperature by evaporating the sweat. Thus by taking up its latent heat of vapourisation, they extract heat from the body and reduce the temperature.

Other Glands : Mammary glands are modifications of sebaceous glands and consist of branching system of tubes and alveoli. These are found in thoracic and abdominal regions. In female they produce the milk which discharges out by ducts onto the teats. The milk nourishes the young. There are other glands situated under the skin called perennial glands between the genital orfice and the anus. Meibomian glands are found on the margins of the eyelids situated just inside the eye lashes.

23.6.5 Functions of the Skin

The skin is a complex structure having a variety of functions.

1. The skin serves to maintain a definite shape of the animal.
2. It is an important protective organ as it protects from the mechanical injuries due to friction and blows.
3. Skin is a germ proof membrane covering the entire body.
4. Skin is closely woven texture therefore it is pliable and can withstand under mechanical pressure rather than to rupture.
5. The dermis of the skin produce, membrane bones, which give strength to various parts of the skull.
6. It also gives rise to claws, horns, hooves, nails which serve as useful tools.
7. It also absorbs materials as oil and ointment.
8. It also helps physical and physiological regulation of the temperature of the body.

9. With the help of sweat glands which are present in the skin, the extra amount of the heat produced after muscular activity is lost by evaporation of sweat produced by sweat glands. In this way the skin helps to maintain the body temperature constantly within a limited range.

10. Skin also acts as an organ of storage as large amounts of fat are stored in the form of subdermal fat in the skin.

11. Mammary glands produce milk, sebaceous glands secrete an oily substance called sebum which is responsible for water proofing the hair and skin. The glands are derived from the skin.

12. Skin serves as nourishing, as it is capable of forming Vitamin D in the presence of sun light.

13. Skin helps in sexual selection. Colour of the skin and various other integumental structures serve to attract opposite sex.

23.7 SUMMARY

Rabbit is a hairy quadrupede feeding on grass and other plant material, warm blooded (38.8°C) and polygamous. On the Ventral side4 or 5 pairs of mammae are present It exhibits plantigrade locomotion i.e., touching the ground]. Skin is glandular. Epidermis is stratified as in other vertebrates. Stratum corneum is keratinised and hence contain dead cells whil the cells of the stratum germinativum are living and actively dividing. Sebaceous or saccula glands secrete sebum while the sudoriferous glands excrete inorganic salts etc., in the form of sweat. mammary glands are the modified sweat glands. Skin serves in many ways as a protective, sensory, excretory, locomotory (bats etc.) and defensive (as claws, nails). Besides producing bones and teeth, vitamin D in the presence of sun light (U.Vlight), it also helps in sexual selection.

23.8 MODEL EXAMINATION QUESTIONS

I. **Answer the following in about 30 lines.**

1. Describe the external characters of rabbit.

2. Give an account of mammalian skin.

II. **Answer the following in about 10 lines.**

1. What are the important functions of mammalian skin?

2. Hair

3. Sweat glands

4. Sebaceous glands

5. Mammary glands.

Unit – 24 SKELETON OF RABBIT

Contents

24.1 OBJECTIVE

- To explain the structure of axial and appendicular skeleton of rabbit.

24.2 INTRODUCTION

Skeleton of rabbit like that of any other vertebrate consists of the **axial skeleton** and the **appendicular skeleton.** The axial skeleton consists of skull and vertebral column, while the appendicular skeleton consists of limbs and limb girdles.

24.3 SKULL

The Skull of rabbit consists of a **cranium** (or brain case), **auditory, olfactory capsules, orbits,** and the **hyrid apratus** and the **jaws.** The skull elongated. Its length is greater than the width. The structure of the bones is prominent. The cranium which lodges brain in it has a posterior opening called the **foramen magnum** through which runs the spinal cord. The four bones surrounding the foramen mangum constitute the occipital region of the cranium. They are, 1) **basi occipital,** a flat bone lying at the base and bearing two prominent occipital condyles, 2) the two lateral **exoccipitals** which also contributed to the occipital condyles. Each exoecipital is produced below into a process called paraoccipital, which is closely applied to the auditory region. 3) the **supra occipital** is a single large bone laying on the dorsal side, whose external surface is directed backwards and upwards and elevated in the middle into shield shaped prominence.

All these four bones of occipital region are united in the adult rabbit to form a single ring of occipital bone.

The roof of cranium, i.e. the dorsal part of the brain case, is formed by a pair of **parietal bones** which lie anterior to the supra occipital and a pair of frontal bones lying anterior to the parietals. The parietals are plate like bones, convex externally and concave internally.

The two parietal bones i.e. the right and left bones, articulate with each other by some what wavy **sagittal suture,** the parietals articulate with the supra occipital by a transverse serrate lambdoidal suture. Anteriorly they are connected to the frontals by a **coronal suture. Between** the supra occipital and the parietal is a median ossification known as the **inter parietal.**

The frontals are united in the middle by **frontal suture.** These are membrane bones forming the roof and also the sides of cranium anteriorly. Each frontal has a prominent crescent shaped ridge,called the **supra orbital process** which projects over the orbit.

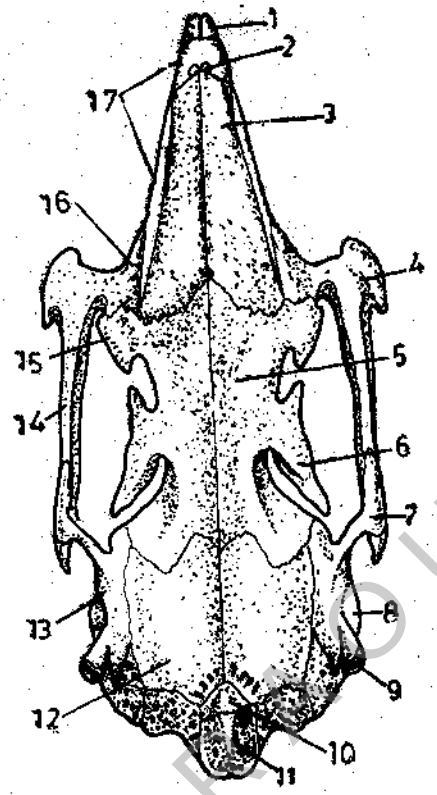


Fig.24.1. A. Rabbit-Skull (Dorsal view). 1.Incisor tooth. 2. Anterior nares. 3. Nasal . 4. Zygomatic process of maxilla 5. Frontal 6. Posterior supra-orbital process of frontal 7. Zygomatic process of squamosal. 8. Tympanic bulla. 9. External auditory meatus 10. Inter parietal 11. Supra occipital 12. Parietal. 13. Squamosal. 14. Jugal.

The base of the cranium is formed by the **basisphenoid** and **presphenoid** bones. Basisphenoid is a horizontal plate forming the middle part of the floor of cranium infront of the basioccipital but separated from it by a cartilage. In the middle of this plate towards the upper side there is a depression called **sella turcica** which lodges in it a vital endocrine gland, **the pituitary.** Just below this depression there is a foramen called the **pituitary foramen.** Anterior to the basisphenoid is the preshenoid which is a laterally compressed bone.

The anterior part of the cranium is completed by an **ethmoid** bone the cribriform plate cartilage bone which contains numerous perforations for the passage of olfactory nerves. The sides of cranium are formed by the **alisphenoids** behind and the **orbitosphenoids** in front. Alisphenoids are broad winglike bones, each produces a bilaminate process, the **pterygoid process.** It is connected laterally to the basisphenoid and presphenoid on its ventral margin, but on the dorsal side it is separated from parietals by **squamosals.**

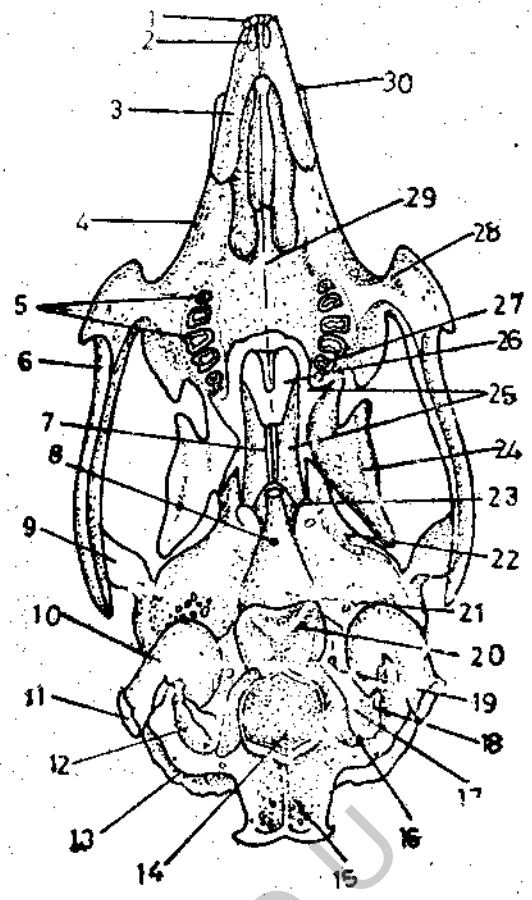


Fig.24.1.B. Rabbit-Skull (Ventral view) 1. Incisor tooth (I) 2. Incisor tooth (II). 3. Premaxilla 4. Maxilla 5. Premolars. 6. Jugal. 7. Pre-sphenoid. 8. Pituitary foramen. 9. Zygomatic process of squamosal 10. Tympanic bulla 11. External auditory meatus 12. Para occipital process of exoccipital 13. Mastoid process 14. Formen magnum 15. Supra-occipital 16. Occipital condyle. 17. Periotic. 18. Exoccipital. 19. Eustachian canal. 20. Basioccipital. 21. Basisphenoid. 22.Alisphenoid. 23. Pterygoid. 24. Supra orbital ridge of Frontal. 25. Palatine. 26. Vomer 27. Molars. 28. Zygomatic process of maxilla 29. Palatine plate of maxilla 30. Nasal.

Orbitosphenoids are a pair of cartilage bones extending outwards and backwards, forming the sides of the cranium in the region of orbits.

Squamosals which infact belong to the upper jaw bones, complete the posteior dorso-lateral portions of the cranium and lie in between alisphenoids, orbitoshenoids. frontals and parietals. From the outer surface of the squamosal is given off a process called the **zygomatic process,** which curves outwards, then downwards and finally forwards to meet the **jugal bone** of the upper jaw to form the **zygomatic arch.** Posteriorly the squamosal gives off a post **tympanic process.**

The auditory capsules are interposed loosely between the squamosals and the ex-occipitals of each side. Connected with each auditory capsule are the **tympanic** and the **pariotic bones.** Tympanic forms the bony part of the wall of the external auditory meatus. It is more or less a flask shaped structure, the lower swollen portion is called the **tympanic bulla,** and encloses the auditory (or ear) ossicles the **malleus,** and **stapes.**

The **periotic bone** is an irregular bone formed by the fusion of three bones, the **prootic,** the **epiotic** and the **episthotic.** It is divisible into two portions the stony petrous and the pours **mastoid** portions. The petrous portion is the internal portion. It encloses the membranous

labyrinth. Externally it presents two small openings, the **fenestra ovalis** and **fenestra rotunda** visible only when the tympanic is removed. The mastoid portion of the periotic is visible on the surface of the skull between the tympanic and exoccipital.

Between the tympanic and periotic bones there are two apertures, one the stylomastoid 7th cranial nerve and the **eustachian aperture,** gives rise to form eustachian tube.

The **olfactory capsules,** which lie anterior to the brain case contain two bones, the **nasals** which form the roof of olfactory cavities. They are flat bones, extending from the anterior margin of frontals to the tip of external nares. The olfactory cavity is divided into two by a median vertical plate of bone called the **mesethmoid,** which lies in front of dribriform plate. Inside each nasal cavity is a scroll like bone, the **ethmo- turbinals** which are fused to the mesethmoid. The **vomer** is a long median bone having lateral wings. It is attached to the inferior margins of mesethmoid.

The **orbits** are the pits formed in between the bones of cranium, auditory capsule, the olfactory capsule and the upper jaw bones. The only circum orbital bone is the **lacrymal** which lies in front of the orbit and connects the frontal with **maxilla** of upper jaw. It contains a small aperture called the lacrymal foramen. The upper jaw is made up of **premaxilla, maxilla, palatine, pterygod, jugal** and **squamosal.**

Premaxillae are the two large median bones forming the snout. They bear the upper incisor teeth. Each premaxilla gives off three processes, the nasal process which runs backwards upto frontals along the nasal bones. The palatine process which runs backwards along the palate. The palatine processes of the two sides meet in the middle and form the floor of the nasal passages. The maxillary process runs along the maxilla.

Maxillae form the greater part of the upper jaw. They bear premolar and molar teeth. Maxillae like premaxillae give off palatine processes which meet in the centre, there by forming the hard portion of the palate. From the outer side of each maxilla arises the **zygomatic arch,** which meets the squamosal posteriorly. The zygomatic arch forms the anterior and outer boundary of the orbit.

Palatines are a pair of thin vertical plates of bone lying internal to the maxillae to which they are attached anteriorly. They articulate posteriorly with **pterygoids** and above with **presphenoid.** They surround the posterior nostrils completely.

Pterygoids are a pair of narrow vertical plates of bone attached posteriorly to the base of the cranium, the pterygoid process of the alisphenoid and anteriorly to palatines.

Jugals or **malars** are a pair of laterally compressed bones extending between the zygomatic process of the maxilla and that of the squamosal.

The lower jaw (Fig.24.2) consists of two lateral halves joined by symphysis in the middle line Each half is made of a single bone, the **dentary** and contains a horizontal portion in the anterior bearing teeth and posterior vertical, ascending portion, which bears the condyle for articulation with the glenoid fossa of squamosals. In front of the condyle is the compressed **coronoid process** An angular process is given off at the junction of the vertical and horizontal portions of the jaw. Both the lower and upper jawposses sockets for the teeth.

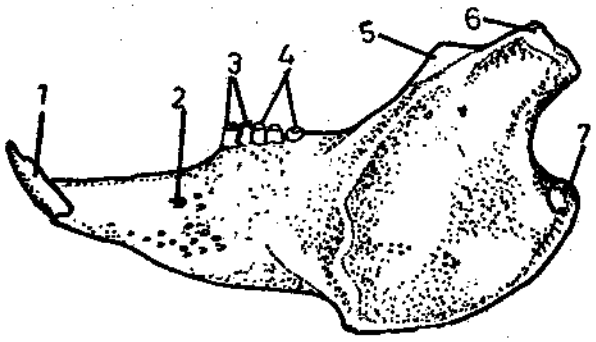


Fig.24.2. Rabbit-Lower jaw. 1. Incisor tooth. 2. Inferior dental foramen.
3. Premolar. 4. Molar 5. Coronoid process. 6. Condyle 7. Angular process.

24.4 VERTEBRAL COLUMN

The vertebral column consists of about 45-46 vertebrae.

The spinal column of the rabbit is divisible into five regions. The cervical, thoracic, lumbar, sacral and caudal. Third lumbar vertebra is taken as **typical vertebra.** It consists of :

i) **a centrum,** which is flat at the anterior and posterior surfaces. The centrum in the embryonic condition contains a central piece, an anterior and posterior thin bones called **epiphyses.** These bones fuse with the centrum in adult condition.

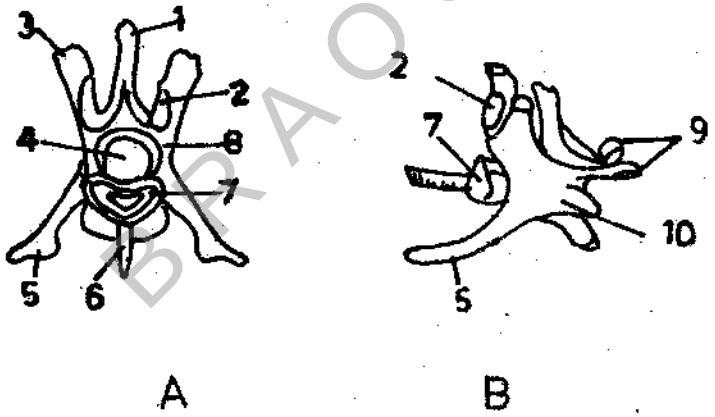


Fig.24.3. Rabbit-Vertebra: A. Anterior Lumbar (Anterior view). B.Posterior Lumbar (lateral view)
1. Neural spine. 2. Prezygapophysis. 3. Metapophysis. 4. Neural canal. 5. Transverse process.
6. Hypapophysis. 7. Centrum. 8. Neural arch 9. Post zygapophysis 10. Anapophysis.

ii) **neural arch** over the centrum encloses a neural canal for the passage of spinalcord (Fig.24.3). It has at its base, in front and behind, a pair of notches called the **intervertebral notches,** which leave passage of openings between the successive vertebrae for the passage of spinal nerves.

iii) **a median dorsal process** which is called the **spinous process,** Neural spine is borne on the apex of the neural arch.

iv) **transverse processes,** which arise from the dorsolateral ends of the centrum and are directed out wards and down wards.

v) a pair of **anterior zygapophyses**, a pair of **posterior zygapophyses**, certain accessory processes, the **metapophyses** and **anapophyses** are also present. Metapophyses lie above the anterior zygapophyses and project upwards and forwards. Anapophyses present at the base of posterior zygapophyses are directed backwards.

Cervical vertebrae

There are seven cervical vertebrae (Almost all the mammals including the long necked Giraffee contain only 7 cervical vertebrae). The cervical vertebrae are characterized by the shortness of centrum, small size of the neural spine, and the presence of **vertebrarterial** foramen at the base of the transverse processes of the first six vertebrae. The first two cervical vertebrae are specialized as atlas and axis.

Atlas, the first cervical vertebra is a ring like structure with very much reduced centrum, reduced neural spine and wing like transverse processes (Fig 24.4). It bears on its anterior face two lateral concave surfaces for the articulation of two occipital condyles.

The second vertebra, the **axis**, bears on its anterior face of the centrum, a peg like process the **odontoid process**, which fits into the ventral part of the ring of the atlas. It has a spine, which is elongate and laterally compressed. Transverse processes are small, directed backwards and are perforated (Fig.24.5.A.)

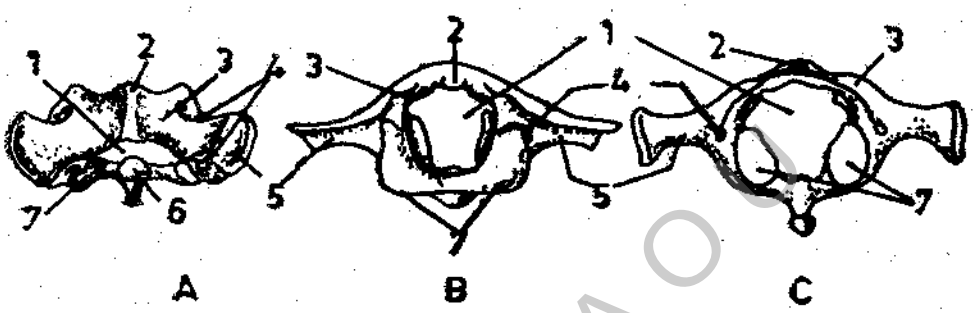


Fig.24.4. Rabbit-Atlas. A. Dorsal view. B. Anterior view. C. Posterior view 1. Neural canal 2. Neural spine 3. Neural arch 4. Vertebrateral canal 5. Transverse process 6. Facet for odontoid process 7. Facets for articualr surfaces on axis.

All the cervical vertebrae, except the last have their transverse processes bifurcated into dorsal and ventral lamellae. The seventh differs from the others in having a more elongated neural spine, in having its transverse processes simple and imperforate, and in the presence of a little concave semilunar facet on the posterior edge of the centrum (Fig. 24.5.B.).

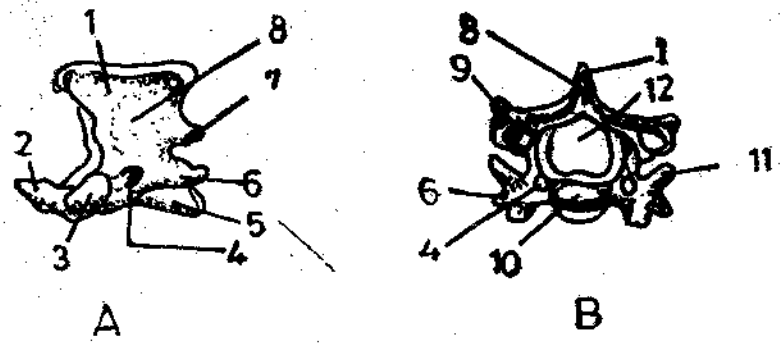


Fig.24.5 Rabbit-Vertebrae A. Axis (Lateral view). B. Typical cervical (Anterior view) 1. Neural spine 2. Odontoid process 3. Articular surface for atlas 4. Vertebrateral canal 5. Centrum. 6. Cervical rib. 7. Post zygapophysis 8. Neural arch 9. Prezygapo physis 10. Epiphyis on centrum 11. Transverse process 12. Neural canal.

Thoracic vertebrae

The thoracic vertebrae are 12 or 13 in number. They have elongated spines which are mostly directed backwards and upwards in the first nine vertebrae (Fig.24.6). The transverse processes are short and stout. Each bears near its extremity a small smooth articular surface, the taberalar facet for the articulation of tuberculum of rib. Pre and post zygapophyses are small but well developed for providing articular surfaces. A small facet born on either sides of the centrum is for the artiulation of the capitulum of rib.

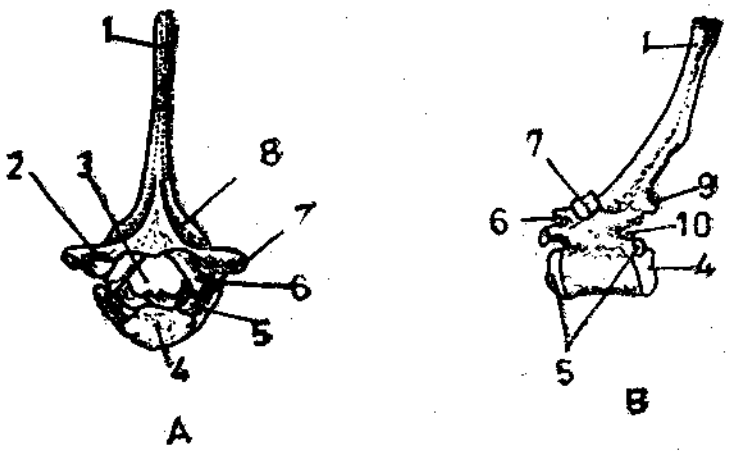


Fig.24.6. Rabbit-Anterior thoracic vertebra. A. Anterior view. B. Lateral view 1. Neural spine 2. Transverse process 3. Neural canal 4. Centrum 5. Demifacets for capitulum of ribs 6. Prezygapophysis 7. Facet for tuberculum of rib 8. Neural arch 9. Post zygapophysis 10. Inter vertebral notch.

Lumber vertebrae are six or seven in number and have typical structure described already.

Sacral vertebrae

The sacral vertebrae are 3-4 in number. They are fused to form **sacrum** (Fig.24.7) which is wedged in between the pelvic arches. The first of the four vertebrae is the largest and its transverse processes are expanded into wing-like structures supporting the pelvis; its neural spine is large. The vertebrae in general resemble those of lumbar region, but anapophyses are absent, and hypapophyses are absent, metapophyses are small. The last two sacral vertebrae resemble the caudal vertebrae.

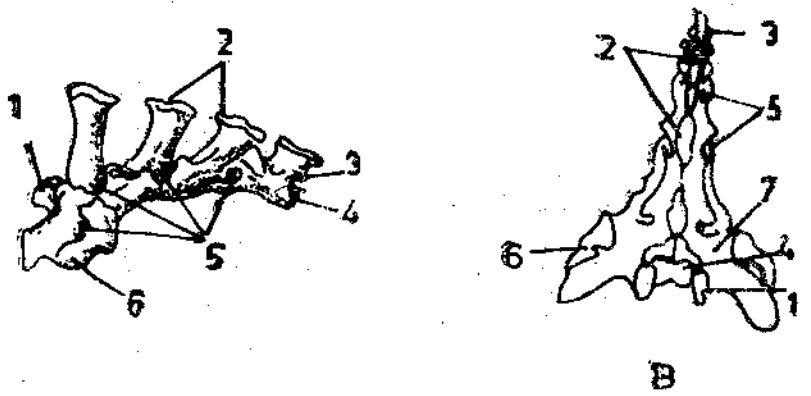


Fig.24.7. Rabbit-Sacrum. A.Lateral view. B. Dorsal view. 1. Pre- zygapophysis 2. Neural spines 3. Post-zygapophysis 4. Centrum 5. Intervertebral foramina 6. Articular facet for illium 7. First sacral vertebra.

Caudal vertebrae

There are fifteen caudal vertebrae. The anterior caudal vertebrae have neural spines much reduced and transverse processes and are similar to those of the sacral vertebrae. There is a gradual reduction in their size posteriorly and the terminal ones consist of only round centra (Fig.24.8). The spinal cord does not project in the tail.

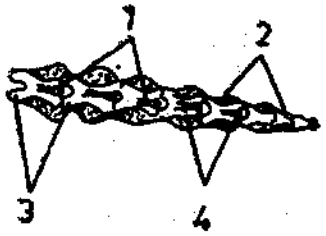


Fig.24.8. Rabbit-Caudal vertebra (Dorsal view). 1. Neural spines 2. vertebrae 3. Prezygapophyses 4. Post zygapophyses.

Ribs

There are twelve or thirteen pairs of ribs, of which the first seven are considered the true ribs. They are connected to sternum. The eighth and ninth are attached to the seventh rib (true ribs), the remaining are free or floating ribs(false ribs). The ribs contain two articular facets on the dorsal side. The ventral **capitulum** articulates with the centrum of vertebrae and the dorsal articular facet, the **tuberculum,** is attached to the transverse process (Fig.24.9).

Fig. 24.9. Rabbit-Rib. 1. Capitulum 2. Tuberculum 3. Vertebral portion of rib 4. sternal portion of rib.

24.6 STERNUM

Sternum consists of seven segments of strenebrae lying in the mid ventral body wall. It is formed by the fused ventral edges of the ribs. The first piece, the **manubrium** or **presternum** bears a keel on the ventral edge. Second to fifth are much alike, but the sixth is small. The last segment is called the **xiphisternum** and extends beyond the attachment of the ribs and bears a cartilage, the **xiphod cartilage.**

Appendicular Skeleton

The skeleton of limbs and their girdles constitute the appendicular skeleton.

24.7 PECTORAL GIRDLE

Pectoral girdle lies outside the ribs and is attached to the axial skeleton by muscles and ligaments. It consists of a broad, thin, triangular **scapula** (Fig.24.10). The base of the scapula or the vertebral edge of the scapula consists of a cartilage, the spura scapula, which is continuous with it. Along the dorsal surface of the scapula runs a ridge, the **spine** which

ends below in an **acromian process.** From this a posterior process the metacromian is given off. At the narrower end of the scapula is the **glenoid cavity** into which fits the head of humerus. Immediately in front of this is a small inwardly curved process, the **coracoid process.** This process is very much reduced in mammals. A slender rod. the **clavicle,** lies obliquely in the region between the **presternum** and the **acromion process. Clavicle** is a membrance bone, which is connected to the scapula and sternum with the fibrous tissue.

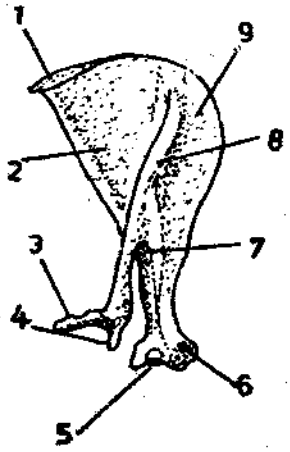


Fig. 24.10. Rabbit-Right pectoral girdle. 1.Supra scapula 2. Glenoid border 3. Metacromian process 4. Acromian process 5. Glenoid cavity 6.Coracoid process 7. Coracoid border 8. Spine 9. Scapula.

24.8 FORE LIMB

The skeleton of fore limb(Fig.24.11) comprises the following bones:

Humerus (Upper arm)

Radius and ulna(Forearm)

9 carpals(Wrist)

5 metacarpals (Palm) and

3 phalanges in each of the digits except the pollex which is with two only (2,3,3,3,3).

Humerus : At its proximal end the humerus consists of a rounded **head** for the articulation with the glenoid cavity of the pectoral girdle, with two prominences, the lesser and the greater tuberosities for the insertion of muscles. A groove, the **bicipital groove,** occurs between the two tuberositites. In continuation with the lesser tuberosity, there is a **deltoid** eridge. At the distal end is a pulley like trochlea, over which lies a **supra trochlear foramen.**

The **radius** and **ulna** constituting the forearm skeleton are firmly fixed together so as to be incapable of movement but are not actually fused. Radius is shorter than ulna. The radius articulates proximally with the humerus, distally with the carpal bones. The ulna presents on its proximal end a deep fossa, the greater **sigmoid cavity** for fixing of the trochlea of the humerus. The prominent process on the proximal side of this is the **olecranon process.** Distally it articulates with the carpal bones.

The carpals of the wrist are arranged in three rows, the first row consists of three pieces, namely **scaphoid (Radiale), lunar (Intermedium),** and cuneiform (**ulnare**). The distal carpals

are four **trapezium, trapezoid, magnum and unciform.** The eighth piece **central** is located in between the two rows.

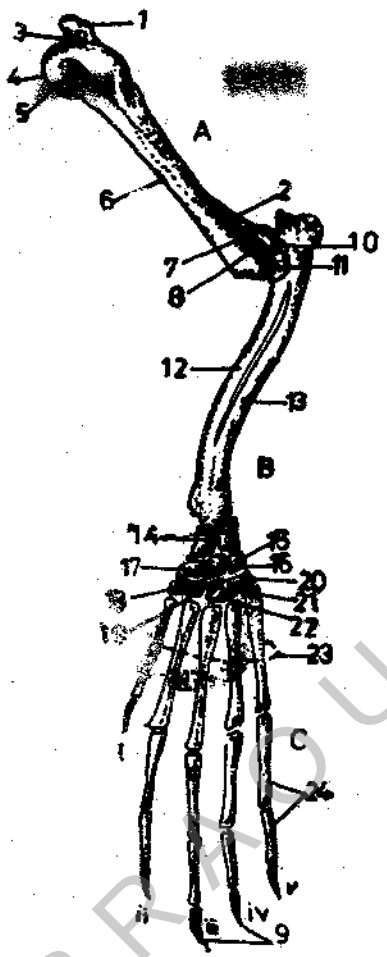


Fig.24.11. Rabbit-Fore limb A. Humerus B. Radius-ulna C. Bones of the hand 1.Lesser tuberosity 2. Coronoid fossa 3. Bicipital groove 4. Head 5. Greater tuberosity 6. Shaft 7. Supra trochlear foramen 8. Trochlea 9. Claws 10. Olecranon process 11. Sigmoid notch 12. Radius 13. Ulna 14. Epiphysis 15. Ulnare 16. Inter-medium 17. Radiate 18. Trapezium 19. Trapezoid 20. Unciform 21.Centrale 22. Magnum 23. Metacarpals 24. Phalanges.

The five **metacarpals** are all small but relatively narrow and elongated bones. The first metacarpal is smaller than the rest. The five digits contain 3 phalanges each except pollex which contain only 2. The distal digits are grooved for the attachment of horny claws.

24.9 PELVIC GIRDLE

The pelvic girdle consists of two halves, each made up of three bones, **Ilium, ischium** and **pubis** (Fig.24.12). The two halves unite ventrally in the middle in a symphysis. The three bones are separate in young condition, but in adult rabbits they are fused together to form **os innominatum.** Acetabular cavity is on the outer side of the **os innominatum.** The ischium and ilium meet in the acetabulum. A small intercalated bone the **cotyloid** bone is present between pubis and acetabulum. Ilium is dorsal in position and lies in front of accetabulum. It has wing like expansion anteriorly; on the inner, of which is a rough surface for the articulation of transverse process of the first sacral vertebra. The pubis and ischium meet at their ventral ends leaving a large aperture in between. This aperture is called the obturator foramen. The pubes of opposite sides unite ventrally in a symphysis.

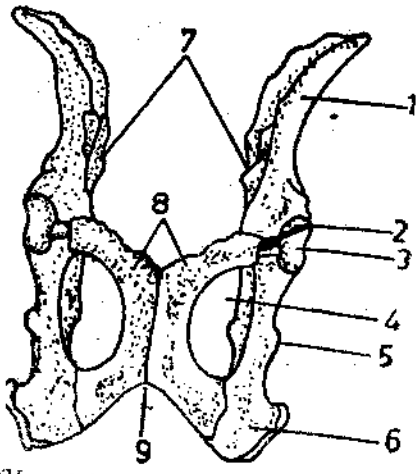


Fig. 24.12. Rabbit-Pelvic girdle (Ventral view). 1. Ilium 2. Cotyloid bone 3. Acetabulum 4. Obturator foramen 5. Ischium 6. Ischial tuberosity 7. Articular surfaces for sacrum 8. Pubes 9. Pubic symphysis.

24.10 HIND LIMB

The hind limb bones are, **Femur** (Thigh), **Tibia** and **fibula** (Shank), **Tarsus** (Ankle), **Metatarsals** (Foot), **Phalanges** (Toes) (Fig. 24.13).

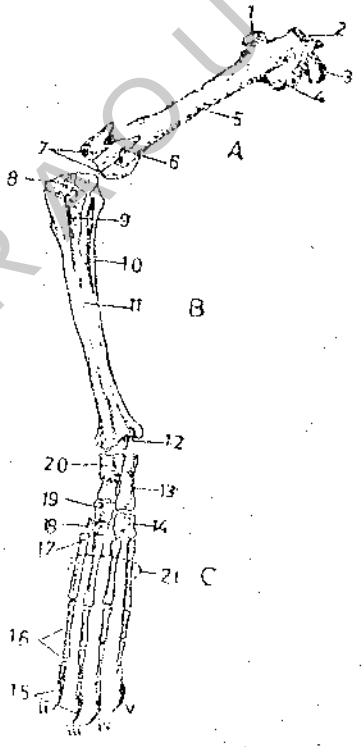


Fig.24.13. Rabbit-Hind limb. A.Femur B. Tibio-fibula. C. Bones of foot 1. Third trochanter 2. Greater trochanter 3. Head 4. Lesser troshanter 5. Shaft 6. Patellar groove 7. Condyles 8. Proximal epiphyses 9. Cnemical crest 10. Fibula 11. Tibia 12. Distal articular surface for tarsals 13. Fibulare or calcaneum 14. Cuboid 15. Claws 16. Phalanges 17. Extocuneiform 18. Mesocuneiform 19. Centrale or navicular 20. Tibiale or astragalus 21.Metatarsals.

Femur: The head of femur articulates with the acetabulam. External to the head is a prominent process called the **greater trochanter** internally there is a **lesser trochanter** and a third trochanter is situated just below the greater trochanter. The digital end of femur contains two prominences or condyles, with a depression between them (Fig.24.13), the **patellar groove.**

Tibia and fibula : These are fused at their lower (distal) ends and are free above. The tibia is a stout bone bearing, a large ridge called the **cnemial crest.** The proximal end of the tibia has an articular surface for the condyles of femur. The fibula is a thin splint bone lying outside the tibia. Between the femur and the tibia, there is a flat **seasamoid bone** called the knee cap or **patella:** it lies in a depression called the patellar groove at the lower end of femur and is kept in position by tendon extending form tibia. Distally tibia has two articular surface one for **astragalus** and the other for **calcaneum.**

The **tarsus** consists of six bones arranged in two rows. In the proximal rows there are two bones the **astragalus** (tibiale) and the **calcaneum** (fibulare), with a strong calcaneal process that forms the heel. The distal row contains 3 bones, the **mesocuneiform, ectocuneiform** and the **cuboid.** One of the tarsal bones the navicular (middle row) is intercalated between the rows.

There are four metatarsals. The **hallux** or first digit is vestigial and fuses with the second metatarsal of the adult. The proximal end of the second is produced into a process which articulates with navicular. Each of the four digits has four phalanges. Claws present.

All the digits of both the limbs have small nodule like seasamoid bones between the phalanges for additional strength.

24.11 SUMMARY

The skeletal system of mammals distinguishes itself from other vertebrates in some respect. The skull bones are fused and can only be distinguished by the sutures. The dicondylic mammalian skull is characterised by the presence of the zygomatic arch and the thecodont and heterodont dentition; diastema is seen in rabbit. Lower jaw is formed of dentary only. Articular and quadrate have been modified as ear ossicles along with the stapes (hyomandibular) moving into the middle ear. Pterygoid reduced and is scale-like. Vertebral column is characterised by the epiphyses. Cervical vertebrae always 7 in number only. Sacrum contains four fused vertabrae. Typical lumbar vertebra contains metapophyses and anapophyses. Strernum is formed of 7 sternebrae, the last one being the xiphoid cartilage. Pectoral girdle is simplified into a broad scapula with a spine and an obliquely placed clavicle. The pattern of the os innominata and the limb skeleton remained basically the same.

24.12 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines

1. What do you know about axial and appendicualar skeleton of rabbit?
2. Give an account of skull bones in rabbit.
3. Describe the vertebral column of rabbit.

II. Answer the following in about 10 lines.

1. Describe the skeleton of fore or hind limb in rabbit.
2. Describe the structure of lower jaw in rabbit.
3. Describe the pectoral girdle of rabbit.
4. Describe the pelvic girdle of rabbit.
5. Describe the structure of a typical vertebra of rabbit.
6. Cranium
7. Atlas
8. Sacrum
9. Sternum
10. Humerus.

Unit – 25 RABBIT - DIGESTIVE SYSTEM

Contents

25.1 OBJECTIVE

- This lesson describes the digestive organs of the rabbit and the process of digestion.

25.2 INTRODUCTION

For any organism on earth energy is required. Food is the fuel for energy. Food is a mixture of several complex ingredients like carbohydrates, proteins and fats. Cells directly cannot deal with such complex molecules and require processing. Hence digestive organs have evolved in nature. Digestion occurs at two levels : (i) breakdown of much larger complex molecules into some what small, molecules in mouth, in gizzard (ii) further breakdown of thus formed smaller molecules into simple molecules (glucose, aminoacids, fatty acids and glycerol which are better soluble in water) with the help of enzymes.

25.3 DIGESTIVE ORGANS

In rabbit the mouth is relatively small and terminal. It is bounded by the hairy movable upper and lower lips. The upper lip is divided by a cleft in the middle, described as hare

lip. This exposes the front teeth and helps in gnawing the vegetable matter. The buccopharyngeal cavity is separated from the respiratory channel by the development of a horizontal portion called the secondary palate. It consists of an anterior hard palate strengthened by bony processes of jaw bones and a posterior soft palate. The roof of the buccal cavity is formed by the hard palate which has transverse ridges of its mucous membrane, the rugae. Posteriorly the hard palate passes into the soft palate which end behind as a small flap, uvula. Many small mucous glands are located on the palate. At the anterior end of the palate is a pair of openings of the nasopalatine canals. They connect the buccal cavity with the nasal chambers above. The buccal cavity contains some important structures like the tongue, teeth and the openings of salivary glands (Fig.25.1).

25.3.1 Tongue

Along the floor of the buccal cavity is the muscular protrusible tongue. It is attached to the floor along the greater part of its length and is directed forwards. The posterior part of the tongue is hard and is slightly elevated. The upper surface of it is with various types of papillae, which contain taste buds in them. Tongue is an organ of taste, besides it helps in chewing and swallowing the food bolus.

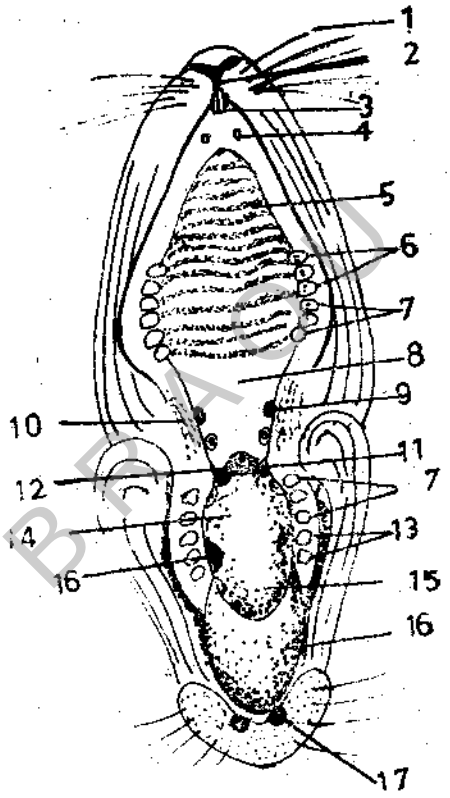


Fig.25.1. Rabbit-Buccal cavity (wide open). 1.Vibrissae 2. Cleft lip 3. Two anterior and two posterior incisor teeth 4. Nasopalatine openings 5. Hardpalate with rugae 6. Three premolars 7. Three molars 8. Soft palate 9. Eustachian tube opening 10. Lateral wall of pharynx 11. Posterior interior nares 12. Epiglottis 13. Two premolars 14. Hard area 15. Tongue 16. Papillae 17. Incisors.

25.3.2 Teeth

Teeth are present in both jaws. They are thecodont i.e., they are embedded within the sockets or alveoli of the jaw bones. There are two sets of teeth in many mammals life. The milk teeth and the permanent teeth. The milk teeth appear in the first set or milk dentition and

are replaced by the permanent second set of teeth. The teeth of rabbit as in other mammals are thus **diphyodont**. They are also **heterodont**, i.e., they are not all alike but differentiated into four types as **incisors, canines, premolars and molars**.. The incisors also called as cutting teeth, front teeth have sharp cutting edges and are used in gnawing the vegetable matter. Behind the incisors is a toothless region, the **diastema**. In other mammals this region is occupied by pointed teeth, the canines, which are absent in rabbit. The premolars and the molars are the grinding teeth. Molars do not appear in the milk set.

They possess broad crowns on the tops. They are similar in their structure but differ in one respect that the molars are not represented in the milk dentition and appear in the permanent dentition only. The number and variety of the teeth is expressed by a dental formula. The dental formula of rabbit is : i=2/1, c:O/O, pm : 3/2, m : 3/3, = 16+12=28. Human dental formula is C 2/2 i 1/1 pm 2/2 m 3/3 = 16+16=32. The letters i.c, pm and m refer to the incisors, canines, premolars and molars respectively. The figures above and below the lines indicate the number of teeth in one half of the upper and lower jaws. When doubled it gives the total number.

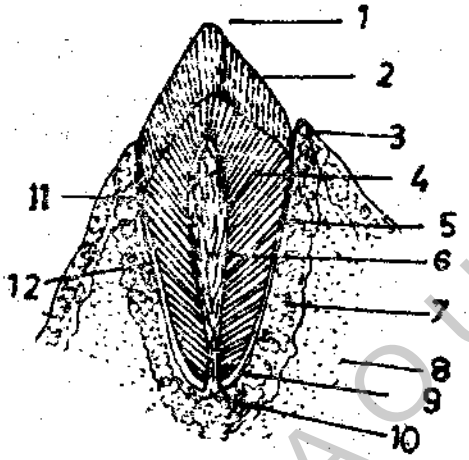


Fig.25.2 Rabbit-Tooth (L,S). 1. Crown 2. Enamel 3. Gum 4. Dentine 5. Cementum 6. Pulp cavity 7. Periodontal membrane 8 Jaw bone 9. socket 10. Apical foramen 11. Neck 12. Root.

The mammalian tooth part that projects up above the gum (skin covering the jaw) is called the **crown** (Fig 25.2). The remainder surrounded by the gum and lodged in the socket of the jaw bone, is described as the neck and root respectively. A vertical section of it shows that it is made up of three tissues which are harder than bone. The crown is covered by the hardest shining white material **enamel**. The outer surface of neck and root is made up of **cement**. But the bulk of the body of the tooth is made up of **dentine (ivory)**. It is permeated by numerous fine canals. They contain the protoplasmic processes of the odontoblasts (dentine forming cells) found along the periphery of the pulp cavity. It is the central part of the tooth and is occupied by the connective tissue, blood vessels and nerve fibres. Between the root of the tooth and the alveolar wall lies a continuation of the periosteum of the bone which forms the alveolar or periodontal membrane.

There are four pairs of salivary glands. Their ducts open into the buccal cavity. They consist of **parotid glands, infraorbital glands, submaxillary** or **submamdibular** and the **sublingual glands** (Fig.25.3).

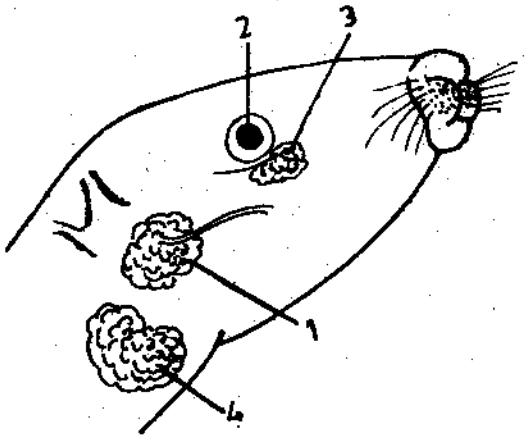


Fig.25.3 Rabbit - Salivary glands. 1. Parotid gland. 2. Eye. 3. Infraorbital gland. 4. Submaxillary gland.

The vestibule and buccal cavity are lined by ectoderm and is called the stomodaeum. Similarly, hinderpart of the rectum has ectodermal lining called as proctodeaum. The remaining middle, region of the roof is lined by endoderm and is known as mesodaeum or mesenteron.

25.3.3 Pharynx

The pharynx is relatively short and wide. It receives the openings of the posterior nares of the respiratory channel. Internal apertures of the Eustachian tubes from the middle ear also open into the pharynx. Posteriorly, the pharynx leads to the larynx ventrally and the oesophagus dorsally. The entrance to the larynx, the glottis, is guarded by the epiglottis. It is cartilage covered by the pharyngeal epithelium.

25.3.4 Oesophagus

The pharynx is followed by the oesophagus which is a long narrow tube. It passes through the neck (dorsal to the trachea) and the thorax perforating the diaphragm, enters the abdomen and opens into the stomach. Oesophagus is very much folded lined by squamous stratified epithelium. At the junction with the pharynx it is having smooth muscles followed by the striated or voluntary muscles.

25.3.5 Stomach

The stomach is the most dilated part of the digestive tract. It is more or less like an ovoid sac lying transversely in the abdominal cavity(Fig.25.4). Where the oesophagus enters the stomach there is a cardiac valve. It prevents the regurgitation of food into the oesophagus. This strongly rounded end of the stomach is called the **cardiac region**. Beyond the entrance of the oesophagus the cardiac part is prolonged as the fundus. The other narrower part of stomach joining with intestine is termed the **pyloric part**. It has a pyloric sphincter. In the lining of the stomach there are the gastric glands. Its wall is strongly muscular. The food is stored in the stomach is churned and partially digested.

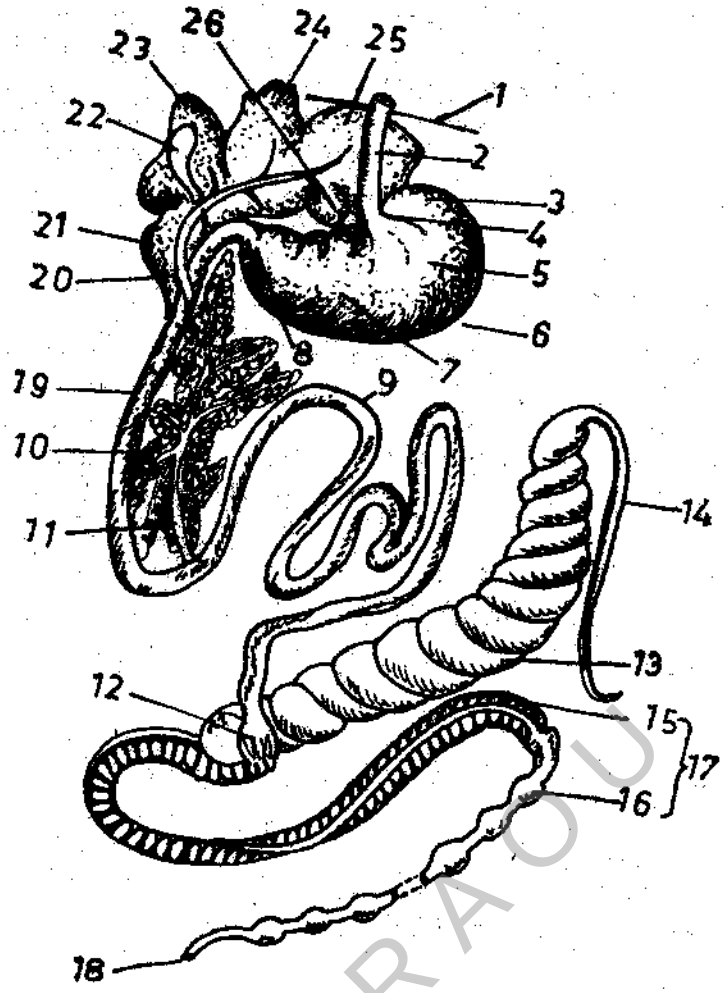


Fig.25.4 Rabbit - Alimentary canal 1. Diaphragm 2. Oesophagus 3. Fundus 4. Position of cardiac valve 5. Cardiac stomach 6. Position of spleen 7. Pyloric stomach 8. Pyloric sphincter 9. Ileum 10. Pancreas 11. pancreatic duct opening into distal limb 12. Sacculus rotundus 13. Caecum 14. Vermiform appendix 15. Colon 16. Rectum 17. Large intestine 18. Anus 19. Deodenum 20. Bile duct 21. Caudate lobe 22. Gall bladder 23. Right central lobe 24. left central 25. Left lateral 26. Spigelian lobe.

25.3.6 Intestine

Next to the stomach is the proximal part of the intestine, the small intestine, a narrow tube about 2 to 2.5 metre long. The first part of it which is in the form of U- shaped loop is the duodenum. In the mesentery of which lies the pancreas. The bile duct opens into expanded beginning of the duodenum and the pancreatic duct into the distal limb of it. Following the duodenum the small intestine farms a series of loops and coils. In the rabbit the small intestine does not show much differentiation. But in some mammals the region immediately after the duodenum is differentiated as the **jejunum** from the more distal portion, the **ileum.** In jejunum, the villi and the intestinal glands are larger than in ileum.

The small instestine serves two main functions Completion of digestion and absorption of digested food. The great length of small intestine provides a large area for absorption. The inner surface of the intestine is produced into finger like projections called the intestinal villi which increase the absorptive surface of the intestine. (Refer Unit 31).

25.3.7 Caecum

From the small intestine the direct course of the digestive tract is into the large intestine. In mammals, at the junction of the two is a blindly ending diverticulum called the **caecum.** It ends in a narrow vermiform appendix. it is 25 cms long. The three way junction is marked by a swelling called the **sacculus rotundas,** within which is valve arrangement, an **ileo - caecal valve.** It directs the food first into the caecum before entering the colon. In a herbivorous mammals like the rabbit, the caecum is associated with the cellulose digestion by bacterial action.

25.3.8 Large Intestine

The large intestine is about 1 metre long. It consists of two regions the colon and the rectum. Colon is wide about 45 cms. long with a sacculated appearance. The rectum is narrower and about 75 cms. long gives beaded appearance. It includes the proctodaeum and opens to the exterior through the anus, which lies under the base of the tail. The large intestine aids mainly in the formation and elimination of faeces and the absorption of water.

25.3.9 Digestive glands

In addition to the glands present within the various regions of the alimentary canal, there are two important glands which lie outside the digestive tract. They are the liver and the pancreas.

25.3.9.1 Liver

The liver is a very large red gland. It is made up of five lobes. The right and left central, the left lateral, the caudate and the spigelian lobes. Its detailed structure is given in Unit 31. The gall bladder is large and lies between the right and left central lobes. The main bile duct or cystic duct arises from it, and receives subsidiary ducts from the various liver lobes and finally opens into the beginning of the duodenum.

Functions of the Liver

Liver is regarded as the chemical workshop of the body, in view of its important functions. It helps to some extent in digestion, but it is not exclusively a digestive organ. Some of its important functions are stated as follows :

1. It produces a greenish alkaline non enzymatic watery fluid called the bile. It carries on the following functions.
   a. It is an antiseptic fluid, destroying bacteria.
   b. It provides an alkaline medium in the intestine, neutralising the **chyme.**
   c. It brings about the emulsification of fat.
   d. It stimulates peristalsis.
   e. It removes excretory products.
   f. Helps in fast and fat soluble vitamins' absorption.
2. Liver stores glycogen converting the excess of glucose (glycogenesis). When needed, glycogen reconverted in to glucose.
3. Liver cells produce **heparin** which is an intra vascular **anit-coagulant.**

4 It produces **fibrinogen** and **prothrombin** which are essential components of blood clotting.

5. Liver cells manufacture less harmful urea from the toxic ammonia.

6. Various enzymes are synthesized in liver.

7. **Kupffer's cells of the liver are phagocytic.**

8. Excess of amino acids are converted into carbohydrates and stored as glycogen in the liver cells(**gluconeogenesis**).

9. In the embryo it produces blood corpuscles.

25.3.9.2 Pancreas

The Pancreas is an irregular, membranous, pinkish gland found in the mesentery between the limbs of the U-shaped duodenum. The pancreatic duct pours the pancreatic juice with in the distal limb of the duodenum. It is both an exocrine as well as an endocrine gland. Histology and functions discussed in Unit.32.

25.4 NUTRITION

Ingestion

Ingestion is the act of taking the food into the alimentary canal. The rabbit is herbivorous and gnaws the vegetable matter with its chisel shaped incisor teeth. Sliced off smaller pieces of vegetable matter are seized by the mobile lips and taken into the buccal cavity.

In the buccal cavity the food is further subjected to the action of the grinding cheek teeth. Instantly the food is thoroughly mixed with the saliva secreted by the salivary glands. This process is called mastication. By the movements of the tongue the food is turned round in the buccal cavity till it forms a pulpy mass or bolus. The saliva is largely watery but contains mucus and digestive enzymes.

Deglutition

After mastication, the bolus is swallowed. In this deglutition the bolus is pushed into pharynx by the raising of the tongue. It is prevented from entering the posterior nares by the soft palate. The epiglottis prevents its entry into the trachea. By the contraction of the pharangeal wall the bolus is forced into the oesophagus. The proximal end of the oesophagus is voluntarily dilated to receive it. Once it enters the oesophagus further progress is involuntary.

25.4.3 Digestion

The food consists of carbohydrates,proteins, mineral salts, vitamins and water. With the exception of the mineral salts and some of the sugars most of the solid food of vertebrates is insoluble. Even if it mixes with water it forms a colloidal solution. Such a solution is incapable of passing through the lining membrane of the gut. The food must therefore be rendered soluble and diffusible before it can be of use to the animal. The process of converting insoluble food into a diffusible form is called **digestion.** In this process the molecular size of the substances is progressively reduced until a true solution is formed, i.e. a colloidal solution is changed into a crystalloid form. Such a change is brought about in the presence of organic bio-catalysts known as enzymes. Enzymes are classified in accordance with the food substance upon which they act. Thus the carbohydrates are digested by diastase

or amylolytic enzymes, proteins by proteolytic enzymes and fats by the lipolytic enzymes or the lipases.

25.4.4 Physiology of Digestion

Mammals retain the food in the buccal cavity and the digestion starts from this part of the tract. During the process of mastication the food gets mixed with saliva. It contains a diastatic enzyme **ptyalin**. This acts on the polysaccharide or starches converting them into disaccharides such as dextrin and maltose. In the buccal cavity the food is in the form of a soft pulpy mass - the bolus. It is swallowed and merely passes through the oesophagus. In the stomach the bolus comes under the influence of the oesophagus. In the stomach the bolus comes under the influence of the gastric juice. The secretion of which is influenced by a hormone gastrin secreted by the enterochromaffin cells. Further the appetite also promotes the secretion of gastric juice. The gastric juice contains over 90% water, the two enzymes usually present in it are the pepsin and renin. Both are a proteolytic enzyme. Pepsin reduces the proteins to proteoses and peptones in the presence of the acidic medium provided by the hydrochloric acid secreted oxyntic cells. **Pepsin** is present in the peptic cells of the gastric glands in the form of inactive precursor, pepsinogen. After pepsinogen is secreted, it is converted into pepsin by the action of **hydrochloric acid**. Further it acts as an internal antiseptic fluid destroying bacteria. **Renin** brings about the curdling (coagulation) of milk forming clots. This is important to the young animal which is being fed on milk by the mother. As curdling causes the milk to be retained longer in the stomach. The clot is more fully acted upon by the pepsin. The tissue surrounding fat is dissolved a way, liberating the fat in the form of free globules. The pyloric sphincter is responsible for retaining the food in the stomach for some time (in man as long as for 2-4 hours). During this period, the rhythmical contraction and relaxations of the stomach muscles churns the food. A thorough mixing of the gastric juice is also ensured. This results in the formation of a thick creamy acid fluid called chyme.

The muscles of the pyloric sphincter relax from time to time. Thus the peristaltric movements force some of the partly digested food (chyme) into the duodenum.

With the formation of chyme, the duodenum is stimulated to secrete three horomones: Secretin, **cholecystokinin** and **enterokinin**. These three hormones respectively induce pancreas, liver and the intestinal glands to pour their secretions. The chyme in the duodenum is subjected to the action of three juices: bile coming from the liver, pancreatic juice from the pancreas and succus entericus from the crypts of Lieberkuhn and the Brunner's glands.

Bile is a greenish alkaline watery fluid. It has no enzymes in it. But adds water and prevents purification. The salts present in it are very essential for the completion of intestinal digestion. They include **sodiumbicarbonate, sodium taurocholate** and **glycocholate**. Sodium bicarbonate reduces the acidity of the intestinal content and provides alkaline medium. The other two brings about the emulsifiation of fats and activate the pancreatic lipase. The bile is greenish in colour owing to the presence of the bile pigments-**bilirubin** and **biliverdin**. They are in a measure excretory products formed by the disintegration of the haemoglobin of the worn out red blood corpuscles.

The pancreatic juice is an alkaline watery fluid. It is very rich in enzymes. It contains **trypsin (proteolytic)** and **chymotrypsin.**. Trypsin is present as an inactive precursor **trypsinogen**. It is activated by another enzyme-**enterokinase**, a constituent of **succus entericus**. Other is a diastatic enzyme amylase or amylopsin. It converts starch and glycogen to maltose. Lipase or **steapsin** (lipolytic) converts emulsified fats into fatty acids and glyceroi.

The succus entericus is produced by the glands of the duodenum and small intestine. It is a watery alkaline secretion containing many enzymes and mucus. These enzymes bring about the digestion of all kinds of the food substances. The more important of them are erepsin consisting of amino peptidases and dipeptidases (Proteolytic) transforming peptones into amino acids. The **enterokinase** activates the pancreatic trypsin. The intestinal lipase hydrolyses fats. Invertase or sucrase, maltase and lactase are diastatic enzymes responsible for reducing the disaccharides to soluble monosaccharides. Thus as a result of enzymatic action, the proteins are all reduced to amino acids, the carbohydrates to glucose and other monosaccharide sugars and fats to glycerol and fatty acids. While passing through the intestine the food received more water from various secretions. This alkaline fluid emulsion is called chyle. It passes through the rest of the intestine.

25.4.5 Absorption

In order to be of use to the organism, the food must be absorbed into the blood vessels. Very little absorption of the digested food takes place from the buccal cavity for the stomach. After the completion of digestion, greater part of absorption takes place in ileum. The absorptive area of the small intestine is enormously increased by the development of villi (Fig. 24.5). Each villus is provided with a central lacteal vessel and is supplied with capillary blood vessels. Villi are bathed within the fluidfood (chyle). Fatty acids and glycerol pass in to the lacteal. Capillary net work absorbs the other food substances.

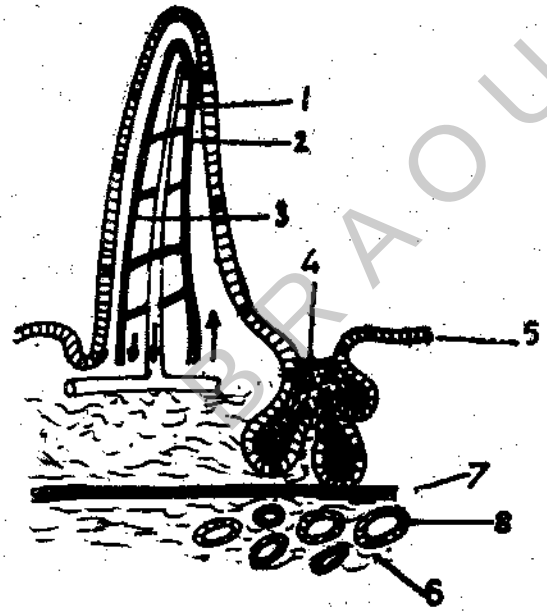


Fig. 25.5 Rabbit-Villus showing absorption of food. 1. Lacteal 2. Artery 3. Vein 4. Crypt of Lieberkuhn 5. Columnar epithelium 6. Connective tissue 7. Muscularis mucosa 8. Brunner's glands

After the absorption of the digested products the fluid contents of the alimentary canal pass into the colon. In this region chiefly water is absorbed from the fluid residue as the conservation of water is the biggest problem with the terrestrial vertebrates. After the removal of water, the residue becomes semisolid in the rectum and form faecal pellets. Which gives a beaded appearance to the rectum region. The pellets are discharged through the anus.

25.4.6 Coprophagy

In order to obtain the maximum nutriment from its food, rabbit has adopted the habit of coprohagy or coprophiia. The faeces produced during the night are soft and moist. The

nocturnal faeces are eaten and consequently subjected to all the digestive and absorptive processes.

25.4.7 Cellulose digestion

In a herbivorous mammal like the rabbit the solid food mostly consists of cellulose. It is not digested by any of the ordinary diastaic enzymes. In such animals, cellulose digestion occurs in the large caecum.

The fluid intestinal contents are directed into caecum. It contains protozoa and bacteria as symbionts. These and the cytases in the plants themselves help in digesting cellulose by a very lengthy process.

25.5. SUMMARY

Rabbit is a herbivore. The digestive system comprises of the digestive tract, the digestive glands and the associated accessory structures like the teeth and tongue. Canines absent. Tongue muscular and is beset with taste buds. Tongue also helps in the mastication of the food. Respiratory channel is partitioned from the food channel by the palate. Protein digestion will be initiated in the stomach and is completed in the small intestine along with the break down of the fats and carbohydrates by the secretions of the liver, pancreas and the intestinal glands. In herbivores, as in rabbit, the intestines are long and there will be a caecum at the junction of the colon and the ileum where, hard undigested plant stuff like the cellulose will be digested with the help of the bacteria and other protozoans that live in the symbiotic association, getting in turn nitrogeneous foods. The cellulose digestion is carried out by the microbes by secreting cellulose and also by other enzymes of plants, the cytases. Villi are the finger shaped processes present through out the small intestine to increase the absorptive surface area. Fats are split up into glycerol and fatty acids and are absorbed into the lacteal vessels of the villi. Starches break down into simple sugars while the proteins into amine acids.

25.6 MODEL EXAMINATION QUESTIONS

I. **Answer the following in about 30 lines.**

1. Describe the digestive system of rabbit.
2. Give an account of the process of digestion in rabbit.
3. Describe the digestive glands and mention the functions of liver in rabbit.

II. **Answer the following in about 10 lines.**

1. Mention the various enzymatic actions involved in the conversion of chyme to chyle.
2. Describe the structure of tooth.
3. Give a brief account on functions of liver.
4. The enzymes of pancreas

Unit - 26 RABBIT - NERVOUS SYSTEM

Contents

26.1 OBJECTIVE

- To appreciate the highly organised brain and distribution of nerve for functional co-ordination in rabbi.

26.2 INTRODUCTION

In general the vertebrate nervous system is divisible into the following parts :

1. The **central nervous system** including the brain situated in the cranium and the spinal cord present in the central canals of vertebrae.
2. The **cerebro-spinal** system including the paired cranial nerves arising from the brain. The spinal nerves which originate from the spinal cord.
3. The **autonomic nervous system** consisting of a pair of ganglionated nerve cords and nerves. The nerves form two sub- systems the **sympathetic** and the **parasympathetic.**
4. Sense organs consisting of Eye, Ear, organs of smell, taste and touch, bring out co-ordination between above mentioned nervous systems and the environment.

26.3 CENTRAL NERVOUS SYSTEM

Central nervous system consists of brain and spinal cord.

26.3.1 Brain

The brain lies in the cranial cavity. It is a soft whitish structure. It is divided into three regions. The forebrain, mid-brain and the hind brain.

1. Fore Brain (Procencephalon)

Fore brain is greatly developed in mammals. It consists of the olfactory lobes situated anteriorly and very large cerebral hemispheres. The two cerebral hemispheres are separated dorsally from each other by a deep groove the **median fissure.** In mammals the two cerebral hemispheres form the **cerebrum.** They are so large that they cover the olfactory lobes dorsally. Only the anterior end of it is visible from the dorsal side. They project backward so that the diencephalon and the optic lobes are overshadowed. The mid dorsal thickening of the cerebral hemispheres formed of neurons is called the **cerebal cortex.** Superficially each cerebral hemisphere is divided into a number of lobes by fissures. In rabbit there is an oblique sylvian fissure about the middle of the hemisphere. It divides each hemisphere into an anterior **frontal lobe** and the posterior **temporal lobe.** Running longitudinally along the ventral surface of the cerebral hemisphere is a **rhinal fissure.** It separates the olfactory tracts and **hippocampal lobe** from the frontal and temporal lobes. Internally the two cerebral hemispheres are connected with each other by a transverse bridge of white matter, the **corpus callosum.** It is in addition to an anterior, posterior and middle commissure present in the hemispheres of other vertebrates. (Fig. 2.1)

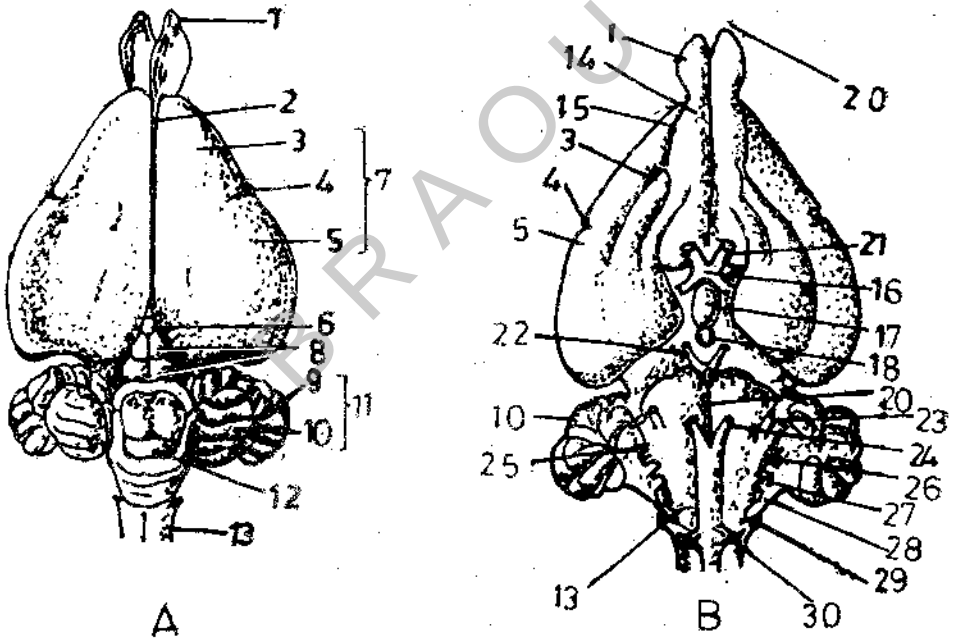


Fig. 26.1 Rabbit-Brain. A. Dorsal view. B. Ventral view nerves origin. 1. Olfactory lobe 2. Median fissure 3. Frontal lobe 4. Sylvian fissure 5. Temporal lobe 6. Pineal body 7. Cerebral hemisphere 8. Four optic lobes 9. Floculus 10. Lateral lobe 1. Cerebellum 12. Vermis 13. Medulla oblongata 14. Olfactory tract 15. Rhinal fissure 16. Optic nerve 17. Pituatory body 18. Corpus albicans 19. Pons varoli 20. Olfactory (First cranial nerve 21. Optic (second) 22. Oculomotor (third) 23. Trigeminal (fifth) 24. Abducens (sixth) 25. Facial (seventh) 26. Auditory (eight) 27. Glosso-pharyngeal (ninth) 28. Vagus (tenth) 29. Spinal accessory (eleventh) 30. Hypoglossal nerve (twelth cranial nerve).

Because of the enormous development of the cerebrum, the **olfactory lobes** i.e. ventrally and only the anterior part is visible. The **thalamencephalon** or **diencephalon** is very narrow. Mid dorsally arises the tubular **pineal stalk.** It extends backwards and ends in the pineal body which lies closely against the roof of the cranium. On the ventral side of the diencephalon

is a funnel shaped depression the **infundibulum.** The infundibulum and the hypophysis (of stonodum) together form the pituitary body an endocrine gland. In front of the pituitary body is the crossing of the two optic nerves forming the **optic chiasma.** The sides of the thalamencephalon are thickened to form the **optic thalami.** The **anterior choroid plexus** (capillary net work in the piamater) arises in the roof of the thalamencephalon and extends through the third ventricle into the **lateral ventricles.**

2. Mid brain (Mesencephalon)

The optic lobes are represented by four rounded prominences, the **corpora quadrigemina** on the dorsal surface. Ventrally there are two large bands of nerve fibres which form the **crura cerebri.**

3. Hind brain (Rhombencephalon)

It consists of two parts-**cerebellum** and **medulla oblongata.** Like the cerebral hemispheres, the cerebellum is also very large. It projects forwards and meets the posterior margin of the cerebrum. It extends laterally and is clearly divided into a median lobe the **vermis** and two lateral lobes having a prominence the flocculi. The entire surface of the cerebellum is marked by transverse folds. On the ventral side the two flocculi are connected by a transverse band of nerve fibre - the **pons varolli.** The cerebellum is connected with various other regions of the **brain** by peduncles. Medulla oblongata forms the terminal part of the hind brain. It's **roof is thin and** the piamater in this region becomes greatly folded and richly vascular, to form the **posterior choroid plexus.** It is pushed into the cavity (IV Ventricle or metacoel) of the medulla.

4. Ventricles of the brain

The brain of the rabbit appears to be a solid structure but the cavities or ventricles are still present. The rhinocoels in the olfactory lobes are not very obvious. The lateral ventricles in the cerebral hemispheres are very much reduced. The two lateral ventricles communicate posteriorly with the third ventricle in the diencephalon through an interventricular **foramen of Monro.** The third ventricle is narrow and joins the equally narrow **iter or sylvian aqueduct.** It opens into the wider fourth ventricle in the medulla oblongata. Small cavities of the carpora quadrigemina, representing reduced optocoels also open into the iter. All the ventricles are filled by the nutritive cerebrospinal fluid.

5. Meninges

The brain and the spinal cord are enclosed by membranes called the **meningeal membranes.** The inner most is a richly vascular **piamater.** In the roof of the diencephalon and the medulla it forms respectively the anterior and posterior choroid plexuses. It is covered by a tough and protective membrane the **dura mater,** forming the lining of the cranium. Between the piamater and the duramater is a third, **arachnoid membrane.** The spaces between these membranes are filled with **cerebrospinal fluid.**

6. Functions

The Olfactory lobes are concerned with the sense of smell. In higher mammals the cerebrum, cerebellum and medulla oblongata are functionally very important. The cerebral cortex is made up of the vast number of neurons. They receive impulses from various receptors (eye, ear, skin) analyse the information and compute appropriate responses in the light of the memories of the past events that are recorded. Thus the characteristic of the mammalian

brain is that instead of local centres each concerned mainly with one receptor system there has developed a cerebral cortex. Cerebral hemispheres are the chief coordinating centres. They are the sites of all voluntary actions, and of all conscious sensations. With the cerebrum are associated intelligence, memory, emotions and the ability to learn from experience. In the human brain various areas have been studied which are associated with special activities. Thus there are motor, visual, and speech centres.

The two pairs of optic lobes, receive the visual fibres. The posterior pair receives fibres from the cochlea, which has greater importance as the organ of hearing. The bulk of the optic fibres end in the thalamus or relaying impulses to the neopallium (Cerebral Cortex). The mammalian thalamus is called the optic thalamus. **Crura cerberi** carry sensory impulses from medulla oblongata and spinal cord to the optic thalami and thence to the pallium. The cerebellum is the centre for co-ordination of equilibrium, motor co-ordination and muscular tone. All the conscious impulses have their origin tin the cerebral hemispheres, but they are executed by the cerebellum.

The medulla oblongata controls the involuntary movements like (respiration, circulation, heart beat, swallowing movements of digestive organs and glandular secretion).

26.3.2 Spinal Cord

The spinal cord is the posterior continuation of the central nervous system. It extends from the medulla oblongata to the region, where it narrows to form thread like **filum terminale**. It is a long, white cylindrical structure situated within the neural canal of the vertebral column. It is slightly flattened dorsoventrally and is some what thickened in the brachial and lumbar regions to form the brachial and lumbar swellings. Histology of the spinal cord is discussed in Unit No. 31.

Functions

The spinal cord conducts the sensory and motor impulses to and from the brain. It is the center for the spinal reflex actions.

26.4 PERIPHERAL NERVOUS SYSTEM

The central nervous system, comprising of the brain and the spinal cord is connected with all parts of the body by the peripheral nervous system. A nerve which carries impulse to the central nerves is described as **afferent** or **sensory nerve.** Where a nerve which is carrying impulse away from the central nervous system to an effector organ is a **motor or efferent nerve.** In a mixed nerve both the afferent and efferent factors are present. The peripheral nervous system consists of the following sub- systems.

1. **Cerebral or cranial nerves** - nerves arising from the brain.
2. **Spinal nerves** - nerves arising from the spinal cord.
3. **Autonomic nervous system** - consists of nerves controlling the functions of the vicera (heart, lung, stomach, intestine etc.).

26.4.1 Cerebral or Cranial nerves

There are twelve pairs of cranial nerves in rabbit. Of these, I. II and VIII are purely sensory. III, IV, VI XI XII are purely motor and V, VII, IX and X are mixed having both

sensory and motor factors in them. The name, origin and distribution of these nerves is as follows :

I. **Olfactory nerves :** It arises from the cells of the olfactory membrane of the nasal cavity. It is connected to the olfactory lobes. It is purely somatic (of receptors) sensory.

II. **Optic nerve :** The fibres of the optic arise from the retina of the eye. These two nerves cross to form optic chiasma along the ventral surface of the brain. Then they get connected with the optic thalamus. It is also purely somatic sensory.

III. **Oculomotor :** It starts from the floor of the mid brain and goes to the four muscles of the eye ball. It is a somatic motor nerve.

IV. **Trochlear or Pathetic nerve :** This nerve starts dorsally and passes at once into the orbit to the superior oblique muscle of the eye ball. It is somatic motor.

V. **Trigeminal nerve:** It arises from the anterior ventral end of the medulla, It is mixed nerve. It divides into three branches.

1. **The sensory opthalmic :** It runs above the eye, supplies the skin of the nose and the upper parts of the orbit and the snout.

2. **The sensory maxillary :** It runs ventral to the eye and is distributed to the skin of the snout, specially to the tactile vibrissae.

3. **Mandibular (mixed) :** It runs to the lower jaw. It gives a sensory branch to the tongue. Then it is distributed to the muscles of the lower jaw and to the teeth.

VI. **Abducens nerve :** It arises from the floor of the medulla. It distributes to the muscle of the eye ball. It is a motor nerve.

VII. **Facial nerve :** It originates from the side of the medulla. It is both sensory and motor. It has three branches :

1. **Palatine branch to** the roof of the mouth.

2. **Chorda tympani to** the tongue, snout and salivary glands.

3. **Hyomandibular :** It supplies the muscles of the lower jaw, neck and pinna.

VIII. **Auditory :** it starts from the ventral lateral part of medulla. It is distributed to the utriculus, sacculus, semicircular canals and cochlea. It is purely somatic sensory.

IX. **Glossopharyngeal nerve :** It arises from the ventral side of the medulla. It is distributed to the sides of the pharynx and the tongue. It is a mixed nerve.

X. **Vagus or Pneumogastric :** it is a mixed nerve arising from the medulla. It divides into the following principal branches.

(1) **Superior laryngeal.** It goes to the muscles of the larynx.

(2) **Cardiac depressor :** It is distributed to the heart.

(3) **Recurrent laryngeal :** It also reaches the larynx.

(4) The main vagus or **pneumogastric :** it enters the thorax and the abdomen. Gives branches to oesophagus, lungs and stomach.

(5) The **cardiac** supplies the heart muscles.

XI. **Spinal accessory nerve** : It is a motor nerve. It arises by the union of fibres from the anterior end of the spinal cord. It is distributed to the pharynx, larynx, neck and shoulder.

XII. **Hypoglossal** : It arises from the ventral surface of the medulla. It is a motor nerve controlling the movement of the tongue and innervates the intrinsic muscles of the tongue. Some branches reach neck muscle.

Spinal Nerves

Spinal nerves connect the spinal cord with the other parts of the body. Corresponding to the number of vertebrae, the spinal nerves are very regularly arranged. There are 37 pairs of spinal nerves in the rabbit and 31 pairs in man. Of the 37 pairs in rabbit, there are 8 pairs of cervical, 12 pairs of thoracic, 7 pairs of lumbar, 4 pairs of sacral and 6 pairs of coccygeal. Most of them go to the skin and muscles of the same region. But some of them go to other parts of the body. The third cervical sends a branch to the pinna or external ear. The fourth cervical, with the branches of fifth and sixth innervate the diaphragm. A **brachial plexus** is formed by the union of the fifth to the eighth cervical and the first thoracic. This plexus gives nerves to the arms. Similarly the last lumbar and the first 2 or 3 sacral 2 or 3 spinal nerves together form the lumbo-sacral plexus, suppiying nerves to the legs.

All the spinal nerves are mixed in nature. Each consisting of the sensory or afferent fibres in the dorsal root. They carry impulses from the receptor organs (skin) to the cells of the central nervous system. In each dorsal root there is an enlargement called a ganglion which contains unipolar neurons. Fibres of the ventral root carry impulses outward from the central nervous system to an effector organ like the muscle. This nerve is otherwise on efferent or motor, because it controls the movements of the striped muscles.

26.5 REFLEX ACTION

The spinal cord conducts impulses to and from the brain. But under certain circumstances the nerve impulses originate in the spinal cord in response to external stimuli. If a pin is pricked in the leg of an animal or a weak acid is applied or a hot body is touched then it is noticed that the leg is withdrawn. In our daily life we are performing a number of such movements. These are all known as reflex actions. In all these examples the movements are produced by the agency of the central nervous system without the intervention of the will. In brief reflex actions are automatic responses to stimuli. An animal never thinks of performing such actions. They are performed in an automatic manner. Few examples of reflex actions are the eyes are shut when strong light falls on them, when the hand accidentally comes in contact with a hot or cold object it is withdrawn. We are startled by the retort of a gun.

Many of our daily ordinary movements which were started by the will and are therefore voluntary become later reflexes. Thus one walks willingly and are therefore voluntary, became late as reflexes. Thus one walks without thinking about it and every step is properly taken. The necessary muscles receive impulses from the central nervous system and contract. The central nervous system itself receives sensory impulses from the eye or the ear or due to the contact of the feet with the ground.

The spinal nerves are mixed, that is they contain both the sensory and motor fibres (Fig 26.2). When the nerve approaches the spinal cord, the fibres separate to form respectively the dorsal, (afferent or sensory) and the ventral root (efferent or motor) in the spinal cord.

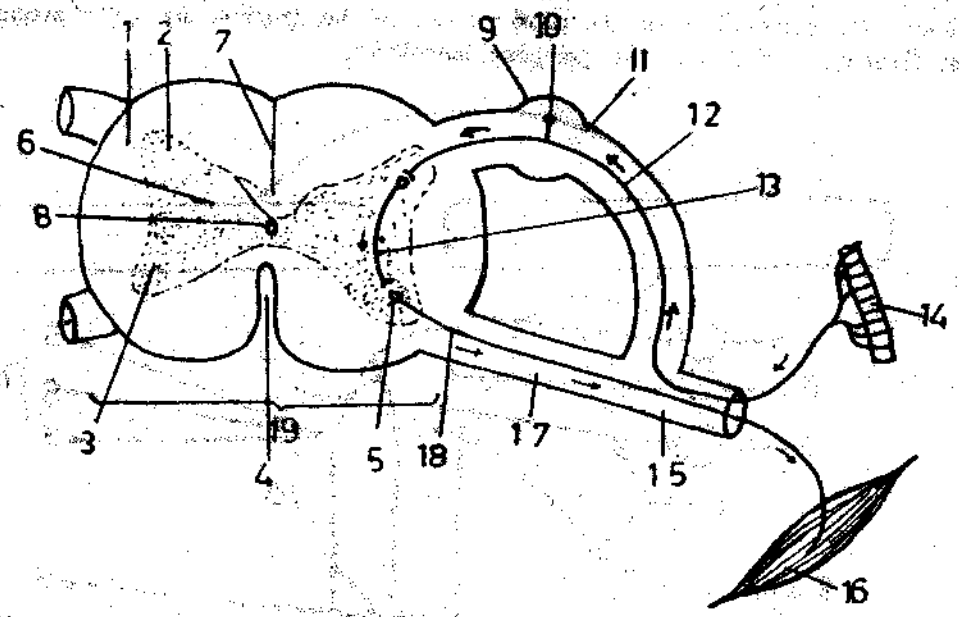


Fig.26.2 Diagrammatic cross section of the spinal cord to illustrate a typical vertebrate reflex arc. The arrows indicate the direction in which impulses are transmitted. 1. White matter 2. Dorsal horn 3. Ventral horn 4. Ventral fissure 5. Motor neuron 6. Grey matter 7. Dorsal septum 8. Central canal 9. Dorsal root 10. Cell body of sensory neurone 11. Dorsal root of spinal 12. Axon of sensory neurone 13. Axon of inter umeral neuron 16. Effector muscle 17. Ventral root of spinal nerve 18. Axon of motor neuron 19. Spinal cord.

Reflex Arc

The path followed by a stimulus during the reflex action is called a reflex arc. In a reflex action the nerve impulse is not transmitted directly from a receptor to the neighbouring effector surface. But it takes a certain course, and the reflex action is produced in the following way.

A stimulus on the skin (a receptor surface) is translated into a nerve impulse. This nerve impulse is conveyed to a sensory neuron located in the dorsal root ganglion or the spinal ganglion. Later this nerve impulse from sensory neuron travels along its axon into the grey matter of the spinal cord and terminates in the ventral horn. Here it is in synaptic contact with the dendrite of a motor neuron. From this motor neuron the impulse passes outwards along the axon to muscle tissue or gland (an effector organ) and stimulates the muscle to contract. Many reflex reactions involve more than two neurons, there being an intermediate neuron. The series of structures involved in the reflex path, i.e., sensory receptor, sensory neuron, relay centres, intermediate neuron motor neuron and effector organ constitute the reflex action.

26.6 AUTONOMIC NERVOUS SYSTEM

The involuntary activities of an animal, such as the beating of the heart, movements of the gut and secretion of sweat are controlled by the autonomic nervous system. It carries efferent impulses to effector organs which are not under the control of the will.

The autonomic nervous system comprises of two parts, the **sympathetic** (Thoracico-lumber) and **parasympathetic** (Cranio-sacral) systems (Fig 26.3). In both cases nerve fibres arise from the brain or spinal cord and pass to the effector organs. Each of the two systems has many such path ways along the course of which there is a complex set of synapses constituting a

ganglion. The nerve fibres on the proximal side of the ganglion are called **preganglionic fibres,** those on the distal side the **postganglionic fibres.**

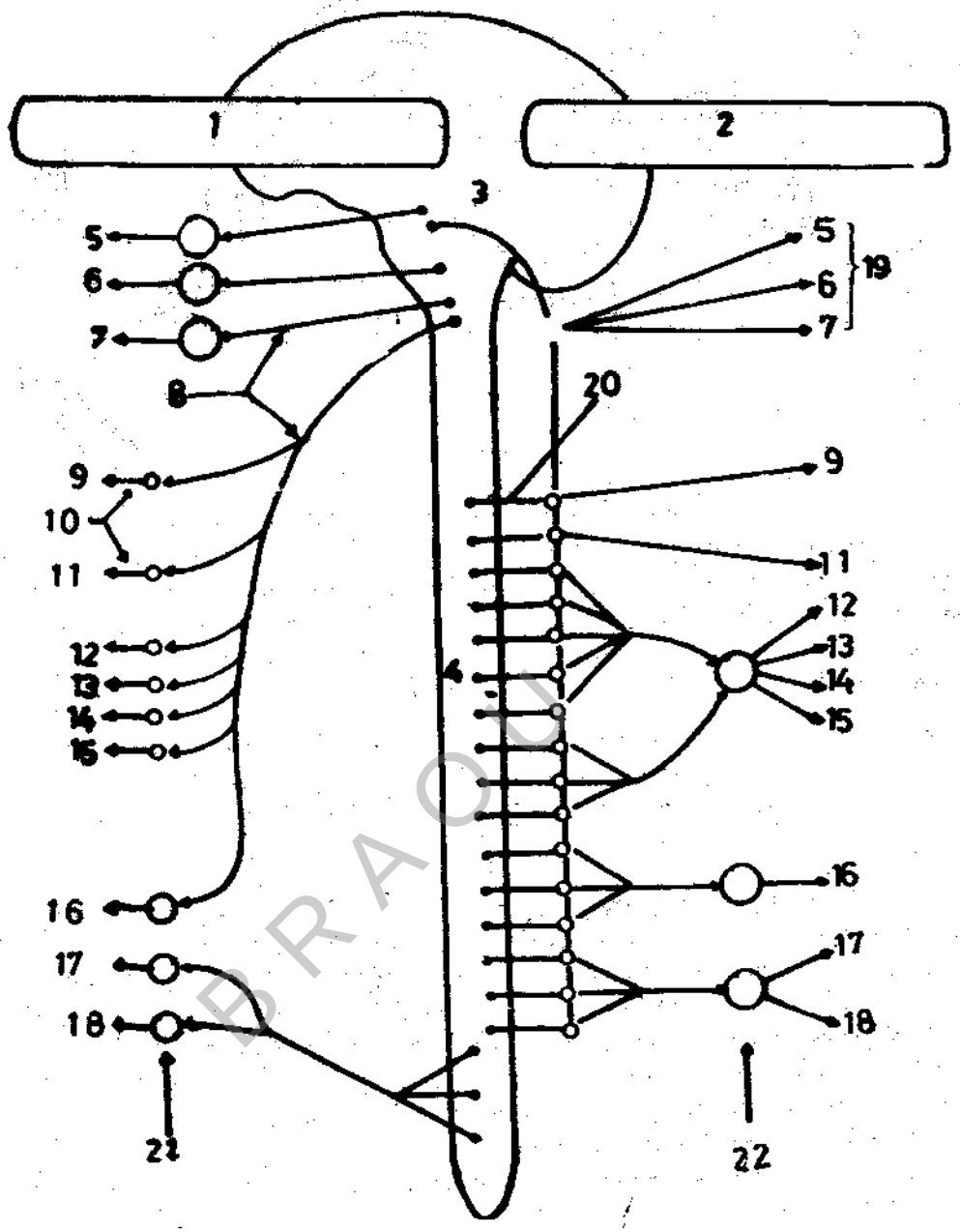


Fig. 26.3. Diagram summarizing the main features of the mammalian autonomic nervous system. 1. Parasympathetic system (cranio-sacral) 2. Sympathetic system (Thoracico-lumber). 3. Brain 4. Spinal cord 5. Iris 6. Tear gland 7. Salivary gland 8. Long preganglionic fibres 9. Heart 10. Short postaganglionic fibres 11. Lungs 12. Stomach 13. Small intestine 14. Pancreas 15. Adrenals 16. Large intestine 17. Bladder 18. Genital organs 19. Long postganglionic fibres 20. Short Preganglionic fibres 21. These ganglia are situated in the wall of the effector, so pre-ganglionic fibres are long, postganglionic fibres short 22. These ganglia are situated close to the spinal cord, so pre-ganglionic fibres are short, post-ganglionic fibres are long.

Structurally the two systems differ in the disposition of the ganglia. In the sympathetic system the ganglia lie by the side of the vertebrae, close to the spinal cord. As such the preganglionic fibres are short, the post ganglionic fibres long. In the parasympathetic system the ganglia are embedded within the wall of the effector organ. In this case the preganglionic fibres are

long and the post ganglionic fibres short. Functionally the two systems differ in producing different transmitter substances. The ends of the sympathetic nerve fibres produce noradrenaline. The ends of (norephedrine) the parasympathetic fibres produce acetylcholine. It is interesting to know that these two systems are antagonistic, i.e., they generally oppose one another. If the sympathetic brings about contraction of a muscle, the parasympathetic relaxes it.

Some functions of the sympathetic and parasympathetic systems are given in the following table which show the antagonistic actions of the two systems.

	Sympathetic system	Parasympathetic system
1.	Accelerates heart	Slows heart
2.	Constricts arteries	Dilates arteries
3.	Contracts bladder and sphincters	Relaxes bladder and anal sphincters
4.	Slow down the gut movements	Speeds up gut movements.

Morphologically, in the trunk region there is a segmental arrangement of the ganglia on each side of the vertebral column. Successive ganglia are linked together by a sympathetic nerve which arises from the brain. The nerve fibres relay impulses up and down the body. Each ganglion is connected to the respective spinal nerve (Ventral root) by a pair of slender rami communicans. From each sympathetic ganglion nerves reach the respective effectors. The parasympathetic system or the cranio - sacral comprises of the whole of the vagus nerve and its branches, plus certain other cranial and spinal nerves. There are no ganglia in the course of these nerves, and the synapses between the pre and post ganglionic fibres are located within the walls of the effector which contain ganglion.

26.7 NERVE–IMPULSE TRANSMISSION

The message transmitted by an axon is called the nerve impulse. It is an electrical phenomenon and in certain respects the axon behaves like an electrical cable.

The experiments on the transmission of nerve impulse in the giant axons (a millimeter in diameter) of a squid has thrown much light on the events that occur inside the axons at the transmission of nerve impulse. The details of these events are discussed below :

The electrical nature of nerve impulse

It has been observed that when axon is in the resting state, i.e., when it is not transmitting an impulse, a potential difference is maintained between the inside and outside of the axon. The inside of the axon is negatively charged to the extent of approximately 60 millivolts and the outside is positively charged. This situation is known as **resting potential.** It shows that the membrane surrounding the axon is polarized which means that it is capable of maintaining different electrical charges on its two sides. When an impulse passes due to a stimulus, the above situation is momentarily reversed, the inside of the axon suddenly becoming positive to the extent of + 60 millivolts and outside negative. This sudden reversal of the resting potential which accompanies the impulse is called **action potential** and clearly it involves the sudden depolarization of nerve membrane. As indicated in the diagram (fig. 26.4) The action potential is extremely short lived. It lasts for about a millisecond, after which the original resting potential is restored again. The nerve impulse thus is a propagated negative

charge on the outside of the membrane caused by a wave of depolarization which passes along the axon.

Ionic basis of the nerve impulse

More recent experiments have provided an ionic explanation of the electrical events described above. When the axon is at rest, the concentration of ions on either side of the membrane are very different. There is an excess of potassium ions K^+ and organic anions inside the axon and an excess of sodium ions Na + immediately outside. The Na ions are actively extruded across the membrane and their properties of permeability prevent them from entering the axon once they have been expelled from it. This active removal of N_a + is called the **sodium pump mechanism** which is the major cause of the resting potential.

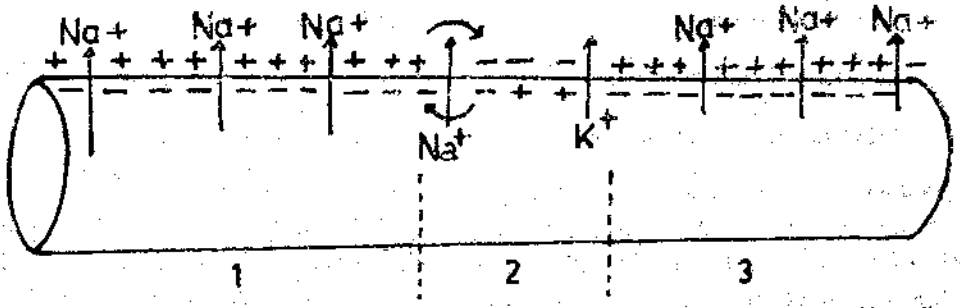


Fig.26.4 Nature of nerve impulse. 1. Membrane polarised outside positive : sodium ions expelled by sodium pumps mechanism 2. Sodium pump stops, and sodium ions enter axon Membrane depolarised; Inside becomes positive to outside negative 3. Sodium pump operates again; membrane repolarised; outside positive, inside negative.

When an impulse passes along the axon the sodium pump mechanism suddenly breaks down and the membrane becomes permeable to N_a + ions, which being about ten times more concentrated outside the membrane, rush into the axon by diffusion. This event takes place

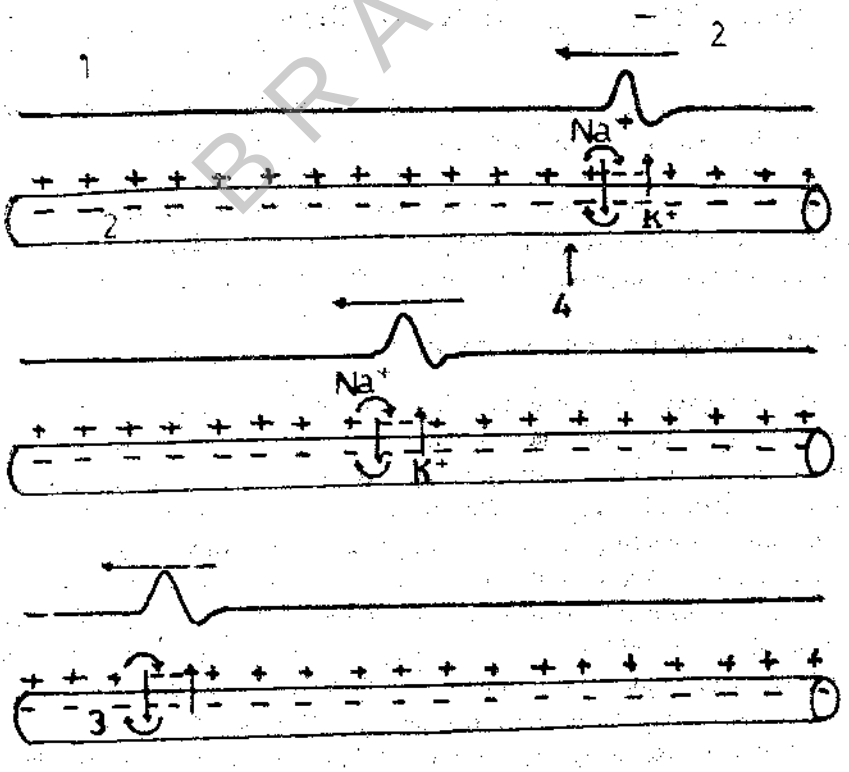


Fig.26.5 Diagram showing three stages in the propagation of an impulse along an axon. 1. Resting potential 2. Action potential 3. Axon 4. Depolarized section of membrane.

rapidly and explosively and reverses the **resting potencial,** the inside of the axon becomes positive relative to the outside, resulting in the **action potencial.** Small local circuits on both sides of the membrane at the leading end of depolarisation, excite the next part of the axon, so the action potential is propagated along it.

As outside axon becomes flooded with the sodium ions, potassium ions begin to re-enter inside and leave. This marks the beginning of the **recovery process** in which the inside of the axon regains its negative charge. Complete **repolarization** of the membrane is achieved by the sodium mechanism starting up again, the N_a + ions being vigorously extruded from the axon once more. The relationship between these various events is summarised in Fig. 26.4 and 26.5 .

Nerve impulse can thus be explained in terms of changes occurring in the properties of the membrane surrounding the axon. The transmission of nerve impulse required energy which comes from A.T.P.

The above account is based on the giant axons of the squid. Experiments carried out suggest that the ionic explanation of the resting and action potential applies in general to all nerves.

26.8. SENSE ORGANS

Sense organs are ear, eye etc.

26.8.1 Structure of the Ear

It is in mammals that the ear has reached the highest degree of development. The middle ear and the inner ear have become far more complex and there is an additional external ear or pinna.

The **outer ear or pinna** is a trumpet like structure of variable size and shape. It is a flap of cartilage covered with skin. In rabbit and in many other mammals it is provided with muscles which can move it in different directions. Thus the external ear is useful only in collecting sound waves and in detecting the direction of sound. Leading from the external ear into the head is a small tubular auditory meatus (having wax or ceruminous glands) which ends in a chamber the **middle ear or tympanic cavity.**

The middle ear is an air filled space of irregular shape contained within the tympanic bone and connected with the back of the buccopharyngeal cavity by the **Eustachian tube.** The middle ear is separated from the auditory meatus by the ear drum or the tympanum. In the inner wall of the middle ear there are two apertures, the upper one is the **fenestra ovalis** and the lower circular aperture is **fenestra rotunda,** both of them covered only by the membranes.

The tympanic membrane is linked to the fenestra ovalis by a chain of three small bones, the **auditory ossicles,** which are named as the T-shaped **malleus,** hammer attached to the tympanum - a long pear - shaped **incus** and a stirrup shaped **stapes,** with its base set in the **foramen ovale or fenestra ovalis.** These three are connected with one another by definite articulations. Tension on tympanic membrane is maintained by a small muscle **tensor tympani** which runs from the inner wall of the tympanic chamber to the malleus.

The membranous labyrinth or the inner ear is lodged in the periotic bone and is formed by the semicircular canals, **utriculus, sacculus** and **cochlea** and the associated structures. The

semi circular ducts are enlarged as **ampullae** at one end of each canal. Each ampulla has a sensory spot called crista. Similarly the Utriculus and sacculus, posses a sensory spot each, similar to crista, called **macula.** Cristae and maculae are the auditory sensory spots.

]But the **lagena or the cochlea** which in other mammals is represented by a bud like outgrowth, becomes fluid filled spirally round, blind sac and is enclosed within a part of the auditory capsule. A transverse section of the cochlea gives the impression of a bony tube. The cochlear canal which is crossed by two membranous partitions so that it is divided into three chambers, an upper **scala vestibuli,** a middle **scala media** and a low **scala tympani** (Fig. 26.6).

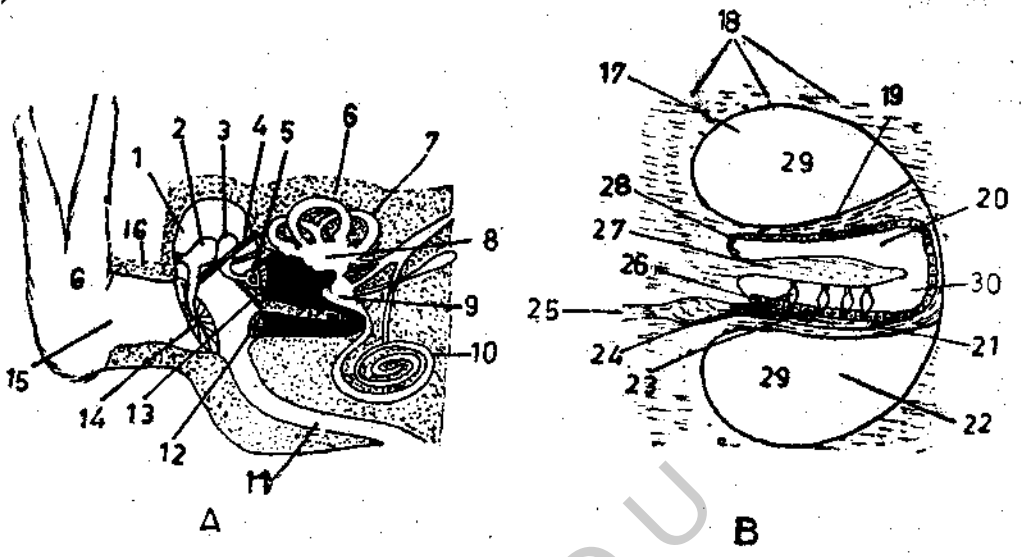


Fig. 26.6. A. Generalised mammalian ear. B. T.S. cochlea of rabbit. 1. Middle ear 2. Malleus 3. Incus 4. Stapes 5. Tensor tympani 6. Inner ear 7. Semicirculars canals 8.Utriculus 9. Sacules 10. Lagena or cochlea 11. Eustachian tube 12. Fenestra rotunda 13. Fenestra ovalis 14.. Tympanic membrane 15. External auditory meatus 16. External ear 17. Scala vestibule 18. Periotic bone. 19. Reissner's membrane 20. Scala media 21. Basilar membrane 22. Scala tympani 23. Supporting cells 24. Receptor cell 25.Auditory nerve 26. Organ of corti 27. Tectorial membrane 28. Auditory epithelium 29. Perilymph. 30. Endolymph.

The middle chamber or scala media is a continuation from the sacculus. Is is filled with **endolymph.** The upper and the lower walls of the scala media are made up of two membranous partitions. The upper one is the Reissner's membrane and the lower the **basilar membrane.**

The upper chamber of the cochlea which is between Reissner's membrane and wall of the bony canal is the scala vestibuli. It is perilymphatic space. The scala vestibuli is connected at the top of the cochlea with the lower chamber of the cochlea which is known as scala tympani by a narrow duct, the **helicotrema.** Scala tympani is also filled with perilymph and ends blindly against the fenestra rotunda.

The some what complicated arrangement of the canals in the cochlea may be visualised if the scale made be imagined as growing out as a spiral tube from the sacculus and as it does so pushing infront of it s portion of the perilymphatic space and the walls of the auditory capsule so that the coiled tubular extension of the sacculus become enclosed in a bony tube from which it is separated by perilymph.

Like the rest of the membranous labyrinth the scala media is lined by an epithelium of ectodermal origin where it overlies the basilar membrane is modified to form the **organ of**

Corti, containing supporting and receptor cells of sense organ (Fig. 2.6 B).

Organ of Corti consists of collection of tall pillar like supporting cells and five longitudinal rows of receptor cells. The receptor cells or the hair cells are over laid by a gelatinous ribbon like membrane the tectorial membrane, in which during life the sensory hairs (Sterocilia) of the receptor cells are actually embedded. Components fibres of the branch of the auditory or VIII cranial nerve supplied the receptor cells of cochlea.

Balance and Hearing

The ear is usually described as a single unit sense organ. But it is concerned with the perception of two totally different kinds of stimuli. By this sense organ the animal is made aware of its movement and of gravity. The animal is enabled to orientate itself and maintain its balance. The upper part of the inner ear (membranous labyrinth) including the utriculus and semicircular canals are concerned with the appreciation of changes in velocity. The ear is also a sound receptor. The sacculus are its outgrowth, the lagena or cochlea (specially the organ of Corti) contain the sound receptor. The outer ear is probably useful in detecting the direction of the source of sound. The auditor meatus acts as an amplifier. The ear ossicles transmit the vibrations induced by sound falling on the tympanic membrane to the fenestra ovalis.

26.8.2 Structure of the eye

The eyes are visual organs. The eye ball is roughly spherical and is lodged in the orbits. Each is further protected by the upper and lower eye lids, which can close the eye. It is only a smaller part of eye which is exposed. In rabbit there is a third eye lid, the **nictitating membrane** which is transparent and can cover completely the front surface of the eye ball. Movements of the eye ball is brought about by the muscles of the eye ball, which are six in number. They consist of the **anterior rectus, posterior rectus and the superior and inferior recti.** There is a superior and an inferior oblique muscle. The front surface of the eye ball is separated from the outside world by a thin transparent layer, the **conjunctiva.** This is really an area of the modified epidermis and is continuous with the epidermis of the eye lids at the periphery. The conjunctiva is kept moist and transparent by the secretion of the **lachrymal or tear gland.** They are situated at the upper outer angle of the eye lids.

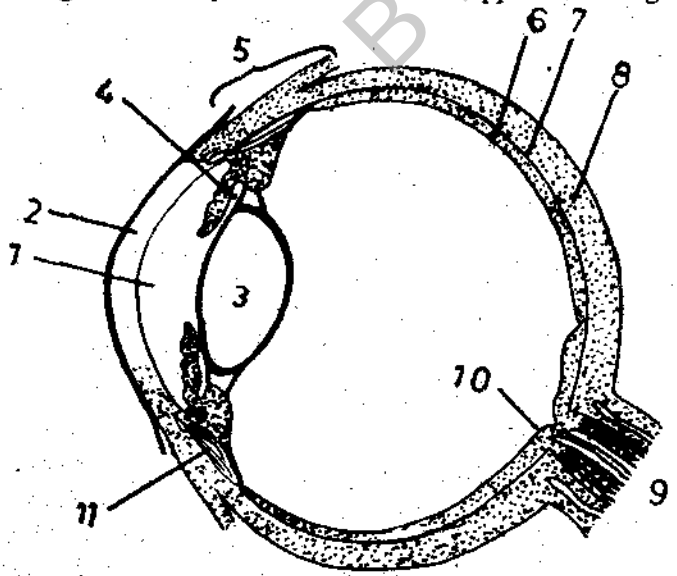


Fig. 26.7. Structure of mammalian eye 1. Anterior chamber 2. Cornea 3. Lens 4. Posterior chamber 5. Ciliary body 6. Retina 7. Choroid 8. Sclera 9. Optic nerve 10. Blind spot 11. Ciliary muscle.

The vertebrate eye corresponds very much with a photographic camera, thus there is light proof box, a diaphragm, lens system and a surface sensitive to light. The internal structure of the eye ball can be seen in the vertical section. The wall of the eye ball is composed of the following layers.

1. The outer firm opaque protective, dense white, connective tissue layer is the **sclerotic.** Between the eye lids it becomes transparent and is bulged out to form the **cornea.** It is to this sclerotic layer that the six muscles responsible for moving the eye ball are attached.

2. The sclerotic is lined by a vascular, muscular and deeply pigmented second layer, made up of connective tissue, the spongy **choroid.** In the region of the cornea it is not continuous with it but forms a sort of curtain stretched across the eye ball, the **iris.** The blue, black and brown colour of the eye is due to the colour of the iris. The iris is perforated by an aperture of variable size the **pupil.** The diameter of the pupil is controlled by two sets of muscles in the iris. The **circular muscles** of the iris by their contraction decrease the diameter of the pupil. The radial muscle by their contraction increase the diameter of the pupil. Thus iris regulates the amount of light entering the eye ball. Lying in the outer margin of the iris of the choroid coat is the **ciliary body.** This is a thickened zone of the choroid which contains larger blood vessels, glands and smooth muscle fibres.

3. The inner most coat of the eye ball is the **retina.** It does not form a complete lining for the eye ball. It is continuous only as far as the iris. It is the sensitive layer which contains nerve cells. The retina is a complex structure but it is only three neurons deep.

Immediately behind the iris lies the **lens,** a transparent biconvex and elastic body. It is attached by the margins of its transparent capsule to the ciliary body by the fibrous **suspensory ligaments.** There are radial and circular muscles in the ciliary body. When the radial muscles contract the lens is flattened. But when the circular muscles contract it assumes a more spherical shape, thus can aecommodate for near and distant object.

Between cornea and iris is the anterior chamber and between iris and the lens is the **posterior chamber.** They together form **aqueous chamber** filled by a transparent watery aqueous humour. While the chamber behind the lens is **vitreous chamber.** It contains a jelly like transparent **vitreous humour.** In the vitreous humour is the remnant of an embryonic blood vessel. It extends from the blind spot in retina to the back of the lens. Hence it perforates the vitreous **humour.**

26.8.2.1 Structure of retina

Beginning from the outside i.e., next to choroid and passing inwards, the retina is composed of the following layers :

(a) **Pigment epithelium.** It is a single layer of polygonal epithelial cells. The cells contain pigment granules. Functionally it absorbs light, prevents reflection.

(b) Beneath this pigmented cells lie the photoreceptor or the visual cells of two types - **Rods and the Cones.** The rods are single cells which bear at their outer end a long slender cylinder. The cylinder contains a a **purple pigments** (visual purple) **rhodopsin** a substance allied to vitamin A containing protein. From the inner end a nerve fibre passes inwards and links up with dendrites of the cells of the next layer. The cones possess short tapering processes and contain (visual violet) iodopsin. A nerve fibre arises from the inner end of each cone as in the rods.

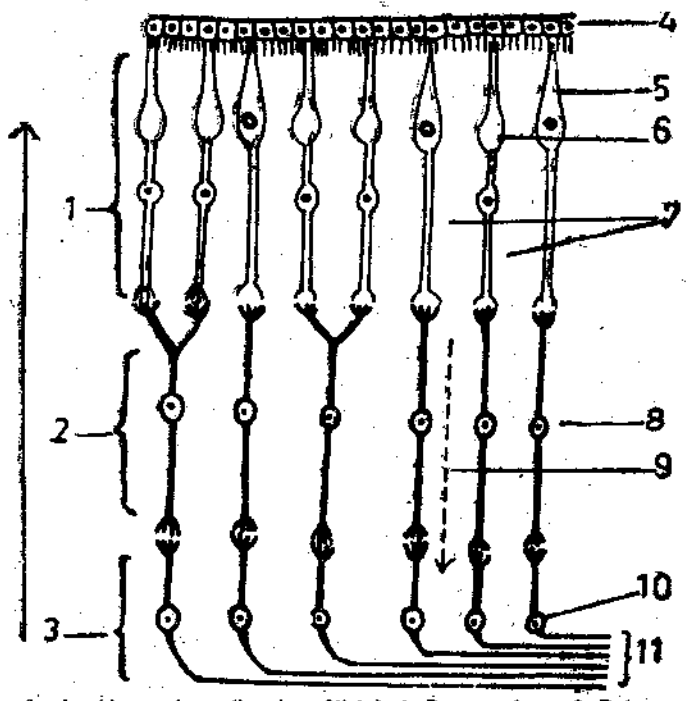


Fig. 26.8. Section of retina (Arrow shows direction of light). 1. Receptor layer 2. Relays nerve impulse 3. Impulses relayed to centres in brain 4. Pigments cells 5. Cone cell 6.red cell 7. Position of packing and supporting neuroglial cells 8. Bipolar neuron. 9. Direction of impulse 10. Ganglion cell 11. Fibres converging to form optic nerves.

(c) After the layer of the rods and cones, there is a layer of bipolar nerve cells, which in turn by their very short axons, relay the nerve impulses received from the visual cells to next inner layer

(d) the inner most layer consists of large ganglion cells. Their axons are the component fibres of the optic nerve

In addition to the nervous components of the retina described above there are packing and supporting cells lying in between the essential components. They are the neurogial cells and the important cells termed **Muller's fibres.**

The rods detect difference in the intensity of light but they do not discriminate finer details of objects. They are concerned with **"twilight vision".** Thus the eyes of nocturnal animals and those living in darkness and deep waters have only rods in the retina. The cones are concerned with the reception of stimuli of high intensity, **"day light vision".** They as well discriminate colours and are associated with colour vision. An imaginary line passing through the centre of the lens will strike the retina at a point described as the **yellow spot** containing **fovea centralis.** This is mostly composed of the cones. The vision is sharpest at this spot. The part of the retina where the fibres of the optic nerve converge is called the **blind spot.** It is a non-sensory region where no image is formed.

The light rays which pass through the conjunctiva, cornea, aqueous humour, the lens and the vitreous humour fall on the retina. All the above structures offer transparent media to the light rays. The lens plays an important part in accommodation and focusing the light rays on the retina where a diminished inverted image is formed at the site known as fovea centralis. The impulses are transmitted through the optic nerve to the brain due to which we can have the sense of vision with the actual size and correct posture of the object.

In addition to the ear and the eye which are important sense organs, a mention is to be made about other receptors. The entire skin of rabbit is sensory and acts as the **tangoreceptor**

i.e., it is sensitive to the touch and other stimuli. The tongue is provided with taste-buds, which appreciates various tastes. Tongue is thus a **gustatory organ.** The nasal epithelium of the nose is receptive to the olfactory sensation, **Olfactoreceptor.** Smell and taste are closely allied senses.

26.9. SUMMARY

The nervous system can be classified into central, peripheral and autonomic nervous systems. Mammalian brain shows its peak particularly the cerebrum with its neopallium cerebral cortex's and carebellum with its vermis and two ventrolateral flocculi. Mid brain represented by corpora quadrigemina. Peripheral nervous system comprise of the cerebral (12 pairs) and spinal (37 pairs) nerves. The autonomic nervous system comprises of sympathetic (adrenergic) and parasympathetic (Cholinergic) components which are antagonistic to each other. * The living nerve is said to be polarised. On stimulation, the live nerve gets depolarised (change reversal) to give rise to action potential (nerve impulse) which will be propagated along the nerve fibre. A nerve impulse can never be stopped (all or none law). * Mammalion ear is highly unique in several respects viz., pinna, ear ossicles and cochlea. The cochlea is elongated and coiled with the organ of Corti which is the organ of hearing while the semicircular canals with cristae and maculae utriculi and saculi are the auditory organs.

As usual, the eye has 3 coats, outer tough **fibrous coat,** middle vascular **uvea** and the inner sensory **reina.** The mammalian retina in formed of rods ad cones containing rhodopsin visual purple) and iodopsin (visual violet) respectively for dim and bright (& colour) vision. Area centralis, is mostly composed of cones. The hereditary diseases, night blindness and color blindness are the respective deficient conditions of rhodopsin & iodopsin.

26.10 MODEL EXAMINATION QUESTIONS.

I. Answer the following in about 30 lines.

1. Sketch the dorsal and ventral aspects of the brain of rabbit. Write a note on its characteristic features.
2. Describe the structure of the brain of rabbit. Enumerate the functions of its various parts.
3. Give an account of the structure and functions of the mammalian ear.
4. Describe the structure of the eye. Add a note on physiology of vision.
5. What is nerve impulse ? How it is transmitted ?

II. Answer the following in about 10 lines.

1. Describe the cranial nerves of rabbit.
2. What are the important functions of brain ?
3. What is reflex action ? Add a note on reflex arc.
4. Give a brief account on the autonomous nervous system.
5. Describe the structure of retina.

Unit - 27 RABBIT–RESPIRATORY SYSTEM

Contents

27.1 OBJECTIVE

- To describe the respiratory system of rabbit and to explain its function.

27.2 INTRODUCTION

For any living organism, energy is essential to carry out various vital activities. Energy is obtained in the living bodies by burning food stuff (fuel). For this, oxygen is needed. In vertebrates, special organs, the lungs have developed to deliver oxygen to the various tissues via blood. In Amphibia and Reptilia, they are accular while in birds and mammals, they are spongy textured non distensible lobes. In mammals, voice box is associated with it. Further the passage is also separated from the food passage in amniotes. The lungs are better evolved with alveoli.

27.3 RESPIRATORY SYSTEM

External nares lead to the nasal passage which is divided into right and left chambers by means of a mesethmoid partition. The epithelium covering the nasal passages is ciliated and prevents the dust particles from entering into the lungs. The nasal passages open into the pharynx by means of the internal nares. From the pharynx, the air passes into the trachea or wind pipe through a glottis which is a slit like aperture present on the ventral wall of the pharynx.

27.3 LARYNX

At the anterior extremity of the trachea there is a chamber called the larynx (Fig. 27.1). It communicates with the pharynx through glottis. Larynx is supported by cartilagenous pieces. A large thyroid cartilage support the ventral and lateral walls of the larynx. A cartilagenous flap like epiglottis arises from the ventral wall of the thyroid cartilage and protects the glottis. It prevents the food from entering the glottis during swallowing. A ring like **cricoid cartilage** lies at the posterior end of the thyroid cartilage. It is broad at the dorsal side but narrow on the ventral side. A pair or **arytenoid cartilages** support the dorsal part of the larynx. A

pair of small nodules, the cartilages of Santorini are situated at the apices of the arytenoids. The vocal cards extend between the thyroid cartiiage and the arytenoids.

Two pairs of vocal cords are stretched dorsoventrally in the laryngeal cavity : one pair extending between anterior part of thyroid and posterior part of any tentenoids are called the true vocal cords. Another pair extends between the anterior ends of the arytenoide and thyroid cartilages; these are called as paleovocal cords.

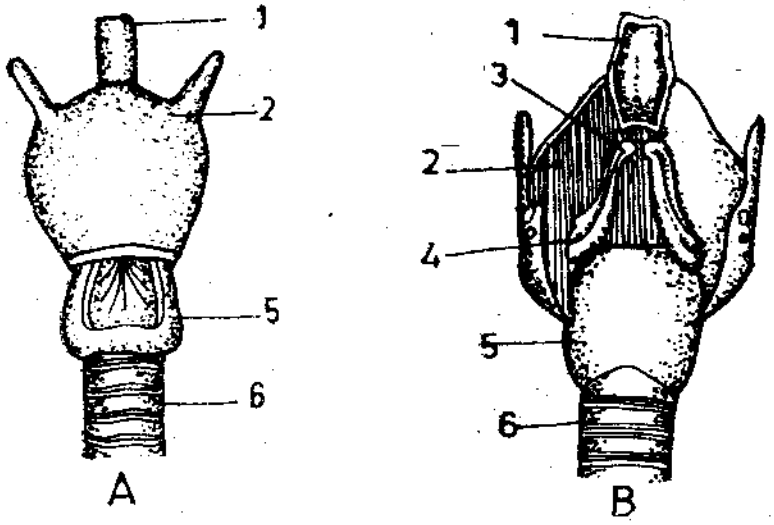


Fig. 27.1 Rabbit-Trachea and Larynx. A. Dorsal view. B. Internal structure

Larynx is essentially a mechanical valve at the entrance to the airway. It has capacity to regulate the air flow from and to the bronchial passages and lungs in response to physiological changes. The trachea extends from behind the larynx. It is a long tube supported by the cartilagenous rings which are incomplete on the dorsal side. It runs through the neck, just below the oesophagus, and enters the thoracic cavity, where it divides into a right and a left bronchus, which enter the respective lung.

27.3.2 Lungs

Lungs are paired, pinkish and spongy masses of tissue lying in the pleural cavities of the thorax. Each pleural cavity forms the lateral portions of the thoracic cavity. The two pleural sacs are separated by a space called the mediastenum, which encloses in it the heart, oesophagus, the arteries and veins of the thoracic region.

Each lung is a lobed structure. They are, in all, six lobes, four in the right lung and two in the left lung. The lobes of the right lung are (i) anterior azygos. (ii) right anterior (iii) right posterior and (iv) the posterior azygos. The lobes of the left lung are (i) left anterior and (ii) left posterior. Inside the lungs, there is a net work of alveoli. Each bronchus enters into the lung of its side and divides repeatedly to form the alveolar ducts, which ultimately terminate into small dialated air sacs or infundibulum. The walls of air sacs form the hollow air cells or alveoli (Fig. 27.2). The capillary net work of pulmonary artery and vein surround alveoli and facilitate the gaseous exchange (Fig. 27.3). The air passages in the trachea are lined by the ciliated epithelium and mucous glands. They help in the prevention of dust particles and bacteria from entering the lung. These particles are entangled in the mucous and the ciliary action helps in the throwing the entangled particles into the pharynx from where they are thrown out.

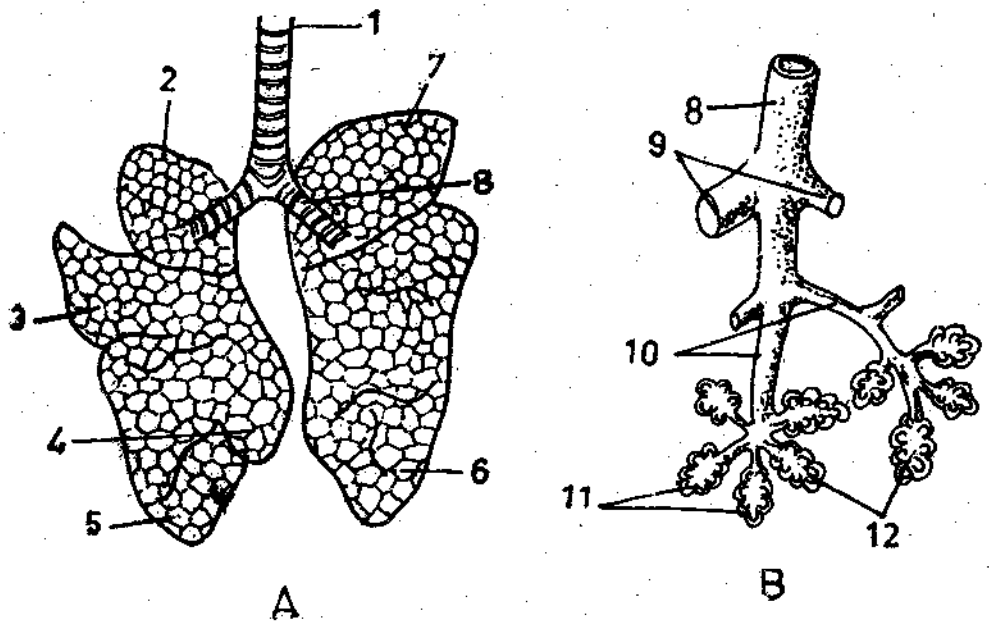


Fig. 27.2 Rabbit. A. Ventral view of lungs with a part of trachea. B. Terminal branch of bronchus. 1. Trachea. 2. Anterior azygos. 3. Right anterior. 4. Posterior azygos. 5. Right posterior. 6. Left posterior. 7. Left anterior. 8. Bronchus. 9. bronchioles. 10. Alveolar ducts. 11. Alveoli. 12. Alveolar sacs.

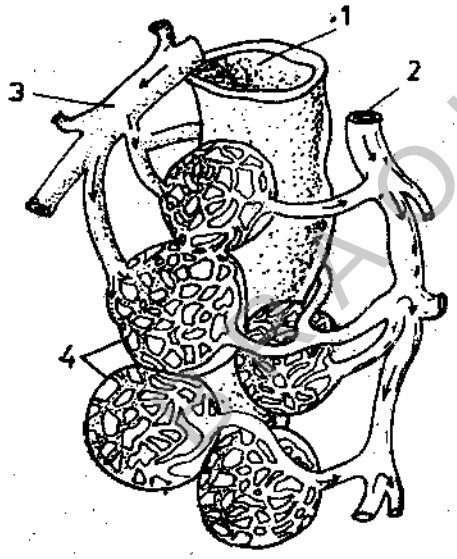


Fig. 27.3 Diagram showing capillary net work around alveolus. 1. Alveolar 2. Part of pulmonary vein. 3. Branch of pulmonary artery. 4. Alveoli showing capillary net work.

27.3.3 Mechanism of breathing

The mechanism of breathing consists of inspiration and expiration Inspiration is the intake of fresh air into the lungs. Expiration is the elimination of respired air out of the lungs.

The diaphrgm, that separates the thoracic and abdominal cavities, the ribs and the inter-costal muscles investing the ribs participate in the process of respiration. There are two pairs of intercostal muscles, the internal and the external (Fig. 27.4). The inspiration is an active process. The external intercostal muscles contract and drag the ribs forward. The diaphrgm is pulled forward and becomes flat. The space in the thoracic cavity increases and the lungs expand. The air flows in through the nasal passages and the trachea, leading ultimately into alveolar spaces. The expiration is a passive process, during which the internal inter-costal

muscles contract and restore the ribs and diaphrgm to their resting position. The thoracic cavity is reduced and the pressure on lungs forces the air out.

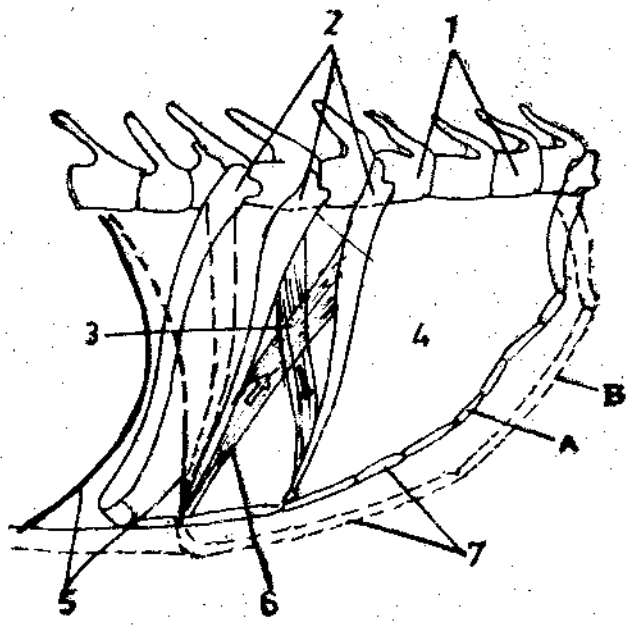


Fig. 27.4. Rabbit-Rib movements during respiration. A. Normal position.B During inspiration. 1. Vertebrae 2. Ribs 3. Internal inter-costal muscles 4. Thoratic cavity 5. Diaphrgm. 6. External inter-costal muscles 7. Sternum.

27.3.4 PHYSIOLOGY OF RESPIRATION

The gaseous exchange at the alveoli involves the intake of oxygen into the blood and the passing out of carbondioxide. The oxygen, thus taken, is carried by the blood to the body tissues where it is used in the oxidation of food stuffs liberating energy and other metabolic wastes. The respiratory of pigment present in the red blood cells helps in carrying O_2, from lungs to the tissues and Co_2 from tissues to the lungs.

Respiratory pigment and its role in carrying O_2. and CO_2

Hemoglobin (Hb) is the respiratory pigment. It is a conjugated protein. One important property is its affinity to combine with oxygen to form an easily dissociated compound known as oxyhaemoglobin (HbO_2). When the oxygen tension is high as it occurs in lungs the haemoglobin molecule picks up oxygen, but under low oxygen tension in tissues it readily gives away the loosely bound oxygen molecule to the surrounding medium. This property helps in carrying the oxygen from lungs to tissues.

Each hemoglobin molecule carries four oxygen molecules when fully saturated. In the lungs, the capillaries of pulmonary arteries surrounding the alveolar spaces contain low oxygen, where as the air in lungs contains about 21% of oxygen and has high oxygen tension, as a result the oxygen diffuses into the blood capillaries and the haemoglobin, present in the red blood corpuscles readily picks up the oxygen molecule. The CO_2 molecule is let out into the alveolar space.

In the tissues the partial pressure of oxygen is low but that of carbondioxide is high. The oxygen bound to the haemoglobin is readily given off. The carbondioxide produced in the metabolic processes in the tissues enters plasma and is hydrated slowly to form the bicarbonate ions (HCO_3).

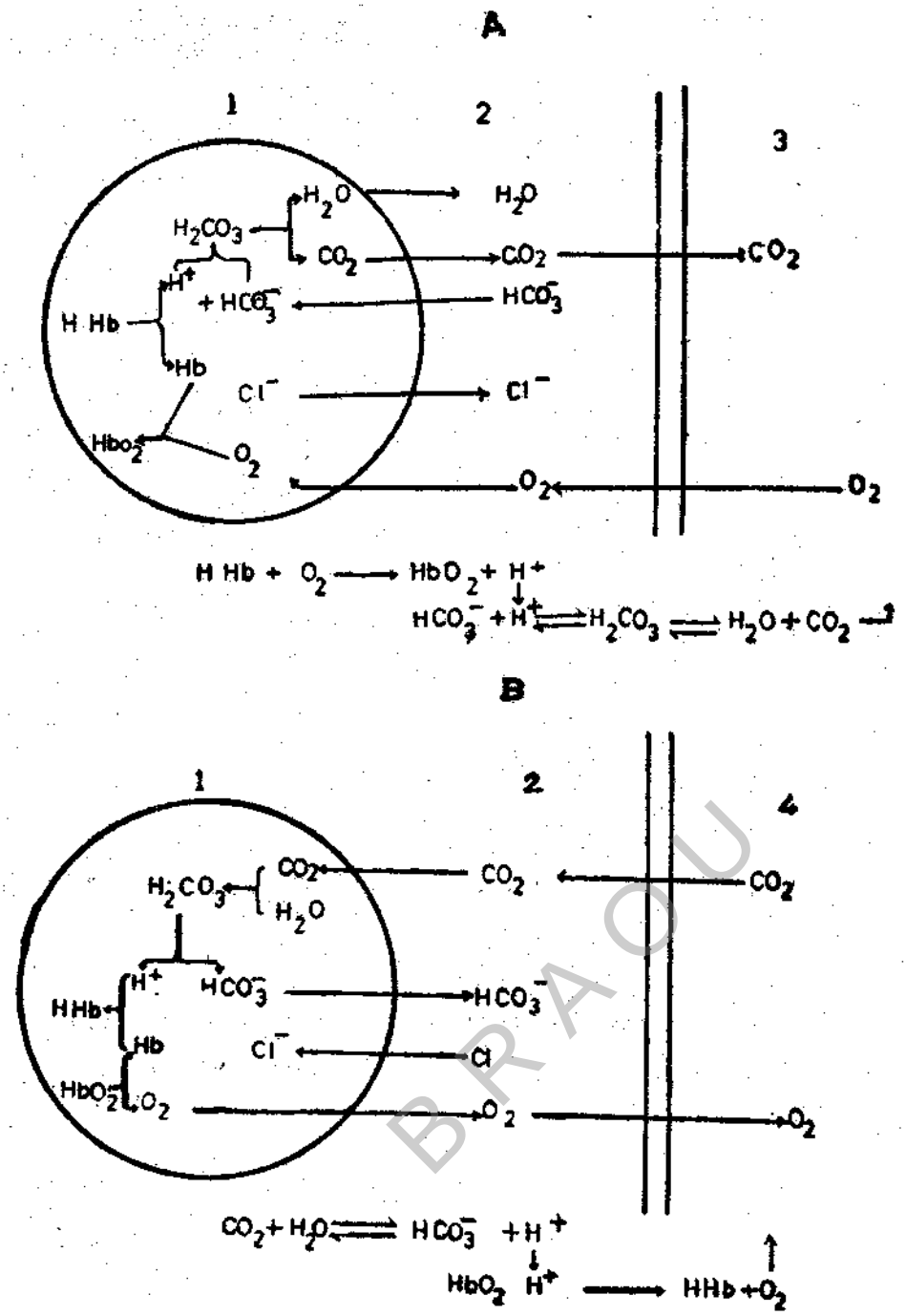


Fig. 26.5 Events in transport of oxygen and carbondioxide. A. in lungs. B. In tissues. 1. Red cell. 2. Plasma. 3. Alveolar space (Air) 4. Tissue fluid

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+HCO_3^-$$

This process is accelerated in the red cells by an enzyme called the carbonic anhydrase. The protons produced in the reaction are buffered by the haemoglobin which forms the reduced haemoglobin. The surplus bicarbonate ions produced in the reaction diffuse into the plasma, and chloride ions move into balance the ionic composition. When the venous blood is

oxygenated, the chloride ions shift back in to the plasma and the bicarbonate ions shift back into red cells. The oxygen entering the cells combines with haemoglobin and releases protons, which combine with bicarbonate to release carbondioxide and water under the influence of carbonic anhydrase and the carbondioxide so released diffuses out into the lungs.

The events in the transport of oxygen and carbondioxide are depicted in figure 27.5.

27.4 SUMMARY

The respiratory system of rabbit includes the wind pipe (trachea) and lungs. The glottis is guarded by the epiglottis. The trachea is supported by the incomplete cartilagenous rings. The right lung consist of 4 lobes while the left one is bilobed. Each branch divides repeatedly into bronchioles, alveolar ducts and alveoli. The alveoli with capillary network allows passive gases exchange. Diaphrgm and the external intercostal muscles help in inspiration actively while their relaxation and the contraction of the internal intercostal muscles bring expiration. In human lung, about 75 crore alveoli, amounting to 100 sq. m. area, have been estimated.

The larynx (voice box) is the proximal dilation of the trachea. It is supported by the thyroid cartilage ventro-laterally and with a cricoid, posterior to the thyroid and a pair of arytenoid cartilages dorsally with cartilages of Santorini at their tips.

27.5 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Describe the structure of lungs and physiology of respiration in rabbit.

II. Answer the following in about 10 lines.

1. Give a brief account on larynx in rabbit.
2. What is haemoglobin? Explain its role in carrying O_2 and CO_2
3. Mechanism of breathing.

UNIT – 28 RABBIT - CIRCULATORY SYSTEM

Contents

28.1 OBJECTIVES

- To expain the structure and functioning of heart and the details about blood circulation in the body.

28.2 INTRODUCTION

Circulatory system of rabbit consists of heart, arteries and veins. It is a **double circulation,** and the oxygenated and deoxygenated blood circuits are separated completely.

The heart is situated in the thoracic cavity and lies on the left side of **mediastinum,** a space enclosed in between the two plural sacs enclosing the lung (Fig. 28.1). It is surrounded by a double walled pericardium enclosing the pericardial fluid.

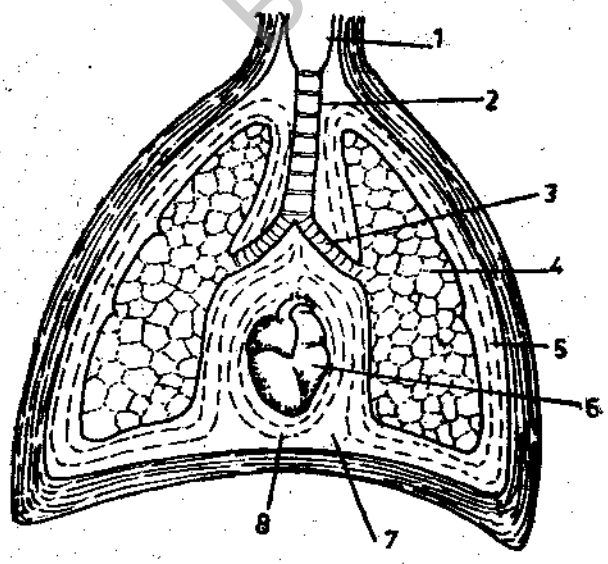


Fig 28.1 Mediastinum showing the location of heart. 1. Larynx. 2. Trachea 3. Bronchus 4. Lung 5. Pleural cavity 6. Heart 7. Meidastinum 8. Pericardium

28.3 BLOOD

The blood is a fluid connecting tissue containing the fluid matrix, plasma and several types of corpuscles. The red blood cells are biconcave and anucleated in mammals (except in camel). The fluid tissue is mainly responsible for supply of oxygen, nutrients, hormones, disposal of carbon dioxide and for body temperature regulation. The blood pigment is **Haemoglobin.**

28.4 STRUCTURE OF HEART

The heart is a conical structure containing two auricles and two ventricles (Fig. 28.2). Auricles are smaller than ventricles and have thicker walls. The two auricles are separated by an inter auricular septum. The right auricle on its dorsal side receives blood from the right and left precavals, which bring blood from the anterior region and the post caval bringing blood from the posterior region of the body. A membranous fold, the remnant of embryonic **eustachian valve** guards the opening of post caval. The left precaval is guarded by the **besius valve,** which is a crescentic fold. The right auricle opens into the right ventricle through the right **auriculo ventricular aperture.** This aperture is guarded by a tricuspid valve, which prevents the backward flow of blood from ventricle to a auricle. The **tricuspid valve** contains three membronous cusps, which are attached to the muscular processes of the wall of the ventricle by means of tendons called the **chordae tendineae.** The muscular processes of the wall of ventricles are known as the **musculi papillares.** The chrodae tendineae allow the valves to be pulled into the ventricle, but when the ventricle contracts, the three cups close the auriculo ventricular aperture and prevent the backward flow of the blood into the auricle. From the left anterior angle of the right ventricle arises the pulmonary aorta Its opening is guarded by three pouch like **semilunar valves.**

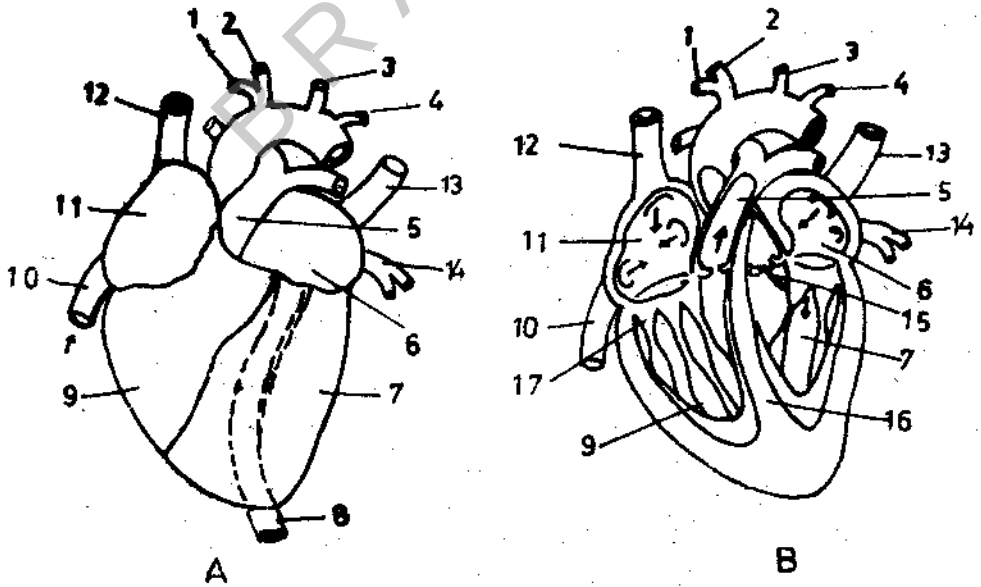


Fig. 28.2 Rabbit-Heart A. Ventral view. b. Internal structure. 1. Right subclavian. 2. Right common carotid. 3. Left common carotid. 4. Left subclavian. 5. Pulmonary artery. 6. Left auricle. 7. left ventricle. 8. Dorsal aorta 9. Right ventricle. 10. Post caval vein. 11. Right auricle. 12. Right precaval. 13. Left precaval vein. 14. Left pulmonary veim. 15. (bicuspid) 3Semilunar valves of the aorta Semilunar valve. 16. Right Septum 17. Auriculo ventricular valve. (tricuspid).

The left auricle receives the oxygenated blood from the lungs by the pulmonary veins. The right and left pulmonary veins open together into the left auricle on its dorsal side. The left auricle opens into the ventricle through a large left auriculo- ventricular aperture, which is guarded by a **bicupsid valve**. it is also known as **mitral valve**. It containes two membranous cusps attached, with chordae tendinear, are raised into the ventricle ridges known as the **columnae coroae.** They are more strongly developed in the left ventricle than in the right ventricle. The left ventricle is larger. The systemic aorta arises from the anterior angle of the left ventricle. Its opening is also guarded by the three **semilunar valves.** Similar to those found at the entrance of pulmonary artery.

28.5 FUNCTIONING OF HEART AND REGULATION OF HEART BEAT

The heart beat is a regular and rhythmic cavity. The contraction of heart is known as the **systole**, while the relaxation is the **diastole.** The systole and diastole constitutes a heart beat systole and diastole movements are wave like motions and are controlled by special centres. In the dorsal wall of right auricle, there is a centre of specialized tissue, called the **sinu auricular node.** This acts as the pace maker from which the heart beat originates. From this the excitation waves are transmitted along with the **purkinje fibres** of the auricular wall. The two auricles contract almost simultaneously. The **auriculo ventricular node** lying at the base of the right auricle but close to the interauricular septum gives off two fibres, the right and left branches which penetrate the wall of the ventricle and break up into numerous conducting fibres of the Purkinje net work. These branches are called the **bundle of His.** When the excitation waves reach the auriculo ventricular node, it is passed on simultaneously to the right and left ventricle through these fibres and the two ventricles contract almost simultaneously.

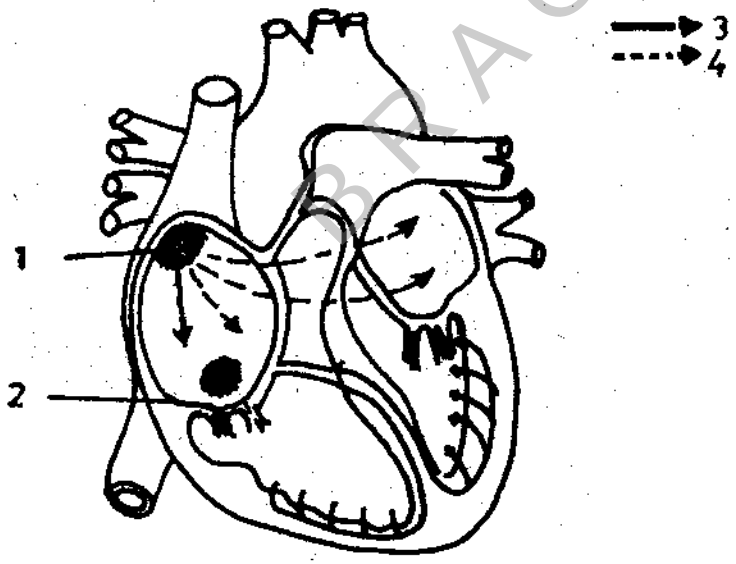


Fig. 28.5 Longitudinal section of the mammalian heart showing the sinu auricular and associated purkinje fibres.1. Sinu auricular node. 2. Auriculo-ventricualr node. 3. Purkinje fibres of atrium. 4. Purkinje fibres of ventricle.

Although the heart beat is a **myogenic** and beat is initiated at the **sinu auricular node**, is also innervated by two types of nerves, the sympathetic and parasympathetic which are antagonistic in their action.

Vagus is the parasympathetic nerve innervating the heart. Its branches end at sinu-auricle node. When the vagus nerve sends impulses to the heart the rate of heart beat slows down.

The sympathetic nerves have many endings among the muscles of heart beat but the nerve endings are concentrated in the sinu auricular and a arriculo- ventricular nodes. The rate of heart beat increases due to the action of sympathetic nerves. These two nerves acting on the heart provide for feedback loops and the heart beat can be regulated very rapidly by balancing the activity of two nerves.

28.6 ARTERIAL SYSTEM

The aorta takes the oxygenated blood from the left ventricle to the body. The coronary arteries arise just at the base of the aorta and supply

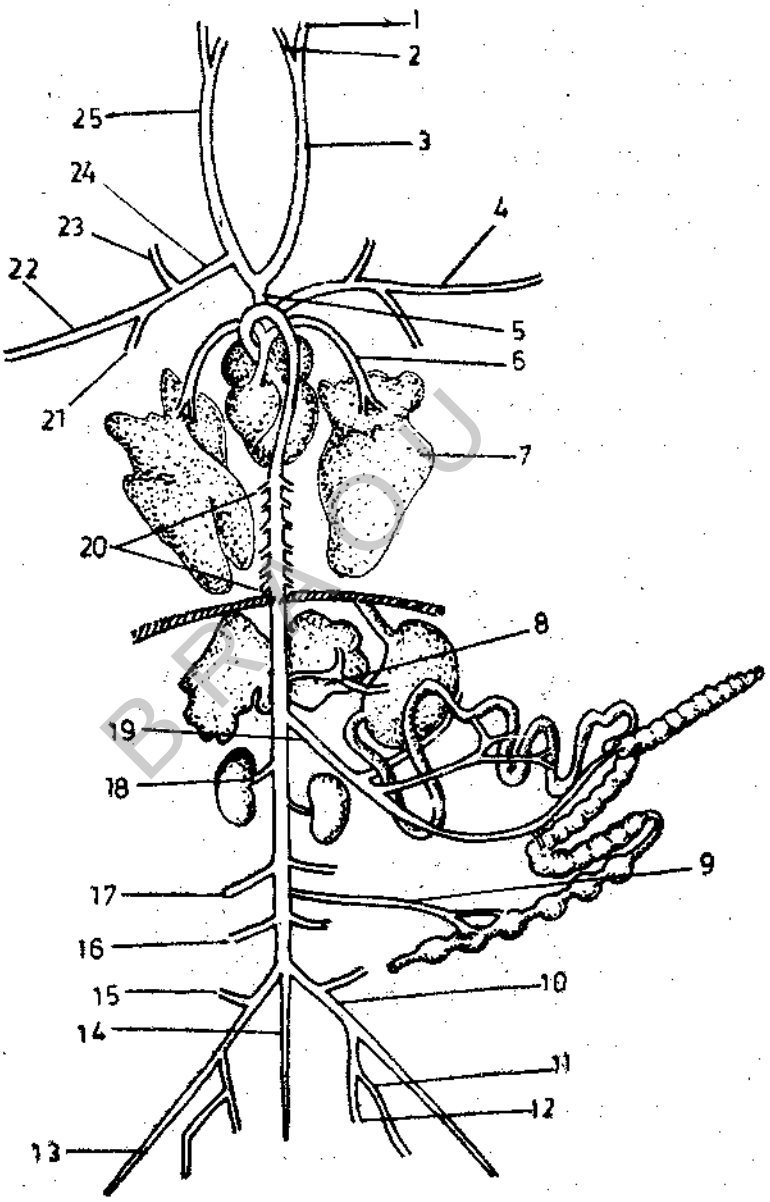


Fig. 28.3. Rabbit - Arterial system. 1. External carotid.2 Internal carotid. 3. Left carotid. 4. Left subclavian. 5. Innominate. 6. Pulmonary artery. 7. Lung 8. Coeliac . 9. posterior mesenteric. 10. Common iliac. 11. Internal iliac. 12. Vesicular. 13. Femoral. 14. Caudal. 15. Ilio-lumber. 16. Lumbar 17. Gonadial. 18. Renal. 19. Anterior mesenteric, 20. Inter costals. 21. Internal mammary 22. Branchial. 23. Vertebral. 24. Right subclavian 25. Right common carotid.

blood to the heart. The aorta first runs forward to form an arch and then bends towards the left side and passes backwards along the middorsal line close to the vertebral column to become the dorsal aorta (Fig. 28.3). Within the thoracic region, the aortic arch gives rise to;

i. An **innominate artery** which divides immediately to give rise to the **right subclavian** and the **right common carotid**. The right subclavian supplies blood to the right forelimb. The right cartoid artery passes upto the neck and divides into the **internal carotid** artery which supplies blood to brain and **external carotid** artery which supplies blood to the head and facial region.

ii. The **left common carotid artery** arise directly from the innominate from the aorta just after the innominate artery. It runs upto the region on the left side and divides into the left internal and external corotids. There is a carotid sinus at the base of internal carotid both on the right and left sides. It contains baroreceptors and recognizes the changes in the blood pressure.

iii. The **left subclavian artery** arises independently from the dorsal aorta and supplies blood to the left forelimb.

iv. Behind the origin of left subclavian, the aorta runs round the left bronchus to become the dorsal aorta which runs along the middorsal line just beneath the vertebral column. Within the thoracic region, the dorsal aorta gives off paired intercostal arteries, which supply blood to the intercostal muscles of the ribs.

In the abdominal region the dorsal aorta gives off:

i. the **coeliac artery** which supplies blood to liver, stomach and spleen,

ii. the **anterior mesenteric**, which supplies blood to the intestine and pancreas,

iii. the **renal artery** supplying to the kidney.

iv. the **gonadial artery** supplying to the gonad.

v. the **posterior mesenteric artery**, which supplies to hinder part of colon and the rectum.

vi. a series of **lumbar arteries** which supply to the side walls of the abdominal cavity.

vii. the **iliac arteries** which supply to the pelvic cavity and hind limbs.

viii. the **caudal artery** which supplies blood to the caudal region the pulmonary aorta which arises from the right ventricle, divides into two arteries and supplies deoxygenated blood to the two lungs.

28.7 VENOUS SYSTEM

As already explained three venacavae, bring blood to the heart and empty into the right auricle. There are two **precavals** (the right and left) and a **postcaval** (Fig. 28.4).

Each precaval is formed by the union of the **external jugular, internal jugular,** and the **subsclavian veins**. The external jugular collects blood from the head and facial region. The internal jugular collects from the neck and the brain region. Posteriorly the internal jugular is connected to the external jugular. The external jugulars of the right and left side are connected to each other by a **jugular anastomosis**. The subclavian vein collects blood from the fore limb. The right precaval receives blood from the **intercostal vein** bringing blood

from the anterior intercostal spaces and also receives an **azygos vein** bringing blood from the posterior intercostal muscles of the two sides and the lumber region. The left precaval receives the blood from the small coronary veins of the heart.

The post caval vein commences at the posterior end of the body in the **caudal vein**, it runs anteriorly and receives blood from:

i. a pair each of **internal** and **external** iliac veins bring blood from the thigh region.

ii. a pair of **ilio lumber veins** from the hinder part of the abdominal wall.

iii. a pair of **gonadial veins** from the gonads.

iv . a pair of **renal veins** from the kidney, and renal portal system being absent and

v. **hepatic veins** from the liver.

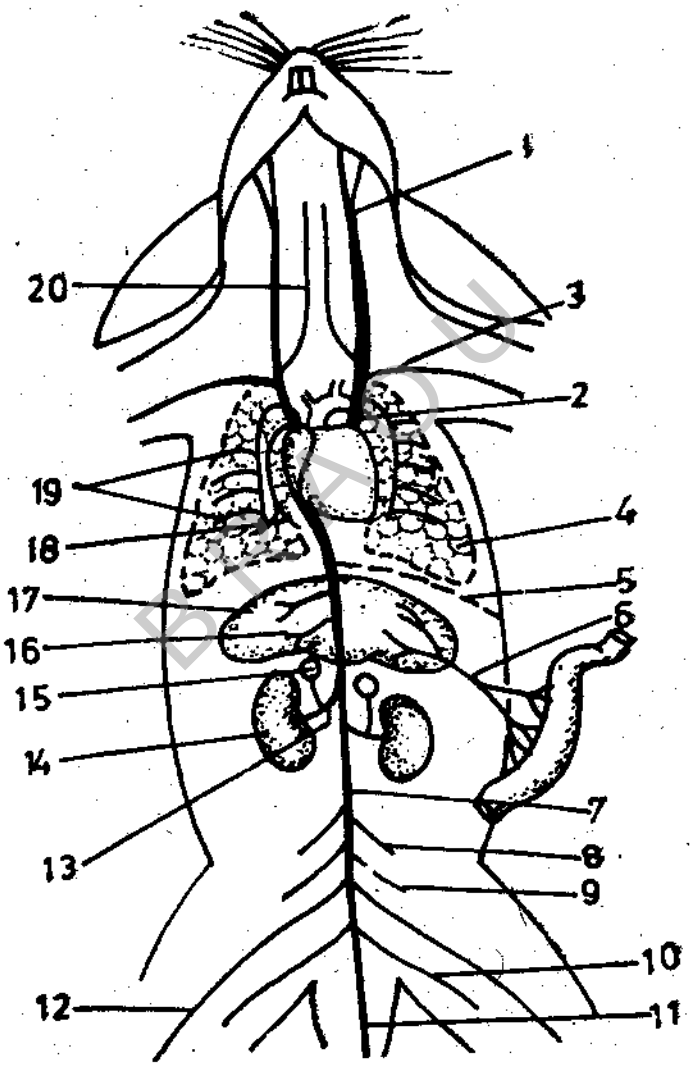


Fig. 28.4 Rabbit-Venous system. 1. External jugular vein. 2. Precaval vein 3. Subclavian. 4. Lung. 5. Diaphragm. 6. Hepatic- portal vein. 7. Postcaval vein. 8. Gonadial vein.9. Ilio-lumber vein. 10. Caudal vein. 11. Internal iliac. 12. Femoral. 13. Renal. 14. Kidney. 15. Adrenal body. 16. Hepatic vein 17. Liver. 18. Azygos vein (vertebral). 19. Intercostal vein 20. Oesophagus 21. Internal jugular vein.

The postcaval then passes through the diaphragm along mediastenum and opens into the right auricle.

The blood from the digestive tract is collected by **hepatic portal system** which opens into liver and from there the hepatic veins carry the blood to the postcaval. The principal veins of the hepatic portal system are the **lineo gastric, duodenal, anterior mesenteric and posterior** mesenteric which unite to form a single, large portal vein. Thus hepatic portal system is well developed to facilitate conversion of nitrogenous wastes and excess sugars from the blood before reaching the heart.

The **pulmonary veins** bringing blood from the lungs meet on the dorsal side of the left auricle and opens through a common aperture.

28.8 THE COURSE OF BLOOD CIRCULATION

The right auricle receives the deoxygenated blood from the three venacavae, two precavals and one post caval. The left auricle receives oxygenated blood from the lungs. When the auricles contract the blood flows into the right and left ventricles. When the ventricles contract the tricupsid and bicupsid valves are closed and the deoxygenated blood from right ventricle enters the pulmonary artery passing through the semilunar valves which takes blood to the lungs. The blood from the left ventricles enters the aorta to be circulated to the body parts. the oxygenated and deoxygenated blood are separated completely in the heart and there is no mixing of the blood in the arteries (Fig. 28.6).

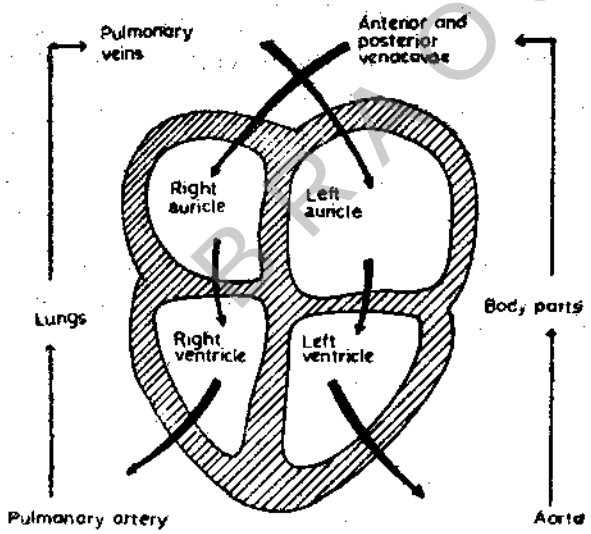


Fig. 28.6 Course of blood circulation.

28.9 SUMMARY

The amniote heart is devised to keep the arterial and venous blood separate. The thick walled ventricle is separated into right and left chambers by developing interventricular septum; however, it is incomplete in Reptilia except in crocodilia. The mammalian heart is characterised by the presence of a right alviculo ventricular tricuspid valve. Only left systemic arch persists as aorta in the adult mammal. Renal portal system has totally faded away in mammals while

the hepatic postal system is well developed to remove urea and excess sugars from the blood before reaching the heart.

The systole and a diastole constitute a 'heart beat. Though the heart is myogenic it is innervated by the sympathetic and the parasympathetic nerve fibres. The pace maker is situated in the sinuauricular node (rt. auricle SA node) where from the heart contraction initiates. The wave of contraction spreads through **purkinje net work** of fibres, called bundle of HIS. The wave of contraction spreads from right auricle to left auricle where from at spreads to right ventricle and then to left ventricle. The rabbit heart beats about 200 times in a minute while the human heart beats only 72 times per minute.

28.10 MODEL EXAMINATION QUESTIONS

I. **Answer the following in about 30 lines.**

1. Describe in detail the structure and function of rabbit heart.
2. Describe briefly the arterial system of rabbit
3 Describe briefly the venous system of rabbit

II. **Answer the following in about 10 lines.**

1. Describe the arterial system of rabbit.
2. Describe the venous system of rabbit.
3. What do you mean by double circulation?
4. Describe the functions of heart and regulation of heart beat.
5. Hepatic portal system.

UNIT 29 : RABBIT - URINOGENITAL SYSTEM

Contents

29.1 OBJECTIVE

- Urinary and genital organs of mammals are discussed. The removal of the toxic nitrogenous wastes from the body is also discussed.

29.2 INTRODUCTION

The excretary and genital organs are closely associated and therefore, the two systems are studied together. The kidney is metanephric, compact and bean shaped located dorsally. Mammals are ureotelic and henle's loop is well developed to conserve water. In the evolution of vertebrates, we will further notice absence of cloaca, seperate openings of the genital ducts and ureters in females while in males the ureters join vasadeferens to form urethra. Mammals are rather unique in ensuring safe and harmonius growth of the young by developing a highly specialised and conditioned chamber,the uterus. The uterus prepares to receive, implant and maintain the embryo in the event of fertilisation. If the ovum fails to be fertilised, the uterus regresses to its normal position. Such periodic cycles are called oestrous cycles, which are unique to mammals.

29.3 EXCRETORY SYSTEM

The mammalian kidney is metanephric. They are a pair of dark red bean shaped bodies situated in the anterior part of the abdomen. They are suspended by mesenteries on either side of the vertebral column. The kidneys are asymmetrical in position, as the left kidney lies behind to right one. This disposition may be due to the position of stomach on the left side, pushing the left kidney backwards. The kidney has an outer smooth convex surface and inner concave, with a notch, the **hilus**. From the hilus the ureter runs backwards to open into the **urinary bladder**. The ureter at the point of its origin from the kidney is slightly expanded and flattened. This part is called as **pelvis**. The renal artery and the renal vein enter the kidney through the hilus.

The mammalian kidney is enclosed in a thin fibrous tissue capsule, the **tunica fibrosa,** enters the renal sinus to blend with similar tissues of the renal pelvis. The sagittal section of the kidney shows an outer **cortex** and the inner **medulla** (Fig. 29.1. A). The medulla towards the hilus is divided into a number of triangular masses called **pyramids.** The cortex is continued inside between the pyramids in the form of renal **columns of Bertini.** The human kidney may have upto twenty pyramids but the kidney of rabbit and carnivores has a single pyramid. The internal end of the pelvis is subdivided into small funnel like divisions called **primary calyces** each of which is further subdivided into **secondary calyces.** The main collecting tubules of the urinary tubules or **nephron** into secondary calyces.

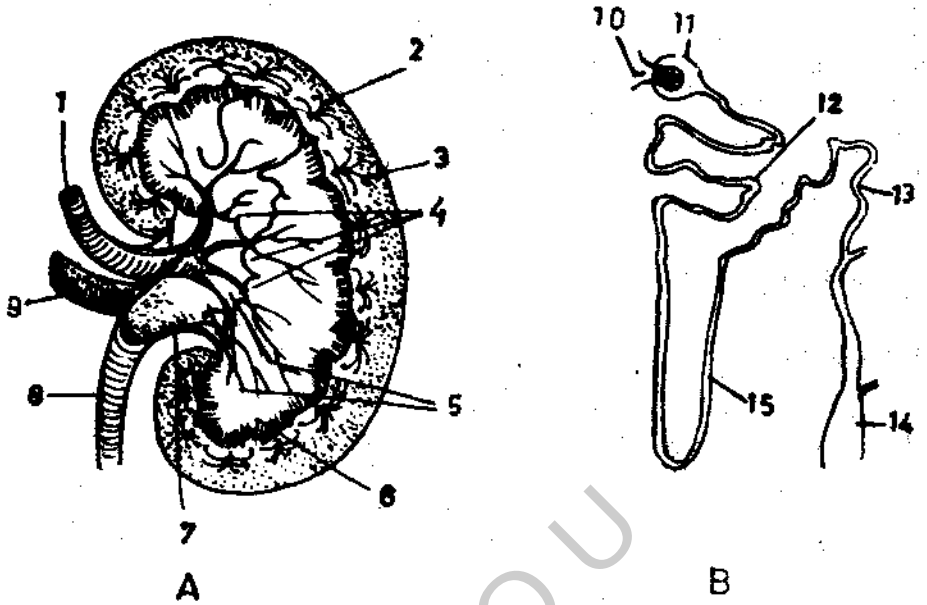


Fig. 29.1. Kidney. Diagram to show the internal structure of kidney of mammal. B. Nephron of mammalian kidney. 1. Rénal artery. 2. Glomeruli in cortex. 3. Cortex. 4. Pyramids. 5. Calyces. 6. Medulla. 7. Hilus 8. Ureter. 9. Renal vein. 10. Glomerulus. 11. Bowman's capsule. 12. Proximal convoluted tubule. 13. Distal convoluted tubule. 14. Collecting tubule. 15. Loop of Henle.

Each kidney is made up of numerous functional units called **naphrons or uriniferous tubules.** Each human kidney may have about one million nephrons.

29.3.1 Structure of a Nephron

Each nephron consists of two parts (a) **Malphighian capsules** and (b) **Renal tubule** or **convoluted tubule** (Fig. 29.1.B).

(a) **Malphighian Capsule :** It is the anterior most part of the nephron. It is found in the cortex. The malphighian capsule has two parts. (a) An invaginated double walled cup the **Bowman's capsule** and (b) a knot is made up of blood capillaries called the glomerulus.

Bowman's capsule : It is a dilated blind end of the nephron. it is invaginated to lodge the capillary tuft called glomerulus. The Bowman's two layers consists of simple squamous epithelium.

Glomerulus : It is a capillary tuft which closely fits into the invagination of Bowman's capsule. The afferent arteriole breaks up into about fifty capillary loops, and forms the glomerular tuft. The capillary tuft reunite and forms the efferent arteriole to emerge out of the capsule. The vessel is short and wide, whereas the effernt vessel is narrow and long. This arrangement makes the blood passing from the afferent arteriole via glomerular capillaries into efferent

arteriole, to flow under great pressure. This facilitates **ultra filter action** of blood.

(b) **Renal tubule or convoluted tubule :** The second part of the nephron consists of much convoluted tubule. It is conveniently divided into a) proxial convoluted tubule b) Henle's Loop and c) distal convoluted tubule.

a) **Proxial convoluted tubule** :This is much contorted structure lying in renal cortex. It is lined by cuboidal cells with characteristic brush border.

b) **Henle's loop :** It is characteristic of mammals. It is 'U' shaped loop dipping into the medulla. It is distinguished into a descending limb and an ascending limb. The former is lined by squamous epithelium, while the latter is made up of cuboidal epithelium. The Henle's loop is meant to increase the surface for water absorption. It is well developed in desert animals.

c) **Distal Convoluted Tubule :** This part is lined by cuboidal epithelium without brush border. The diameter of the lumen is larger than that of proximal tubule. The distal convoluted tubule joins with the collecting tubule and the latter opens into the pyramid.

Each tubule is profusely supplied with blood buy the efferent arteriole, whose branches envelops the tubule for proper reabsorption.

Ureters : The ureter are slender, transparent ducts arising from the hilus. They run backwards, bend inwards to open into urinary bladder.

Urinary bladder : It is a median pear shaped sac, with thin transparent and muscular wall. The bladder leads into the urethra. In males the urethra forms the duct of the penis and opens at its tip (a common opening for urinary and genital matter). In female the urethra is short and opens into a vestibule. There is a separate opening of the vagina. In both the sexes the urethra has a sphincter of voluntary muscles that regulates the passage of urine.

29.3.2. Physiology Of Excretion

The nitrogenous wastes are formed by the breakdown of various proteinaceous compounds. The nitrogenous wastes are in the form of ammonia, urea, uric acid and bile pigments. Bile pigments however, are thrown and excreted through faecal material. Ammonia, urea and uric acid are filtered in the kidney. mammals are ureotelics i.e., the chief excretory product is urea. The formation of urine involves three distinct phases.

Glomerular ultra filtration

Ultrafiltration takes place in the malphighian capsule which acts as a biological filter. The afferent arteriole is short and wide. It branches immediately and forms the glomerulus, which leads to the efferent arteriole. When compared to the afferent arteriole, the glomerulus and the efferent arteriole have high blood pressure. The wall of the Bowman's capsule being thin and selectively permeable, allows substances to pass through except proteins.

In each afferent arteriole there appears a thickening containing granulated cells. These constitute juxtraglomerular apparatus. These cells secrete a proteolytic enzyme - renin which causes a rise in the blood pressure. Thus the blood pressure is regulated.

When ultrafiltration takes place, the filtrate contains many soluble substance such as glucose, urea, sodium chloride and other salts besides water. This filtrate is called glomerular filtrate. The blood is now left only with blood corpuscles and blood proteins.

Selective reabsorption

The glomerular filtrate moves backwards by the action of cilia. Some important substances like glucose, amino acids, salts of sodium and potassium and water are reabsorbed by the tubular part of the nephron, which is richly supplied by blood vessels from the efferent arteriole. The reabsorption takes place by diffusion or by active transport. Diffusion being a physical process occurs automatically due to concentration gradient. Active transport on the other hand is a vital process occuring against the concentration gradient, requiring an expenditure of energy. Water is absorbed by diffusion in the proximal part of Henle's loop. The loop of Henle is chiefly concerned with the conservation of water. mammals are the only vertebrates which can produce a markedly hypertonic urine. The desert mammals, which have a longer loop of Henle, produce a particularly concentrated urine.

The formation of hypertonic urine by regulation of water content is explained by the principle **countercurrent multiplier hypothesis.** As the renal fluid flows along the ascending limb, the sodium chloride is actively removed and deposited in the descending limb. Thus the concentration is raised in the descending limb and the fluid in the ascending limb becomes more and more dilute. The term counter - current refers to the fact that the movement of fluid in the descending limb and in ascending limb is in opposite directions.

Tubular secretion

Some important salts are absorbed by the tubules to be released into blood stream. Few substances are added to the filtrate by the secretion of the tubule cells, such as creatinine, potassium and hydrogen ions and ammonia. The filtrate thus modified by resorption and tubular secretion is called urine. The quantity of urine is much less when compared to the glomerular filtrate. The urine is normally light yellow due to a pigment called **urochrome** derived from the break down of haemoglobin. Urine is produced and drained continuously from the nephrons, into pelvis ureter, urinary bladder, urathra and then to the exterior.

29.3.3 Formation of urea

Mammals excrete their nitrogenous wastes in the form of urea. Most of ammonia upper normal conditions is converted into urea. About 80% of total urinary nitrogen is found in the form of urea. Urea is actually formed in the liver. The biosynthesis of urea involves many intermediate stages and the cycle is called **Kreb's Ornithine cycle.**

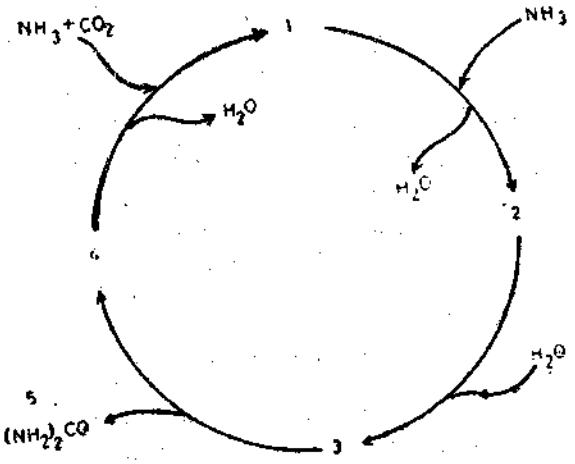


Fig. 29.2. Kreb's ornithine cycle. 1. Citrulline. 2. Arginine. 3. Arginase. 4. Ornithine 5. Urea.

The amine and arginine is broken down by the enzyme arginase (found in the liver) into **urea and ornithine.** The latter combines with ammonia and carbondioxide forming **citrulline.** Citrulline combines with another molecule of ammonia and synthesises **arginine,** which again breaks down into urea and ornithine. By this cyclic repitition more and more urea is formed.

The sources of urea formation are :

a) from deamination of amino acids

b) from salt like ammonium carbonate, loctate etc. in diet.

c) from the amino acid, arginine.

The normal volume of urea in the blood is about 20-40 mg per 100 ml of blood, any excess may indicate malfunctioning of the kidney.

29.3.4 Functions of the kidney.

The kidney apart from being an excretory organ performs the following functions.

1) It plays an important role in homeostasis i.e., maintainance of the internal environment.

2) It extracts nitrogenous waste products.

3) It serves to maintain the pH of body fluids and electrolytes.

4. It acts as an osmoregulatory organ i.e., it maintains water balance of the body.

5) It maintains the optimum concentration of certain blood constituents.

6) It eliminates certain toxic and drug substances from the body.

7) It synthesises substances like ammonia, hippuric acid and inorganic phosphates.

8) Juxtraglomerular cells found in afferent arteriole secrete an enzyme, the renin, which helps in ultrafiltration by increasing the blood pressure.

29.4 REPRODUCTIVE SYSTEM

The sexes are separate in mammals and the reproductive system is well developed.

29.4.1 Male Reproductive Organs

Male genital organs consists of a pair **testes,** a pair of **vasa deferentia, uterus masculinus, urethra** and **penis.** It also includes a number of accessory glands like **postrate glands, cowper's gland,** perennial glands and rectal gland.

Testes :

Testes are pink coloured, oval bodies found in the scrotal sacs. one on each side. The migration of the testes out side the abdominal cavity may be due to its high temperature. which does not favour spermatogenesis. Each testis is attached to the scrotal sac at the hinder end by means of a band of tissue called **gubernaculum.** Each scrotal sac retains its connection with the abdominal cavity through a narrow passage, the **inguinal canal.**

A testis is enclosed in a tough fibrous coat, the **tunica albuginea,** Outer to this a serous membrane, the **tunica vaginalis,** which is found continued over the gubernaculum and then

lines the scrotal sac. The tunica albuginea has a number of ingrowths called septa, which divide the testis into lobules. The lobules contain convoluted **seminiferous tubules.** The seminiferous tubules are the functional units of testes. The inner ends of the seminiferous tubules are straight and unite to form a net work knows as rete testes. From the **rete testes,** fine tubules, the **vasa efferentia** are given off which unite to form a thick convoluted long tube, the **epididymis.**

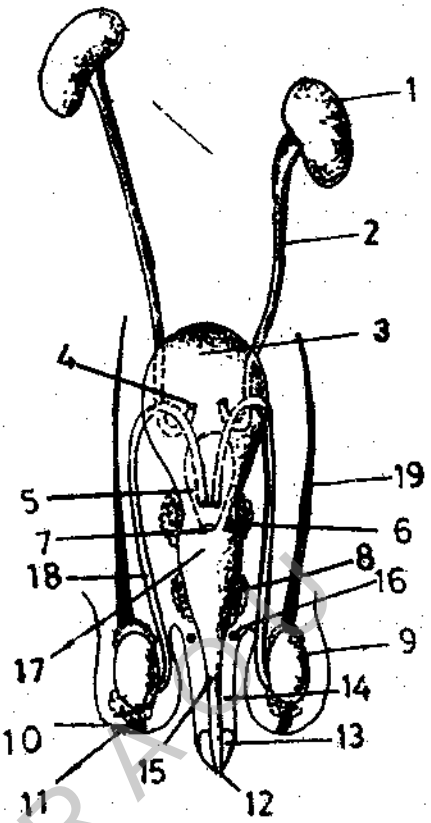


Fig. 29.3. Rabbit-Male urino genital system. 1. Kidney. 2. Left ureter. 3. Urinary bladder. 4. Ureter opening. 5. Uterus masculinus 6. Prostate gland. 7. Opening of uterus masculinus. 8. Cowper's gland 9. Testis 10. Gubernaculum 11. Scrotal sac. 12. Urinogenital opening. 13. Glans. 14. Penis. 15. Urethra. 16. Perineal gland, 17. Urethra 18. Vas deferens. 19. Spermatic cord.

Vasa deferens : The vas deferens is a continuation of the epididymis and leaves the testes. The epididymis lies along the inner side of each testis and extends anteriorly as **caput epididymis** and posteriorly as **cauda epididymis.** The **gubernaculum** connects the cauda epididymis and the inner wall of the scrotal sac. The caput epididymis is joined by a cord the spermatic cord, consisting of spermatic artery, vein and nerve passing though the inguinal canal. The vas deferens after emerging from the scrotal sac enters the abdominal cavity, where it curves round the ureter of its side and runs backwards to open into uterus masculinus.

Uterus masculinus : It is a fairly large median sac situated dorsal to the urinary bladder, It is bilobed anteriorly. It receives the vasa deferentia on its ventral wall.

Urethra : The uterus masculinus is posteriorly continued into urethra or urinogenital chamber leading into urethra. It is a straight tube and runs backwards just dorsal to the pelvic symphysis, and ventral to the rectum. The urethra opens to the exterior.

Penis : It is cylindrical, muscular, erectile organ hanging from the ventral wall of the abdomen infront of the anus. Its posterior wall is made up of a highly vascularised **corpus spongiosum.**

The tip of the penis is soft and obliquely truncated and is called glans. It is enclosed in a a loose retracticle fold of skin called **prepuce.**

Prostate gland: It is gland with four or five lobes, lying on the dorsal and lateral sides of the uterus masculinus. It opens into urethra by small ducts. The secretion of the prostate gland nourishes and activates spermatozoa.

Cowper's gland: These are a pair of oval glandular bodies located on the roof of the urethra behind the prostate glands. The secretion of these gland neutralises the acidity of the urethra and vagina thereby protecting the sperms from any adverse effect.

Perinatal glands : These are a pair of dark elongated glands lying next to the cowper's glands. They open to the exterior through perineal pouches. The secretion of these glands impart a characteristic odour to attract the other sex for copulation.

29.4.2 Female Reproduction Organs

The female reproductive organs include a pair of ovaries, oviducts, vagina, vestibule, clitoris. Barthorin's glands, cowper's glands and perinatal glands. There are no prostate glands.

Ovaries : These area pair of small oval bodies attached to the dorsal body wall by **mesovarium.** They are whitish and measure about 18 mm long. They lie behind the kidneys in the abdomen. The surface of the ovary is marked by several small rounded transparent projections called ovarian foillicles which produce ova. For histological structure of the ovary see Unit 31. The ova are released into the coelomic cavity by the rupture of the Graafian follicles in primary oocyte condition. The follicles are also endocrine in further producing estrogen, progestrone and relaxin (see Unit 30).

Oviduct : The oviduct is differentiated into three regions. Its anterior end is transformed into a wide frimbriated funnel the **ovidccal funnel.** The funnel lies opposite the ovary with a central opening called **ostium,** to receive ova as they are shed. The funnel leads into a slighlty narrow tube called the fallopian tube, which is convoluted and lined by ciliated epithelium. The **fallopian tube** leads into a wider, less convoluted part called uterus.

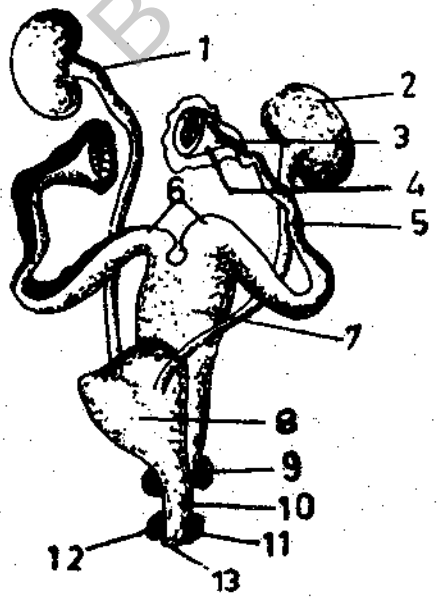


Fig. 29.4. Rabbit - Female Urinogenital system. 1. Ureter. 2. Kidney 3. Mesovarium. 4. Fimbriated funnel. 5. Fallopian tube. 6. Uterus. 7. Vagina. 8. Urinary bladder. 9. Bartholin's gland. 10. Urinogential sinus. 11. Rectal gland. 12. Perineal gland. 13. Vulva.

Uterus : It is a distensible and vascularised chamber. The uterus and fallopian tubes are suspended from the dorsal body wall by peritoneal folds called **mesometrium** and **mesosalpinx** respectively.

Vagina : The two uteri unite medially to open into a muscular sac the vagina. The vagina runs dorsally to receive the urinary bladder. It unites with the neck of the bladder to form a common passage the **vestibule.**

Vestibule : The vestibule is a wide tube, which extends backwards ventral to the rectum. The vestibules opens to the exterior by vulva or urinogenital opening, which is a slit like opening. The vulva is surrounded laterally by two prominent folds called **libia majora.** Inside the vulva, on the ventral wall of the vestibule, there is small rod like structure called **clitoris.** The clitoris corresponds to penis of the male. The urinary opening and reproductive openings are separate in the female mammals.

29.4.3. Glands

Bartholin's glands : These are a pair of small glands present on the vestibule opening into it. These glands secrete a clear viscid fluid which helps in lubrication during copulation.

Cowper's glands : They are reduced in size. These glands may or may not be present. When present they lie on the vestibule.

Perineal glands: The secretion of these glands is strong smelling and helpful in attracting the other sex for coopulation. The perineal glands are like those of the male.

29.5 SUMMARY

The kidney is metanephric in rabbit situated dorsally on either side of the vertebral column. The kidney in sagittal section shows an outer cortex and the inner medulla. There are about 20 pyramids in the human kidney while the rabbit and carnivores have only a single pyramid. The functional units of kidney are uriniferous tubules or nephron. In human, they may number about one million per kidney. The nephron consists of malpighian capsule and convoluted tubule [ascending & descending limbs with Henle's loop in between]. Glomerulus effects ultra filtration, when the filtrate is hypotonic; it becomes hypertomic as Na^+ is deposited in the descending limb and in the Henle's loop water is drawn out; and isotonic in distal ascending limb which is thick and impermeable to water and also pumps out Na^+, besides, the ascending limb secretes ammonia, creatine, K^+ &H^+.

80% of the ammonia is converted into urea via ornithine cycle. Ornithine is an amino acid formed in the body in the protein metabolism or in the ornithine cycle. The ornithine combines with ammonia and Co_2 to form citrulline; it reacts with ammonia to give rise to arginine which in the presence of an exzyme arginase, it gives off urea and ornithine. Now the fluid on entering the common collecting duct it may be termed the 'primary urine'.

Sexes separate. Testes descended into the scrotal sacs. In males, a pendant penis is present. The prostate glands' secretion provides nutrition and stimulus to the sperms. In females the ovaries are studded with grafian follicles which harbour and nurture the maturing ova. It also acts as the endocrine gland secreting estrogen. Progesterone and relaxin.

26.6 MODEL EXAMINATION QUESTIONS :

I. Answer the following in about 30 lines.

1. Describe the male reproductive organs of rabbit.
2. Describe the female reproductive organs of rabbit.
3. Describe the structure of mammalian kidney.
4. Describe the physiology of excretion of mammals.

II. Answer the following in about 10 lines.

1. Describe the structure of a nephron.
2. How urea is formed ?
3. Describe the glands associated with reproductive organs.
4. Malphigian Capsule
5. Counter current multiplier hypotheses.

Unit – 30 : ENDOCRINE GLANDS

Contents

30.1 OBJECTIVE

- This lesson is about the **ductless glands** and their secretions. They aid in transmitting messages through chemicals hence called **chemical messengers.**

30.2 INTRODUCTION

The **endocrine glands** are ductless glands located at specific regions in the body. They may be modified forms of either nervous or specialised somatic tissues. Their secretions are called as **hormones** (= L arouse) which stimulate an organ to carrry out a function to a stimulus at a proper time. Since they are ductless, the secretions are directly carried by the blood, to the parts where needed.

The hormones are defined as **chemical messengers** or transmitters to co-ordinate various activities of the body. Hormones are chemically complex organic compounds called proteins, steroids etc., which disintegrate after the desired effect is brought.

There are two types of endocrine glands. The first category includes **pituitary gland, thyroid, parathyroid, thymus, adrenal** and **pineal glands.** The second category includes those endocrine glands which are situated in organs like **pancreas, gonads, mucus membranes** of **alimentary canal.** which are basically exocrine in their function such organs are termed as heterocrine glands.

30.3 PITUITARY GLAND OR HYPOPHYSIS

It is referred as the **"Master gland of the endocrine orchestra".** It controls all the other endocrine glands as far as their secretions are concerned. The pituitary gland is located on the ventral side of diencephalon and is conveniently divided into three parts, viz., (1) **Anterior lobe or Adenohypophysis** (2) **Middle lobe** or **Pars Intermedia** and (3) **Posterior lobe** or

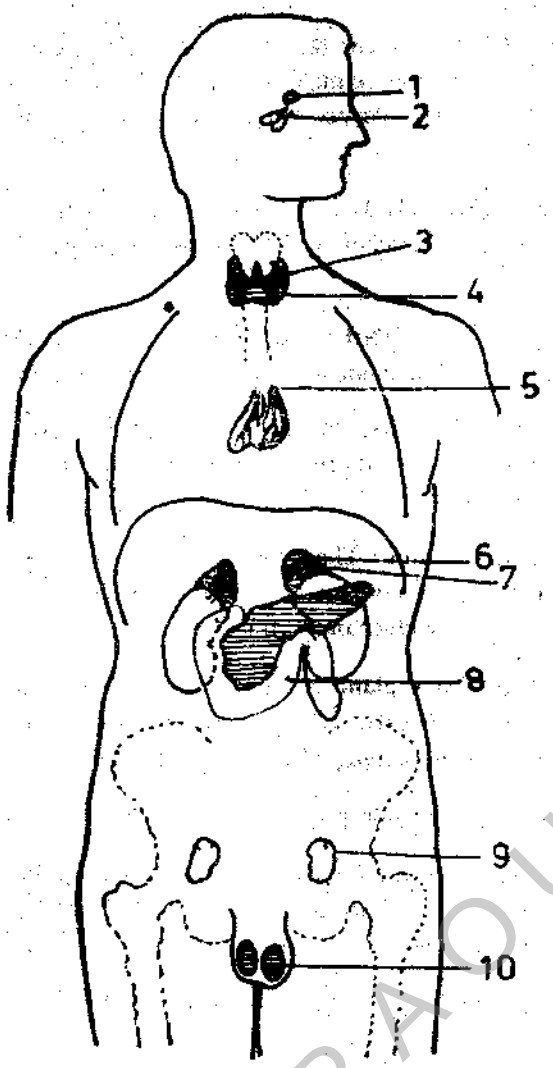


Fig. 30.1 Diagrammatic representation of location of endocrine glands in man. 1. Pineal body 2. Hypothalamo - hypophyseal system 3. Parathyroid 4. Thyroid 5. Thymus 6. Adrenal medulla 7. Adrenal cortex 8. Pancreas 9. Ovarie 10. Testis.

Neurohypophysis. Each part is responsible for the secretion of a number of hormones which not only activate some other ductless glands have direct effect over organs. The anterior lobe of pituitary gland produces seven distinct hormones, of which a few are stimulating.

The hormones and the area of function they coordinate are as follows :

1) **Growth Hormone** (GH) or **Somatotropic Hormones** (STH) : The GH regulates the protein metabolism, development and growth of skeleton. The hyper secretion causes an unproportionate growth of body parts giving an awkward appearance called **acromegaly** or **gigantism.** The hyposecretion of the same results in stunted growth or **dwarfism** or **infantism.**

2) **Gonadotropic Hormone** : This hormone initiates the reproductive organs to produce their own hormones.

a) **Follicle stimulating hormone (FSH)** : The FSH stimulates the ovarian follicles to secrete the female sex hormone, the oestrogen which causes to develop the secondary sexual characters. It also initiates oogenesis and ovulation.

b) **Interstitial cell stimulating hormone (ICSH):** The ICSH produced by hypophysis initiates the Leydig cells of testis to produce male sex hormones. They are called **androgens** which control the development of secondary sexual characters in males. It also regulates production of spermatozoa.

c) **Leutinising Hormone (LH):** The LH in female mammals helps in the formation of **corpus luteum.** The LH also causes ovulation and secretion of progesterone by corpus luteum in females.

3) **Thyroid stimulating Hormone (TSH):** The TSH stimulates the thyroid gland to secrete its own hormone, the **thyroxin** causes metamorphosis in lower vertebrates.

4) **Adreno - Corticotropic hormones (ACTH) :** The adrenal cortex of the adrenal gland is stimulated by the above hormone. It produces the cortisones to regulate the mineral, protein and carbohydrate metabolism.

5) **Prolactin or Lactogenic hormone :** The lactogenic hormone initiates the secretion of milk in mammary glands. It also brings the maternal instinct in birds such as nesting before laying eggs. It stimulates ovary to produce progesterone.

The **intermediate lobe of pituitary gland** secretes a single hormone called **intermedin or melanocyte stimulating hormone (MSH).** It causes the spreading of colour in chromatophores of the skin. This increases the darkening of the skin and results in protective colouration.

The posterior lobe or neuro-hypophysis produces three hormones, they are :

a) **Oxytocin or Pitocin :** This hormone induces contraction of uterus for the delivery of the foetus. It also causes the release of milk in mammary glands and also induces gall bladder, intestines and urinary bladder (Pitressin)

b) **Vasopressin:** It controls blood pressure. Constriction of all blood vessels except those going to kidney.

c) **Anti-Diuretic Hormone (ADH):** This hormone is similar in function to vasopressin. It regulates the selective resorption in uriniferous tubules of kidney. It prevents much loss of water through urine. Its over production results in much absorption of water in nephrons and concentration of urine. Its low production results in loss of water leading to dehydration and causing a disease called **diabetes insipidus.**

Some authors consister ADH and Vasopressin are one and the same.

The above mentioned hormones are actually produced by the neurosecretory cells situated in the hypothalamus (floor of the thalamencephalon). From the hypothalamus, these secretions are transported to the cell of neurohypophysis (posterior lobe of pituitary). So the neurohypophysis stores these hormones, to be released into the blood stream later.

30.4 THYROID GLAND

It is a bilobed gland beneath the larynx. It is made up of numerous vesicles which are secretory. It secretes thyroxine hormone containing iodine. The thyroxine regulates the rate of oxidation of food in the body to liberate required quantity of energy for muscular activity. It also regulates the metamorphosis in lower vertebrates. The hyper secretion of thyroxine causes an increase in oxidation of food, high blood pressure, high rate of heart beat. It

causes exophthalmic goitre. The hyposecretion of thyroxine causes cretinism in children. There will be delay in dentition, delay in speech, and walking habits of infants. In adults it causes myxoedeema where there is more accumulation of fats in cheeks, feet etc. The idiotic looks, dribbling saliva and protruding tongue are all due to oversecretion of thyroxine. The deficiency of iodine in diet results in the enlargement of thyroid gland called simple goitre. The hypoactivity reduces the basal metabolic rate, mental retardatian, deaf and mutism in children.

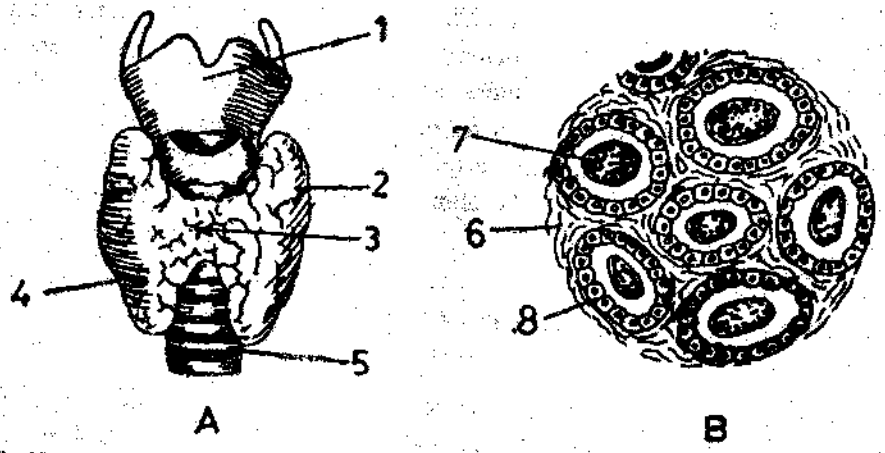


Fig. 30.2. Thyroid gland A. Structure (anatomy). B.T.S. of thyroid gland (showing histology).
1. Thyroid cartilage 2. Right lobe 3. Isthmus. 4. Left lobe 5. Trachea 6. Interlobular connective tissue 7. Gelatinous Colloid 8. Follicular epithelium.

30.5 PARATHYROID GLANDS

The thyroids are surrounded by four lobes on either side of it called **parathyroid glands.** They secrete a hormone called **parathormone collip's hormone.** It regulates the metabolism of minerals particularly that of calcium and phosphrous. It regulates the ossification of bones and deposition of calcium phosphate. The parathormone helps in the absorption of calcium in the gut and prevents the loss of phosphorous through urine. The hyperactivity of parathyroids results in the brittle bones or osteotis-fibrosa, a condition in which bones loose calcium phosphate. As calcium is required in muscle contraction and blood clotting this hormone regulates the calcium level in the blood. Hypoparathyroidism causes tetany due to hyperirritability of the nervous system. During this condition the blood calcium level falls

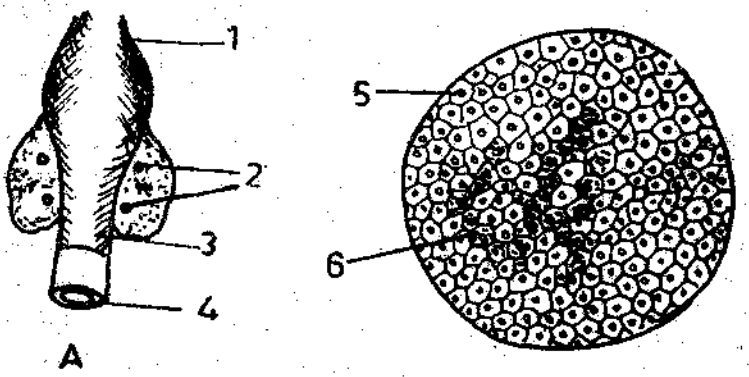


Fig. 30. Parathyroid gland. a. Structure B.T.S. of parathyroid (showing histology). 1. Pharynx. 2. Parathyroid glands. 3. Oesophagus. 4. Trachea. 5. chief cells. 6. Oxyphillic cells with cytoplasamic granules.

from 10 mg per 100 ml to 7 mg per 100 ml, if the level further falls, convulsions occur; urine output also decreases. During this condition, the blood phosphrous level increases, from 5 mg per 100 ml to 9 mg per 100 ml.

30.6 THYMUS GLAND

Thymus gland is well developed in the juvenile stages than in the adult. There is a controversy regarding its endocrine nature. It lies behind the upper part of breast bone and extends into the neck. It is pinkish in colour and diminishes beyond recognition in the adults. The outer region called **cortex,** though lymphoid in its morphology secretes a hormone. It accelerates the growth and division influencing the early growth. The thymus hormone also hastens the attianment of sexual maturity. Once the animal attains the puberty, the thymus gland either disintegrates or remains inconspicuous.

30.7 ADRENAL GLANDS OR SUPRA RENAL GLANDS

Adrenal glands are paired structures lying at the anterior side of kidneys. Each gland is composed of an **outer cortex** (mesodermal in origin) and an **inner medulla** derived from nervous tissues. The cortex secrets the hormones called **cortisones,** comprising **glucocorticosteroids** and **mineral corticosteroids.** The cortisones also comprise **aldosterone** and **sex hormones.** It regulates the metabolism of carbohydrates, proteins and maintains the levels of sodium and potassium in the blood. It also controls the development of accessory reproductive organs. The hypo activity of cortex cause **Addison's disease** where it impairs metabolism of carbohydrates and proteins. The cortisones influence water and salt metabolism. Aldosterone controls salt and carbohydrate metabolism. The hyperactivity of adrenal cortex (glucocorticoids: Cortisal, cartisone and corticosterone) cases Cushing's disease showing the sympoms of hyperglycemia, high rate of glucogensis, more protein catabolism, muscle weakness, hypertesion, diabetes and also precocios development of secondary sexual characters in children like virilism.

The medulla produces two hormones, **adrenaline** or **epinephrine** and **noradrenaline** or **norepinephrine.** The latter regulates the blood pressure in routine circumstances. The epinephrine or adrenaline is also called as **"fight or flight hormone".** It regulates emotion, anger, fear etc. and prepares an animal to face any type of adverse condition. Therefore, the adrenals are also reffered as "Glands of Emergency". Some neuro-transmitters like **sympathin** and **adrenaline** are similar in their mode of action. Removal of adrenals results in immediate death.

30.8 PANCREAS

The pancreas is a **heterocrine gland.** The acinar cells are exocrine producing **pancreatic juice** containing enzymes. Scattered in between the acini are the specialised groups of endocrine cells called **"Islets of Langerhans".** They have three types of cells **alpha, beta** and **gama cells.** The alpha cells produce **glucagon hormone.** The beta cells praduce **insulin.** These two hormones are antagonistic to each other. Insulin helps in the oxidation of glucose in the body. It promotes the glycogenesis i.e., conversion of glucose into reserve food in the liver called glycogen. The over secretion of insulin causes hypoglycaemia, where normal blood sugar level is reduced. The low activity of insulin causes an increase in blood sugar level and its loss through urine. It results in a disease called **diabetes mellitus or glycosauria.**

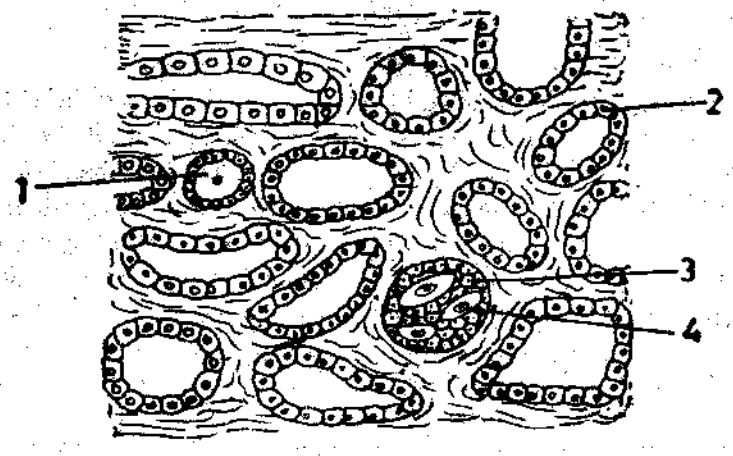


Fig. 30.4. T.S. of Pancreas. 1. Interlobular duct. 2. Pancreatic-acinus. 3. Islets of Langerhans. 4. Blood vessel.

Glucagon produced by alpha cells elevates the blood sugar level and causes hyperglycaemia. Its low secretion results in fall of blood sugar level. Thus both these hormones are antagonistic in their behaviour checking the acitivity of the other and maintaining blood sugar level. The **gama cells** are few in number and do not contain secretory granules. So far it has not been proved to be the source of any endocrine factor.

30.9 MUCUS MEMBRANE

The epithelial lining of the gut also plays an important role in the production of hormones. The epithelial cells of mucus membrane secrete enzymes and hormones, hence are heterocrine in their nature. The mucus membrane of the stomach secretes hormones called **gastrin** and **enterogastrone**. This hormone gastrin stimulates the gastric glands to produce the gastric juice. Enterogastrone inhibits the pepsin production. Similarly in the mucus lining of intestine are present the cells which secrete four more hormones. (1) **Cholecystokinin** which causes the contraction of gall bladder thereby releasing bile into duodenum. (2) **Secretin** stimulates the acini of pancreas to produce alkaline pancreatic juice. The hyper or hypo activity of these hormones cause gastric disorders. (3) Pancreozymn controls the secretion of pancreatic enzymes. (4) Enterocrinin a protein in nature, controls secretin of the intestinal juice.

30.10 GONADS

Gonads apart from being cytogenic also participate in endocrine secretions. However, they are initiated by the influence of gonadotrophic hormones produced by the pituitary gland.

Testes

In the connective tissue of testes scattered between the crypts are present numerous cells. These cells are called as **Leydig cells** or **interstitial cells** of endocrine function. They produce the male sex hormone called **androgen** or **testosterone**. This hormone is produced by the influence of ICSH of pituitary. It controls the development and growth of the male sex organs to their full size, so that they become functional. It regulates spermatogenesis and leads to the development of secondary sexual characters in males such as change in voice, appearance of hair on face etc.

Ovary

The Graafian follicles of the ovary produce female sex hormone called (Follicle Stimulating Hormone) **oestrogen.** The production of this hormone is initiated by FSH/of pituitary gland. The oestrogen initiates ovulation, enlargement of mammary glands. It also causes the appearence of secondary sexual characters like enlargement of hips, soft voice, in female. Oestrogen develops the genital tract. The **carpus luteum** of the ovary produces two hormones, **progesterone,** which prepares the uterus for the implantation of the embryo and the pelvic ligaments during pregnancy. It also inhibits the production of oestrogen. The other hormone is **relaxin** which causes the relaxation of smooth muscles of uterus parturition and helps in widening of the cervix. The placenta in mammals produce hormones to prevent ovulation. They also prepare mammary glands to secret milk for the young.

Thus the endocrine glands are internal co-ordinators of various physiological activities.

30.11. SUMMARY

Endocrine or the ductless glands secrete hormones releasing directly into the blood stream to be effective far away from its place of birth. **Hormones** are the **chemical messengers** in regulating the various physiclogical metabolic activities. Chemically, hormones are the complex organic proteins insulin, parathormone, oxytocin, ADH, hormones of mucosa, trophic hormones of the adenohypophysis or steroids (androgens, estrogens & adrenocorticoids and some others like adrenaline or epinephirine are simple compounds, being neither proteins nor steroids. Hormones vanish as soon as their job is over. The endocrine glands in essence act as pace-makers for various activities and the pituitary gland or master gland thus acts a **remote control** organ for all the other endocrine glands except adrenal medulla. However, even such a master gland is put under the control of hypothalamus.

As vitamins do, any disturbance in the production of the hormones causes diseases like **exophthalmic goitre, cretinism, myxoedema, osteitis fibrosa,** Addisons disease, **diabetes mellitus** etc.

Gonads also act as endocrine glands and are responsible for secondary sexual characters and for proper functioning of the system. Corpus luteum produces progesterone for the preparation of the uterine bed to receive and maintain the embryo and relaxin, for parturition.

30.12 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Describe briefly the mammalian endocrinal system.
2. Discuss the functions of pituitary, thyroid and adrenal glands.
3. What are endocrine glands ? Describe the sturcture and role of pituitary gland.

II. Answer the following in about 10 lines.

1. Distinguish exocrine and endocrine glands with examples.
2. Write a brief account on the hormones produced by posterior lobe of pituitary gland.

3. Described the structure and function of thyroid gland.

4. Give a brief account of adrenal glands.

5. Gonadotropic hormones 10. Pancreas

6.Neurophysis 11. Islets of Langerhans

7.Parathyroid glands 12. Insulin

8.Thymus gland 13. Leydig cell

9.Cartisones 14 Corpus luteum

30.13 GLOSSARY

Acromegaly	:	Disproportinate growth of bones of jaw and limbs giving an awkward appearance
Adrenal gland	:	A ductless gland present above kidney
Addison's disease	:	A deficiency disease caused by cortisone lowering the rate of carbohydrate and protein metabolism
Collip's hormone	:	It is parathormone
Corpus luteum	:	An yellow tissue filling up around follicles after ovulation
Cretinism	:	Delay in speech and walking of the child due to deficiency of thyroxine.
Diabetes millitus	:	Delay in speech and walking of the child due to deficiency of thyroxine
Diabetes insipidus	:	A disease in which there is loss of water due to dificiency of ADH
Diencephalon	:	The second part of the forebrain from where pituitary gland arises
Emergency glands	:	The adrenal glands which meet the emergency requirements of the body
Epididymes	:	A thick convoluted duct surrounding the testes from which vas deferens arises
Gigantism	:	Overgrowth of body parts
Graafian follicles	:	The proliferations of germinal epithelium surrounding ova.
Gubernaculum	:	The cord connecting the testes to scrotal sac
Heterocrine gland	:	A gland which secretes externally as well as internally
Henle's loop	:	A part of convoluted nephron to increase absorptive surface for water
Hilus	:	The concave part of kidney from where ureter arises.
Homeostasis	:	Maintanance of internal environment
Inguinal canals	:	The coeclomic canal joining perivisceral coeclome and scrotal coelom
Leydig cells	:	These are interstitial cells present in the testes to produce androgens.
Melanophores	:	The pigment cells containing melanin.

Microvilli	:	Cytoplasmic projections to absorb fluids
Myxoedema	:	Formation of fat below checks etc. in the adults
Oestrogen	:	A female hormone regulating ovulation
Osmo-regulation	:	Regulating water level inside the animal
Parturition	:	Delivery of the child in mammals
Pelvis	:	The flattened part of ureter at its origin.
Pyramids	:	The lobes of medulla of kidney
Scrotum	:	The coelomic sac outside into which the testes descend
Ultra filtration	:	Filtration under high pressure in Bowman's capsule
Urethra	:	A common passage in males for urine and gametes
Uterus masculinus	:	Seminal vesicles to store sperms in males
Vagina	:	The passage leading from the uterus to the exterior in female mammal.

BLOCK - II
HISTOLOGY

Unit – 31 EPITHELIUM, CONNECTIVE, MUSCULAR AND NERVOUS TISSUES

Contents

31.1 OBJECTIVE

- The objective of this lesson is to know about the minute structures of the tissues and the organs.

31.2 INTRODUCTION

Histology is the study of the minute structure of the tissues and organs. Literally histology means the study of the tissues. A tissue is predominantly a group of similar cells (together with their cell products), where the cells are specialized to perform a common function. The cells forming a tissue are bound together by an **intercellular** or ground substance. It is present with in the inter cellular spaces. It is produced by the cells themselves.

There are four major classes of tissues which have a distinct structure and function.

1. **Epithelium** or Epithelial tissue
2. **Connective** or supporting tissue
3. **Muscle** or Muscular tissue

4. **Nerve** or Nervous tissue

The details about each kind of tissues are as follows :

31.3 EPITHELIUM

Epithelium, usually consists of closely packed cells. The cells are held together with a very small amount of intercellular substance. This substance or the matrix is produced by the cells themselves. The cells are arranged in sheets and rest on a thin structureless non cellular membrane known as the basement membrane.

Epithelia cover the outer surface and the inner and outer surfaces of various internal organs. They line the walls of most of the internal cavities. The secretory part of various glands of the body is composed of the epithelia.

Epithelium may be composed of one or more layers of cells. If it consists of one layer of cells, it is described as **simple epithelium.** If the epithelium is composed of many cellular layers of cells, it is described as **stratified epithelium.** Based on the shape of the cells simple epithelium is classified as following.

Kinds of Simple Epithelia

31.3.1 Simple Squamous Epithelium

Squamous epithelium consists of a single layer of thin flat cells. The cells are plate like with their sides fitted close together (Fig.31.A-B). Squamous epithelium is often called **pavement epithelium** as the cells are like cement slabs in surface view. The cell outline is polygonal. In certain cases the outline of the cells is wavy, it is then said to be **tessellated epithelium**

Squamous epithelium is found lining the Bowman's capsule of the kidney, the body cavities, **Henle's loop,** inner side of the tympanic membrane and alveoli of the lung. The blood and lymph vessels and the peritonium are lined by the tessellated type.

31.3.2. Simple Cuboidal Epithelium

Simple cuboidal epithelium is formed by cubical cells, i.e., the cells have about the same height and width. In the surface view, they have hexagonal in appearance as in the squamous epithelium. In vertical section they are like rows of squares (Fig. 31.1. C.D).

Cuboidal epithelium forms the lining of many glands, like the sweat gland, parts of the liver and the thyroid. It forms the free surface of the ovary and the lining of the uriniferous tubules of the kidney. It also lines the pigmented epithelium of retina, inner lens capsule.

31.3.3 Simple Columnar Epithelium

In columnar epithelium, the cells are distinctly taller than their width (fig. 3.1.E-F). The inner end of the cell towards the basement membrane narrows. The cells appear as small polygons in the surface view. The nucleus is elongated parallel with the long axis of the cell. The free surface of the columnar cells differ in various situations. The alimentary canal from the stomach to the rectum is lined by columnar epithelial cells. This epithelium is secretory or absorptive.

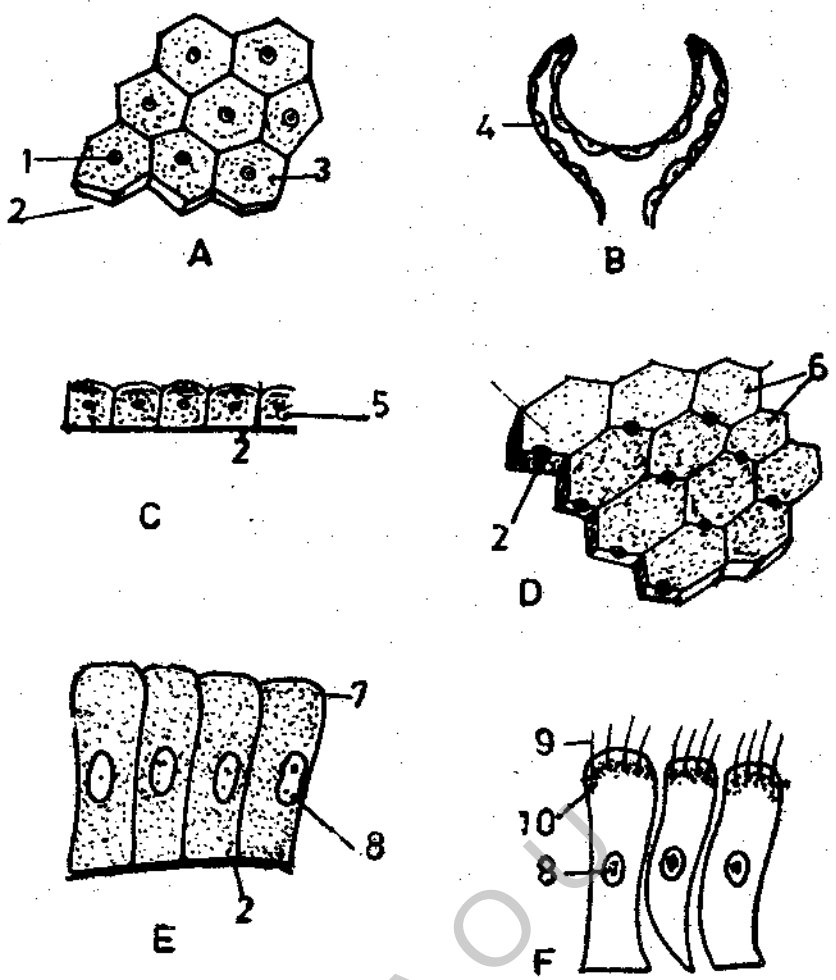


Fig. 31.1. Simple epithelia. A-B: Squamous epithelium. C-D: Cuboidal epithelium. E-F: Columnar epithelium 1. Nucleus in the centre 2. Basement membrane 3. Flattened hexagonal cells 4. Bowman's capsule with squamous epithelium 5. Cubical cell 6. Hexagonal appearance of cuboidal cells in the surface view 7. Elongated columnar cells 8. Elongated central nucleus 9. Cilia 10. Basal capsule.

Specialized types of Simple Epithelia

Simple epithelia undergo certain specialisations for performing distinct functions. There are four such types.

31.3.4 Ciliated Epithelium

The free surfaces of the simple epithelial cells bear tiny protoplasmic lashes, the cilia (literally eye lashes). The linings of the nasal cavities, the trachea (wind pipe), the bronchi, uterine tube and uterus contain ciliated epithelium.

31.3.5 Glandular Epithelium

Simple epithelial cells. May become secretory and form either the unicellular or multicellular glands, thereby forming a glandular tissue. Generalised secretory cells of the stomach lining are unicellular glands. Likewise the goblet cells of intestinal lining are also unicellular. In multicellular glands, the epithelium invaginates to form a number of tubules in the form of dilatations. Lung alveoli and pancreatic acini are the good examples.

31.3.6 Pigment Epithelium

The cells of such epithelia contain coloured pigment granules, as in the pigmented epithelium of retina.

31.3.7 Neuro Epithelium

Some simple columnar cells are specialised for receiving sensory stimuli. eg., Receptive cells of taste, hearing and smell.

31.3.8 Pseudostratified Epithelium

Pseudostratified epithelium consists of a single layer of cells. All the cells touch the basement membrane. But the free surfaces of the cells are not at one level and the nuclei of the cells are at different levels (Fig. 31.2 A).

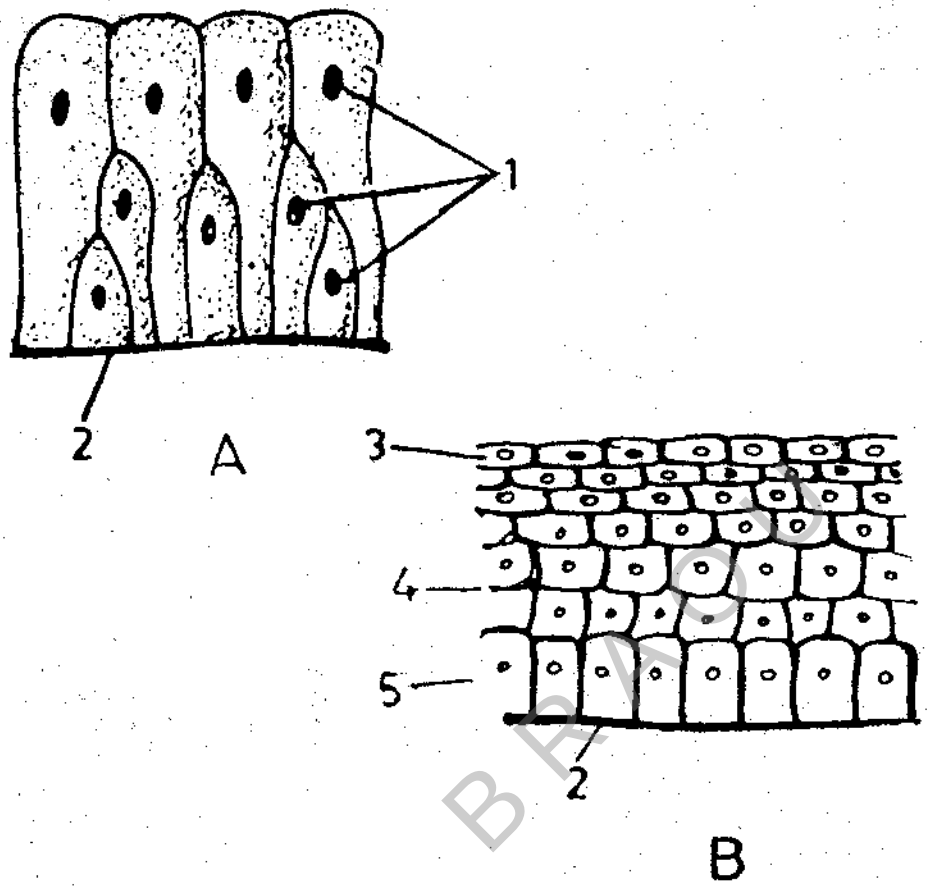


Fig. 31.2 A. Pseudostratified epithelium. B. Stratified squamous epithelium. 1. Disposition of the nuclei at three levels 2. Basement membrane 3. Stratum corneum (squamous) 4. Stratum spinosum (polyhedral cells) 5. Stratum malpighil (columnar).

Such an arrangement of the cells gives a deceptive appearance of many layers of cells or stratification. Hence such tissue is described as pseudostratified epithelium. The trachea and the bronchi are lined by a Pseudostratified columnar ciliated epithelium.

31.3.9 Stratified Epithelium

Stratified epithelia consist of many layers of cells. They, like simple epithelia, are classified into the following based on the shape of the cells :

a. **Stratified Squamous Epithelium :** This is present in the epidermis of the skin, buccal cavity, oesophagus, conjectiva and the vagina, where the superficial layers are with squamous cells (Fig. 30.2. B).

b. **Stratified Cuboidal Epithelium :** In this type of compound epithelium, the superficial layers of the cells are cuboidal in shape, as in the testis, tubules, Graafian follicles of ovary, and epidermis of urodeles.

c. **Stratified Columnar Epithelium :** The superficial cells are tall and the deeper layers consists of irregular polyhedral cells, This epithelium is rare. Pharynx and larynx in part have this type of epithelium.

31.3.10. Transitional Epithelium

In this type of stratified epithelium, the surface cells are large dome shaped (Fig 31.3 A), somewhat flattened, but not as flat as the cells of squamous epithelium. The intermediate layers consist of polygonal cells, below which are small rounded cells. In the transitional epithelium, there is no basement membrane. The most characteristic feature of the transitional epithelium is its elasticity hence it also referred to as **plastic epithelium.** That is way it is also called transitional epithelium. This is suitable for the lining of hollow organs or tubes which are expansible. It is present in the mucous membrane of the excretory passages of the urinary system, the pelvis of the kidney, the ureters and the urinary bladder.

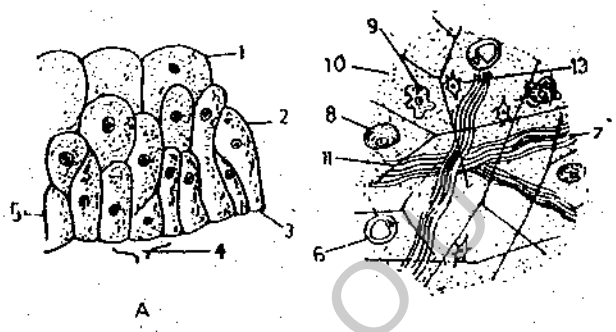


Fig. 31.3. A. Transitional epithelium. B. Areolar tissue. 1. Superficial large cells 2. Cellular layer 3. No basement membrane 4. Capillary pushing into the epithelium 5. Transitional epithelium in bladder wall 6. Fat cell 7. Fibroblast attached to bundle of white fibres 8. mast cell 9. Macrophage histiocytes 10. Amorphous ground substance 11. Bundle of white fibres 12. Net work of yellow fibres 13. Fibrocyte.

31.4 CONNECTIVE TISSUE

As the name suggests, connective tissue serves as a supporting system binding the tissues together. It acts as a packing and supporting elements for the body. Some of the cellular components of the tissue are active in storage and phagocytosis. Connective tissues in general contain large amount of intereellular substances referred to as amorphous substances, i.e., matrix in which are found embedded various types of cells and fibres as Reticular cells, Fibroblasts, Macrophages, plasma cells, Mast cells, Fat cells, Connective tissue fibres and Plastic cells.

31.4.1. Loose Connective Tissue

This connective tissue is characterised by the loose arrangement of fibres. They serve to bind the tissues together and to form protective membranes round the organs. There are of three distinct types : 1. Areolar 2. Reticular 3. Adipose tissues.

1. Areolar tissue

The word areolar refers to the little areas or space occurring within the tissue. It is a loosely arranged fibro elastic connective tissue and displays a greater variety of cells and fibres than any other connective tissues (Fig. 30.3. B).

There are two types of fibres i.e (i) Soft, strong, flexible but non-elastic, straight and unbranched collagenous **'white fibres'** (ii) branched, elastic **'yellow fibres'** formed of a protein called elastin. Among the cells the mast cells produce an anti coagulant, heparin while the plasma cells produce antibodies.

It provides support and allows some mobility. It acts as a packing material between parts of the body. It provides path way for vessels and nerve. It is defensive and healing tissue.

2. Reticular tissue

Reticular connective tissue is made up of branching cells whose processes are usually in contact with one another, forming a reticulum or net work of cells. The reticular cell are embedded in a thick fluid matrix.

In the matrix are fine fibres, the reticular fibres. They lie closely associated with the cells. This type of tissue forms the framework of lymph glands, spleen and red bone marrow.

3. Adipose tissue

It is a modification of the fibro-elastic areolar tissue, in which large numbers of cells have become active in sorting fat (Fig. 3.4). The fat stores in this cells is liberated by metabolism and used as a source of energy. Adipose tissue serves as heat insulating layer. There are two types of adipose tissues : i) white ii) brown cells of brown adipose tissue do contain mitochondria as that of white one but the cristae are without the elementary particles. Hence the ATP synthesis does not take place for future store.

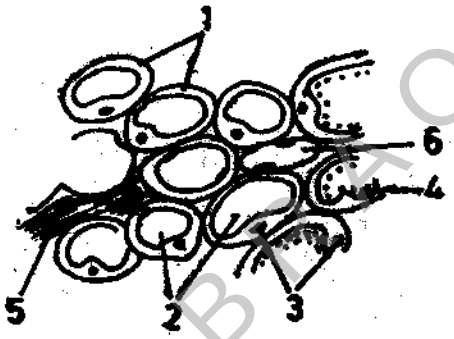


Fig. 30.4. Adipose tissue. 1. Adipose or fat cells 2. Accumulated fat 3. Nuclei shifted to the periphery 4. Peripheral cytoplasm 5. Collagenous fibres 6. Blood vessel.

Dense Connective Tissue

This tissue has an abundance of fibres which are compactly arranged. Cells are proportionately few as compared to the loose connective tissue. The best examples of dense connective tissue are tendons and ligaments.

31.4.2. Skeletal Tissue

The skeletal tissue is characterised by the possession of a tough matrix. It forms the endoskeleton of the vertebrates supporting the soft parts of the body. There are two types of skeletal tissues.

(i) Cartilage and

(ii) Bone

I. Cartilage

The cartilage is bounded externally by a stiff sheath called the perichondrium. It contains blood vessels. Nutrient material diffuses into the cartilage. Cellar part of the cartilage consists of **chondroblasts which** give rise to the **chondrocytes.** They are found in fluid filled spaces called lacunae or cell nest. The ground substance of the cartilage consists of a firm substance called the **chondrin** and collagen fibres. On the basis of the composition of the inner cellular material four types of cartilages are commonly distinguished. They are :

(a) Hyaline (b) Calcified (c) Elastic (d) Fibrous

a. Hyaline cartilage : Living hyaline cartilage has a clear, translucent bluish white and some what elastic matrix. It often contains network of very fine collagen fibres. The matrix consists of chondrin secreted by the chondroblasts (Fig 31.5. A). The cartilage is surrounded by a fibrous membrane, the **perichondrium.** The chondroblasts just beneath the perichondrium are flattened. Other cells lying deeper are found in group of two or more in lacunae. In mammals xiphisternum, sternal ribs and the trachea possess this variety of cartilage

Fig. 31.5 A Hyaline cartilage. B. Fibro cartilage. C. Elastic cartilage. 1. Matrix of chondrin 2. Lacuna 3. dividing cartilage cell 4. Perichondrium 5. Cells parallel to the perichondrium 6. Matrix composed of chondrin and many white collagenous fibres. 7. Cartilage cells in lacunae 8. Yellow elastic fibres, presents in chondrin 9. Cartilage cells lying in chondrin matrix 10. Lacuna.

b. Calcified Cartilage : Hyaline cartilage whose matrix is impregnated with calcium salts forms the calcified cartilage. It forms a much harder nonnelastic and rigid support. It forms the skeleton of some elasmobranches and supra scapula of amphibia.

c. Elastic Cartilage : The elastic cartilage has numerous flexible yellow fibres forming a net work in the matrix and running in all directions (Fig. 31.5.C). The yellow fibres increase the flexibility of the cartilage. Elastic cartilage is found in the pinna (external ear lobe etc.)

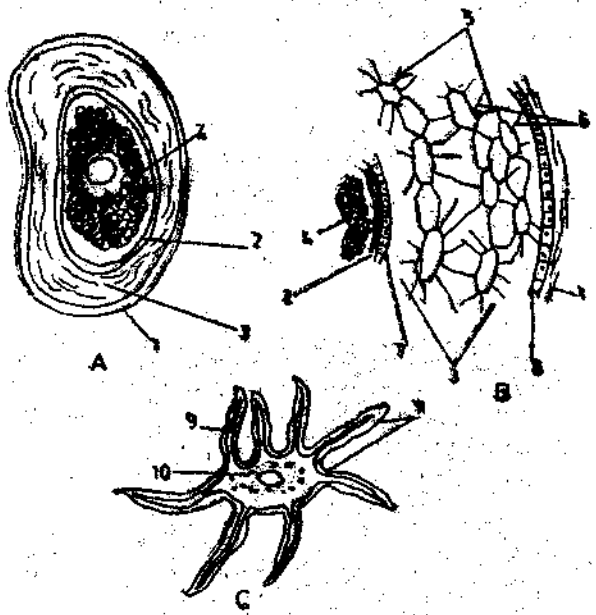


Fig. 3.6. Bone. A. Cross section. B Cross section of a portion of bone (magnified). C. Osteocyte. 1. Periostenum 2. Endosteum 3. Concentric layers of lamellae 4. Marrow cavity with bone marrow 5. Concentric layers of lacunae containing osteocytes 6. Canaliculi with protoplasmic processes of osteocytes 7. Inner layer of osteoblasts 8. Outer layer of osteoblasts 9. Protoplasmic process 10. Osteocyte 11. Canaliculi.

d. Fibro Cartilage : In this type there is a predominance of collagenous white fibres (Fig. 31.5. B). This kind of cartilage forms the shock proof pads known as inter vertebral disc, which lie between adjacent vertebrae.

ii. Bone

Bone or osseous tissue is a very hard, rigid form of connective tissue. It constitutes the endoskeleton of most of the higher vertebrates. The bone tissue consists of living cells the **osteocytes** embedded in a hard matrix.

Each bone, except over its articular surfaces is enveloped by a specialised connective tissue coat, the **periosteum.** A similar but less well developed connective tissue layer, the **endosteum** lines the narrow cavity and narrow spaces. The periosteum and the endosteum like the perichondrium are richly supplied with blood vessels and nerves. It serves to nourish the inner tissue of the bone. The matrix of the bone consists of an organic part chiefly osteo collagen fibres and an inorganic component which form approximately 2/3 of the weight of bone. The inorganic salts which are responsible for the hardness and rigidity of the bone include calcium posphate (85%), calcium carbonate (10%) and others. Collageneous fibres contribute to the strength and elasticity of bone. The most characteristic features of the finer detail of bone is its lamellar arrangement of the calcified intercellular substance or bone matrix or bone cells in concentric layers around the central narrow cavity.

The concentric layers of lamellae alternate with the concentric layers of the osteocytes or the bone cells, developed from the osteoblast. They are found within fluid filled spaces called the **lacunae.** Each bone cells gives off branching protoplasmic processes. these processes are found within the branching processes of the lacunae called the **canaliculi.**

The processer of adjacent bone cells like the canaliculi unit to form a continuous net work through out the matrix. Both lacunae and canaliculi contain a fluid which enable the bone cell to live in a medium which is otherwise solidified by the mineral salts. The fluid comes from the blood vessels of the periosteum and the endosteum.

Harversian System

In a mammalian long bone there are additional channels running parallel to the centrally located marrow cavity. These are the Harvesian canals. Each Harvesian canals is surrounded by concentric layer of the lamellae and lacunae (Fig. 31.7). Thus forming a system called the Harversian system. These cannals contain marrow and are connected with each other by the volkmanis canals.

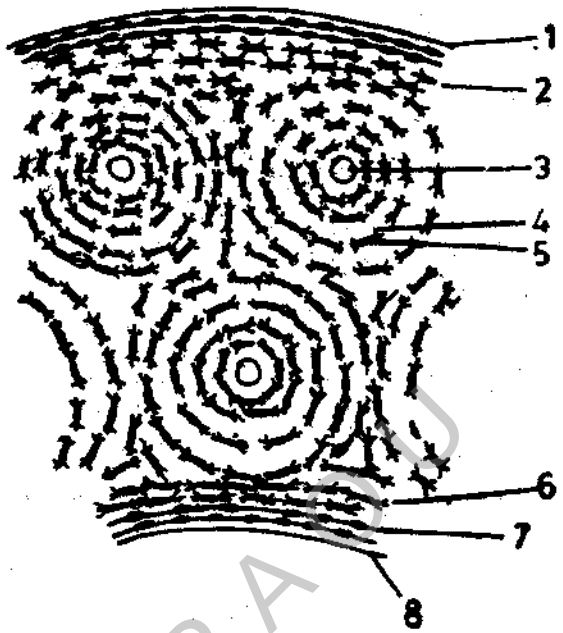


Fig 31.7. T.S. of mammalian long bone-Harversian system. 1. Periosteum 2. Concentric lamella 3. Harversian canal 4. Concentric Lacunae 5. Canaliculi 6. Inner connective lamellae 7. Endosteum 8. Marrow cavity.

Bone marrow

Bone marrow is a substance which occupies the central cavity of the bone. It is a soft vascular myeloid tissue. Its primary functions are to produce myeloid cellular elements, erythrocytes, phagocytic cells and to store iron. Yellow bone marrow is found in the marrow cavities of long bone. It consists principally of fat cells. Red bone is marrow is found at the end of most of the long bones and in the flat bones of the cranium like skull sternum, clavicles, pelvis ribs and bodies of vertebrae. Red bone marrow consists of stroma and free cells within it. Red bone marrow is concerned with the formation of blood cells (haemopoiesis).

31.4.3. Blood And Lymph

Blood and lymph are the examples of liquid connective tissue.

Blood

Vertebrate blood is red in colour. It forms about 6-10 % of the body weight in mammals. It has a saltish taste and a faint- alkaline reaction. Aerated blood is bright red and purple when non-aerated. The blood consists of a liquid portion the plasma, in which there are cells or corpuscles. In plasma there are two types of corpuscles, erythrocytes or the red

blood corpuscles and the leucocytes or the white blood corpuscles. The plasma also contains blood platelets, which are the fragments of certain larger fragile leucocytes called the megakaryocytes. The blood forms a transport medium and a defensive mechanism against the microbes.

Plasma

The plasma which represents the matrix is a faint yellow liquid. About 90% of it is water. Plasma is a mixture of inorganic salts in true solution and blood proteins in colloidal form. The salts form 1% of the plasma. These include the chlorides, bicarborates, sulphate and phosphates of sodium and potassium. The blood proteins present in the plasma are albumins, globulins and fibrinogen. They form 7 to 8 % of the plasma. Dissolved in the Plasma are various useful and waste substances forming 1 to 2% of the plasma. They include the nutrients absorbed from the alimentary canal and also waste products of metabolism like urea uric acid etc. Hormones, enzymes, vitamins and anti bodies are also found in the plasma. Gases like carbon di oxide and oxygen are also present.

Erythrocytes (Red Blood Corpuscles)

The red blood corpuscles are yellowish when seen singly, but reddish when viewed in bulk. Each is enclosed within an elastic membrane. The cytoplasm contains a respiratory pigment, hemoglobin and inorganic ions of sodium, potassium, calcium magnesium chloride and phosphate. In resting slow flowing blood the erythrocytes form piles called rouleaux. The important role of erythrocytes is in respiration carrying oxygen as oxyhaemoglobin from, a respiratory surface to the tissue and to some extent CO_2 in the opposite direction. In mammal the mature red blood corpuscles are without nuclei, biconcave, circular and disc like. In other vertebrates they are oval biconvex and nucleated. In adult mammals the red corpuscles are produced within the red bone marrow. Each is 7.2 microns in width and 2.2 microns thick in man. In other vertebrates, they are formed probably in the vascularized connective tissue of the liver, spleen and kidney. In one cubic millimeter of human blood there are 4.5 to 5 million red blood cells. They remain functional in circulating blood for about few weeks only (approximately 120 days). After which they are destroys either in the blood a or in the liver and spleen.

Leucocytes (white blood corpuscles)

Leucocytes or the white blood corpuscles are otherwise called **amoebocyes**, because of their irregular shape. They are called wandering cells also, as they can squeeze through the

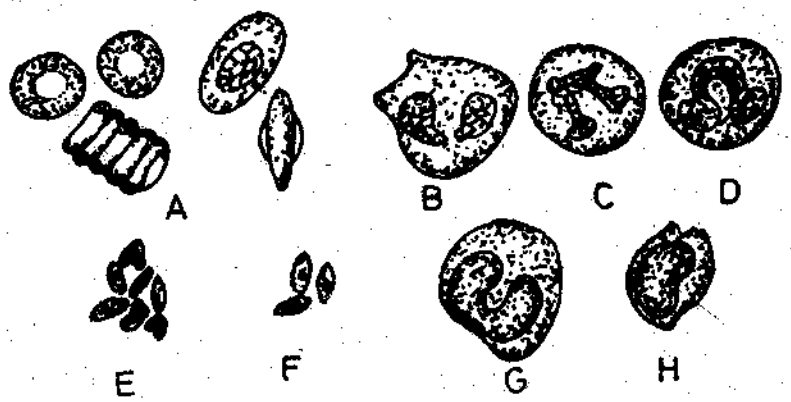


Fig.31.8.Blood corpuscles. A. Erythocytes.. B. Eosinophil. C. Neutrophil. D. Basophil. E.Blood platelets.

capillary walls and reach other tissues by a process called diapedesis. These cells because of the phagocytic function are described as scavenger cells. Leucocytes are much fewer than the erythrocytes. Each cubic millimeter of human blood contains eight to ten thousand of white corpuscles. They are nucleated and each measures 10-15 microns in size. They are of two types (i) The granulocytes or granular leucocytes which contain granules in the cytoplasm and originate in the red bone marrow in mammals. (ii) Agranulocytes or non-granular leucocytes, which lack the granules in the cytoplasm and they originate in the lymphatic nodules.

Granulocytes

The granulocytes are of three types: 1. Neutrophils. 2. Basophils and 3. Acidophils.

Neutrophil: The neutrophils are stained by both the acid and basic dyes. They measure 10 to 12 micron. The nucleus is polymorphic i.e.,it is made up of three or 4 lobes which are connected by thin strand. They are also called polymorphs. They form 60 to 70% of the white blood cells. The neutrophils are very important phagocytes. The granules in them are mainly a special type of lysosome which contain principally hydrolytic enzymes. There number increases in pus forming infections. Live for 30 hours.

Acidophils or Eosinophils: Acidophils are closely related to neutrophils. They have larger granules that strain strongly with acidic dyes. The nucleus is less markedly polymorphic or bilobed. They measure 10 to 12 micron and from 2 to 5% of the white blood cells. Acidophils are also important phagocytes. They increase in number in allegic (asthma) conditions and infections of digestive tract.

Basophils : The basophils stain darkly with dyes and the granules are still larger and the nucleus is slightly lobed. They constitute 1/2% of the total white cells. They are not phagocytic and their significance is not known. They ingest small particles like carbon.

Agranulacytes : There are two such types of the agranulocytes. Lymphocytes and monocytes. Both of them develop within the lymhphatic nodules.

Lymphocytes : The Lymphocytes are about 10 micron in size with a large nucleus filling the cell. They form 20% of the white cells. They produce antibodies and anti toxins which neutralise the toxins released by the foreign micro organisms.

Monocyte: The Monocytes are the largest being 12 to 15 microns in size. They posses a kidney shaped nucleus and are 5% of the leucocytes. These are also very important phagocytes. The monocytes leave the blood and enter the tissues where their life span as macrophages may be as long as 70 days. They are phageytic as the neutrophils and also are good scavenger.

Blood platelets or Thrombocytes

In the blood of mammals there are rounded or oval granular bodies. Platelets which arise as detached portions of peculiar giant cells of bone marrow- **Megakarycytes.** Platelets take an important part in the clotting of blood. Each is 2 to 4 microns in diameter. There are as many as 200 to 300 thousand per millimeter.

Lymph

Lymph is fluid collected from the tissues and returned to the blood stream. It originates from the fluid that occupies the tissue spaces of the body. Lymph has much the same composition as the plasma but lacks red blood corpuscles and blood proteins. Lymph always bathes the tissues. Lymphocytes are added to the lymph as it passes through the lymph

nodes. The lymph nodes also add antibodies to the lymph and from these to the blood stream.

Lymph from small intestine (chyle) is milky because of fat globules taken up. Lymph from the liver is unusually rich in protein. Lymph coagulates but the process advances slowly and the clot is soft.

Hemopoiesis

The process of forming blood cell is known as **Hemopoiesis.** This occurs in the haemopoietic tissue. Lymphocytes and monocytes are developed chiefly in the lymphoid tissues and are termed lymphoid element. Erythrocytes and granulocytes are produced within the bone marrow called myeloid tissue. There is also a view that monocytes and some lymphocytes arise from precursor cells within the bone marrow.

31.5 NERVOUS TISSUE

The nervous tissue forms the entire nervous system. It is developed from ectoderm. It is formed by a collection of highly specialised cells called neurous which develop from the neuroblasts and the supporting cells.

A typical **nerve cell or neuron** consists of a **cell body or cyton or perikaryon.** It has two or more protoplasmic processes. Functionally the proceses are of two types - **dendrons and axons**

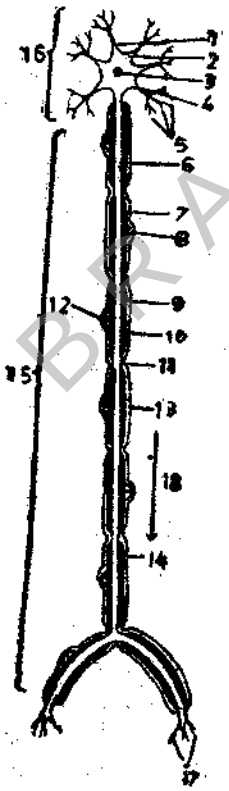


Fig. 31.9 Neuron and neurofibril (myelinated). 1. Cell membrane 2. Cytoplasm containing Nissal's granules mitochondria etc. 3. Nucleus 4. Dendron 5. Dendrities 6. Axoplasm 7. Thin membrane surrounding axoplasm 8. Schwann cell 9. Myelin sheath 10. Neurilemma 11. Node of Ranvier 12. Schwann cell nucleus 13. Inter node 14. Endoneurium 15. Axon 16. Cell body

(Fig. 31.9). Dendrons carry impulses to the cell body. Axon which is a single long process conducts impulses away from the cell body.

Nerve impulses can travel in only one direction through a neuron from the dendrites through the cell body to the end of the axon. Impulses can travel from one neuron to another by passing from the axon of one to the dendrite of another neuron but they must cross a space called a **synapse**, between their neighbouring processes. Thus a synapse is a functional and not an anatomical contact between an axon and a dendron.

Neurons vary greatly in size and shape. Each consists of a cell body or perikaryon covered by **axolemma** enclosing **neuroplasm** with one or more large nucleoli. In addition to the other cellular contents a nerve cell possesses Nissl bodies. They are present in the dendrons also but in the axon these granules are associated with protein synthesis. Another prominent feature of neuron is the presence of neurofibrillae present in the neuroplasm and extending into dendrites and axons. There are three types of neurons: 1) **Unipolar** with a single protoplasmic process 2. **Bipolar** with two protoplasmic processes and 3. **Multipolar** with more than two protoplasmic processes (Fig. 31.10). Certain of the specialised neurons of the multipolar variety are the pyramidal cells of the cerebrum (Cerebral hemisphere and **Purkinje** cells of the cerebellum).

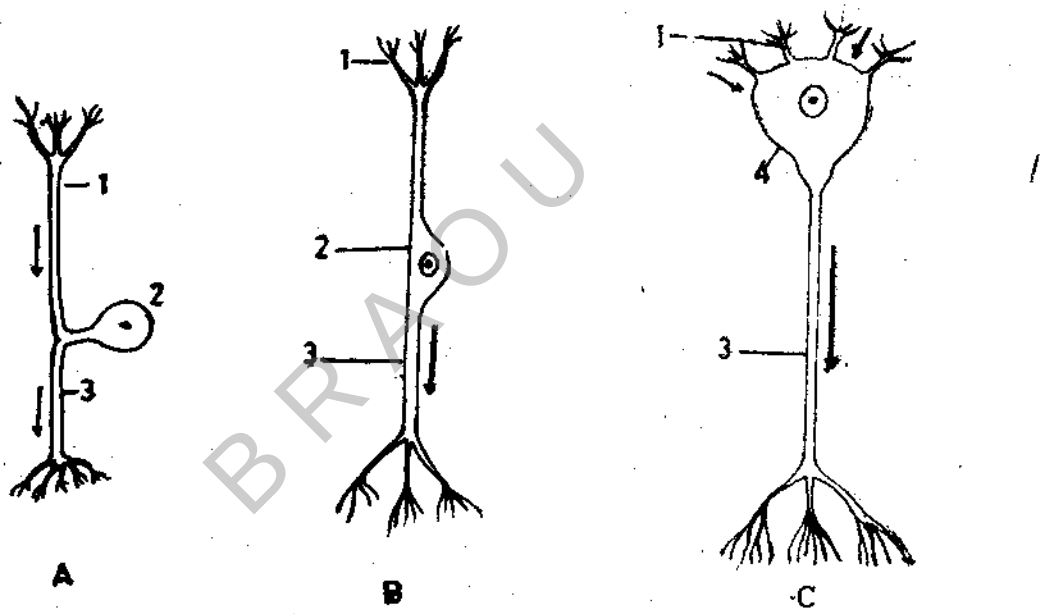


Fig. 31.10. Types of neurons A. Pseudo unipolar B. Bipolar neuron C. Multipolar neuron
1. Dendron 2. Cyton 3. Axon 4. Cell body.

Nerve fibre sheaths

The nerve fibres are wrapped in one or two sheaths. The axis cylinders are ensheathed within one or two sheaths-1. **Myelin** and 2. **Neurilemma.** The myelin sheath is a soft, whitish fatty material which is almost fluid in character. Nerve fibres which have thick myelin sheath appear white and are called **myelinated** or **medullated fibres.** All the fibres in the central nervous system, i.e., brain and the spinal cord and ensheathed within myelin covering. Myelin sheath insulates the axon and from the nerve impulses traveling along the nearby fibres.

The **neurilemma** is a sheath composed of a single layer of cells with elongated nuclei known as **Schwann cells.** The neurilemma and the Schwann cells surround the myelin sheath and form a continuous outer layer. Nerve fibres in the central nervous system have no neurilemma.

The myelin sheath is a not a continuous one and is absent at places in the peripheral nerves to form the nodes of Ranvier. At such constriction, since there is no myelin sheath, the neurolemma touches the axis cylinder. The portion of nerve fibre between two nodes is an **internode.** In the nerves of the autonomic nervous system (responsible for regulating involuntary activities within the body. The nerve fibres are enclosed within the neurilemma only, there being no myelin sheath. Such nerves are described as the non medullated or unmyelinated nerves. The neurolemma itself is surrounded by very thin sheath of fibrous connective tissue, the **endoneurium.** The Schwann cells produce myelin. The neurilemma is derived from Endoneurium of the nerve.

31.6 MUSCLE TISSUE

The most important functional feature of muscle tissue is the capacity to contract. On account of this contractibility, it plays an important part in all movements of an organism. Associated with this functional feature are greatly elongated muscle cells known as **myofibres.** They contain intracellular thread like structures, the myofilaments which are embedded within a more fluid cytoplasm, the **sarcoplasm.** Proteins called **myosin** and **actin** have been extracted from muscle fibres. There is very small amount of intercellular substance, and like the epithelial tissue, the muscle cells are very closely bound together by connective tissue.

Types of Muscles

There are three types of muscles. They differ in structure, location within the body and the type of innervation (nerve supply).

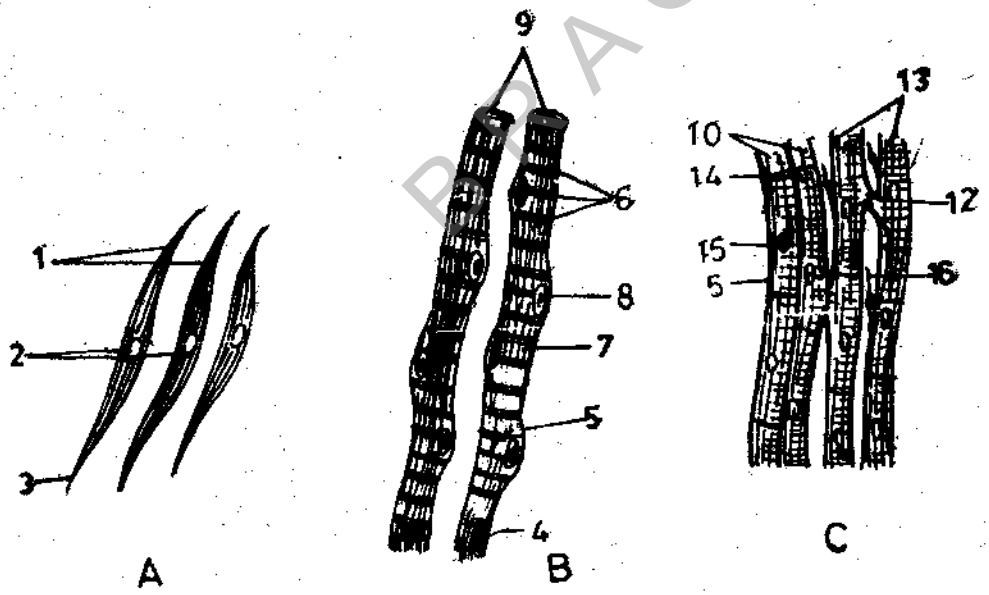


Fig. 31.11 Types of muscles. A. Unstriated muscle B. Striated skeletal muscle. C. Cardiac muscle
1. Longtitudinal myofibrillae 2. Rod shaped nuclei 3. Tapering end of the cell 4. Cylindrical muscle fibres 5. Sarcolemma 6. Transverse striations 7. Sarcoplasm 8. Oval flattened nucleus 9. Longtitudinal myofibres 10. Cylindrical fibres of cardiac muscle 11. Cross striations 12. Oblique cross 13. Myofibrils

1. **Unstriated** - Smooth muscle - Involuntary or visceral

2. **Striated** - Skeletal muscle - Voluntary

3. **Cardiac** - Heart muscle

1. Unstriated Muscle

In this variety of muscles there are no cross striations in the cells, hence known as unstriated or unstriped. It receives its nervous from the autonomic nervous system. Hence its contraction is not under the control of the animal and designated as the involuntary muscles. This muscle occurs in the digestive tract, genital tract ducts, blood vessels and urinary bladder and hence called as viscera muscle. Meseodermal myoblast cells are responsible for forming the muscle cells. The Unstriated muscle cells are spindle shaped. Each elogated cell tapers to a fine point at the end. The cell contains a single central nucleus (Fig 31.11A). The sarcolemma is so thin that it cannot usually be seen. In addition to the myofibrillae or myofilament there are granules near the nucleus in the sarcoplasm.

The visceral muscles contract slowly, but can remain contracted for a long time without getting fatigued.

2. Straited Muscle

The myofibrils show alternating dark and light cross band or stripes, hence striped or striated muscles(Fig.31.11B). This type of muscles is found in the body wall and limbs and is responsible for the movements of the skeleton, hence the name skeletal muscle. It is under the control of the voluntary nervous system (supplied by cerebo spinal nerves) hence is called as voluntary muscle. skeletal muscle makes up the lean meat of an animal and constitutes nearly half the animal's body weight. Striped muscle is very complex in structure. It consists of long, cylindrical fibres with blunt ends. The fibres are bounded by sarcolemma and contain many nuclei forming a syncitia. In mammals the nuclei are present just beneath the sarcolemma in the sarcoplasm. The Skeletal muscle is enclosed within a shealth of connective tissue known as **epimysium**, which is continuous with tendons attached to bones. From the epimysium further connective tissue membranes extend into the muscle tissue and surround the bundles of striated muscle fibres (fasiculi of fibres). This is the **perimysium** individual muscle fibres are surrounded by a thin sheath of the same connective tissue the **endomysium**. This connective tissue allows blood vessels and nerves to reach the muscle tissue for nourishment and nerve impulses respectively.

3. Cardiac Muscle

The cardiac muscle is involuntary but striated. It is confirmed to the walls of the heart and the large vessels joining the heart. Cardiac muscle consists of short columns or cylinders, united into a close mesh work (Fig 31.11 C). The mesh work forms a syncytium,because cell junctions are not easily seen. The columns are connected by slanting branches. A cell contains sarcoplasm and myofibrils like skeletal muscle but only one nucleus. The cell is enclosed in sarcolemma. Sarcoplasm is in abundance. It is correlated with the capacity to with stand fatigue. The myofibrils are distinct. The transverse light and dark bands are faint. There are intercalated discs at the junctions of the cardiac muscle cells. Contraction of cardiac muscle is not under the control of the will. It contracts quickly but not get fatigued. It receives both the cranial and autonomic nerves.

31.7. SUMMARY

The study of the tissues constitute **histology** and the **tissue** is an aggregation of cells that perform a specific functions on nervous and muscle **tissues.** There are 4 major classes of tissues viz. **epithelial, connective,nervous and muscle tissues.**

Epithelial tissues are generally seen lining the organs either internally or on the surface or both. They are secretory or absorptive and protective **in function.**

Connective tissues are mesodermal in origin and are characterised by possessing a ground substance called **matrix.** As the name indicates, these tissues bind or connect different tissues as the blood,ligaments,tendons, **Adipose** tissue serves in storing the fats. Skeletal tissue has a tough matrix. Mammalian bone is characterised by the presence of **Haversian system.** Red bone marrow is haemopoietic (production of blood cells). Blood is 'red river' of the body. It Contains RBCs,leucocytes and platelets kept circulated in the plasma. Neutrophils and monocytes fight infection. Lymphocytes produce antibodies and antitoxins. Lymph is similar to blood with corpuscles and proteins.

Muscle tissue is contractile in nature. Cardiac muscle keeps up rhythmcity as it is syncitial,much wider with sarcoplams, with larger and more number of mitochondria compared to the smooth and skeletal muscle fibres.

The nervous tissue is formed of highly specialised cells called **eurons** with dendrites and axons. The axons are medullalled or myelinated to act as insulation. The dendrons lacks nissl granules while the mitochondria are more at the axon terminals.

31.8. MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. What is an epithelium ? Describe the various types epithelia.
2. Describe the various kinds of muscle tissues.
3. Describe the various components of blood.

II. Answer the following in about 10 lines.

1. What are specialised types of simple epithelia?
2. Give a brief account on connective tissue.
3. Give a brief account on cartilage.
4. Describe the structure of bone .
5. What are granulocytes ?
6. Describe the general structure of muscle.
7. Neuron

Unit - 32 HISTOLOGY OF ORGANS OF RABBIT

Contents

32.1 OBJECTIVES

- To know the microscopic details of the Liver, Pancreas, Stomach, Intestine, Kidney, Testis, Ovary, Nerve, spinal cord, Lund and Spleen of rabbit.

32.2 INTRODUCTION

In the previous unit, we have learnt about different types of tissues and their functions. In this unit, we will be learning the histology of the various organs and organ systems. The cells together constitute tissues. The tissues in their turn give rise to organs and organ systems. The study of organs is called **organology** or **special histology.** It deals with the structure and tissue adaptations. An organ is a complex, structure of different tissues arranged in a definite pattern, performing a specific function. Typically, an organ is developed by a sheet of connective tissue fibrous capsule (eg. Glisson's capsule) an interstitial connective tissue or stroma. The stroma contains blood vessels, lymph, nerves and the epithelial lining. Organs are linked together into organ systems. The organ systems are interdependent as for example, the digestive tract is effective only when coordination of nervous and circulatory systems in conjunction with the accessory digestive glands is possible. The system can be classified as;

(i) Integumentary (skin & its derivatives),

(ii) Digestive

(iii) Circulatory

(iv) Lymphatic

(v) Nervous

(vi) Endocrine &

(vii) Urinogenital.

32.3. LIVER

The liver is the largest gland in the body. It is a dark red solid gland found within the dome shaped concavity of the diaphragm on the right side of abdomen. It is made up of five lobes (refer the digestive system of rabbit). It is enclosed within a fibrous connective tissue. The tissue eenters into each lobe and divides it into the hepatic units called the liver lobules.

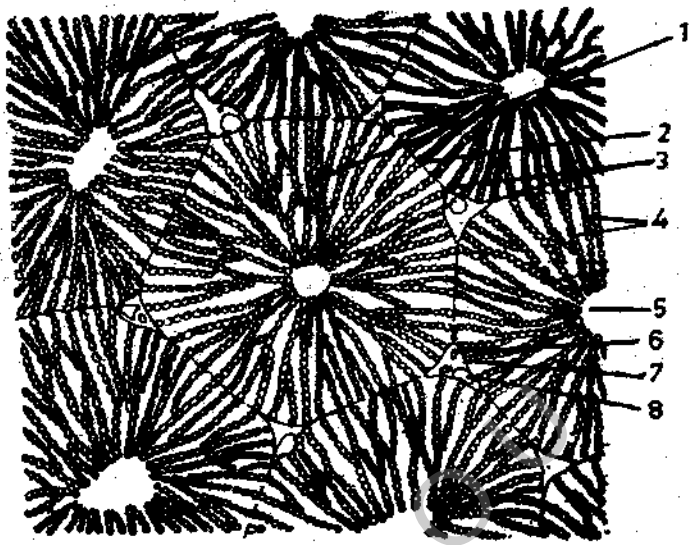


Fig. 32.1 Section of human liver. 1. Classic lobule not surrounded by a capsule in man. 2 Position of Glisson's capsule in pig. 3. Portal area. 4. Liver cords-usually one cell thick with kupffer's cells 5. Central vein (intralobular branch of hepatic portal vein 6. Hepatic artery. 7. Bile duct. 8. Hepatic portal vein.

Histologically each liver lobule is a polygonal prism bounded by the fibro conceive tissue called, the **Glisson's capsule** (Fig. 32.1). It contains in it blood vessels (branches of hepatic portal vein and hepatic arteriole). and small bile duct which together forms portal areas.

The liver lobule is the unit of hepatic structure in mammal: Each lobule is roughly five or six sided polyhedral prism in form and is composed of anastomosing and branching plates of cords of parenchymal cells (Hepatocytes) radiating outwards from the center like the spokes of a wheel from a central hub. Hepatic cells are polygonal with six or more surfaces each enclosed within a clearly defined cell membrane; The surfaces of cells are related to sinusoid space or partially separated from an adjacent cell to form a bile canaliculus.

Nuclei of liver cells are spherical or oval. Each nucleus has scattered chromatin granules. The cytoplasm stores glycogen and fat droplets Pigment granules may also be present.

Blood supply

Liver receives blood both by the hepatic portal vein (foodladen blood) and the hepatic artery (Oxygenated blood) (Fig. 32.2). The hepatic portal vein and the hepatic artery forms branches which run though the Glisson's capsule in between the lobules. They are described as the interlobular veins and the hepatic arterioles. The inter lobular veins are connected with a centrally situated intra lobular (Tributary of the hepatic vein) or central vein of the lobule.

This connection is by the sinusoids which form extensive sponge work between the cord of hepatic cells. Blood enters the sinusoidal mesh-work at the periphery of a lobule from inter lobular branches of the hepatic portal and hepatic artery and passes in a radial fashion though sinusoidal spaces to drain from the lobule by the intralobular or central vein (Tributary of hepatic vein). In the sinusoidal lining of the adult liver, two types of cells with intermediate forms are present. Large part of the sinusoidal lining consists of endothelial type, secreting bile. Among the endothelial cells are the kupffer's cells with cytoplasmic processes. These cells are actively phagocytic and frequently contain engulfed and degenerating erythrocytes, pigment granules and iron containing granules.

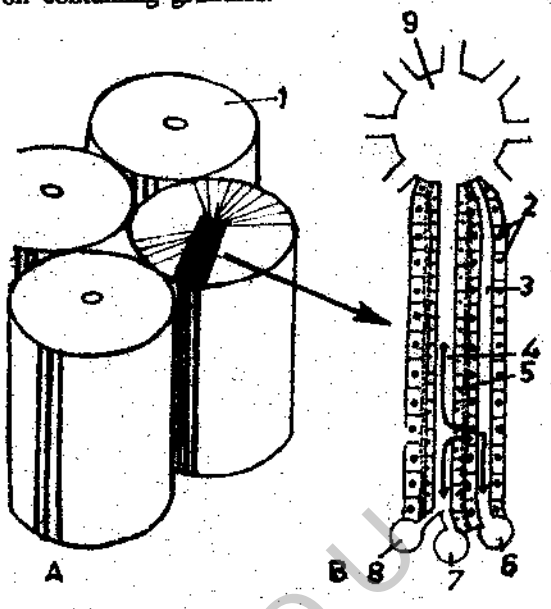


Fig. 32.2 Liver. A. Structure of a liver lobule. B. A portion magnified. 1. Lobule. 2 Liver cord. 3. Canaliculus. 4. Sinusoid. 5. Endothelium of sinusoid. 6. Bile ductile. 7. Branch of hepatic portal vein. 8. Branch of hepatic artery

Bile canaliculi

Between the adjacent rows of liver cells are tiny channels, the bile canaliculi, which drain peripherally into bile duct. The bile canaliculi are simply spaces between adjacent liver cells and have no other lining epithelium. The liver cells secrete bile into the bile canaliculi from where it passes into bile duct.

The liver is a very important gland of the body. in view of its functional importance, it is regarded as the chemical work shop of the body. (Ref. digestive system of rabbit for functions) (Unit 25).

32.4 PANCREAS

The pancreas is a large, elongated membranous gland lying in the U-shaped concavity of the duodenum. In the fresh condition it is pale pink or white. It is covered by the areolar tissue. This tissue extends into the gland and divides it into lobules or end pieces or acini (Fig. 31.3).

Pancreas is both an exocrine and endocrine gland. The two functions being performed by different cell types.

Exocrine portion (Acini)

The acini or lobules form the exocrine part of pancreas. Acini are tubular or pear shaped, surrounded by a thin connective tissue containing blood vessels, lymphatics, nerves and excretory ducts. Microscopic study shows that each acinus is made up of 5 to 8 pyramidal cells arranged around a small central lumen. The sections of acini may be round, oval or elongated with their respective lumens.

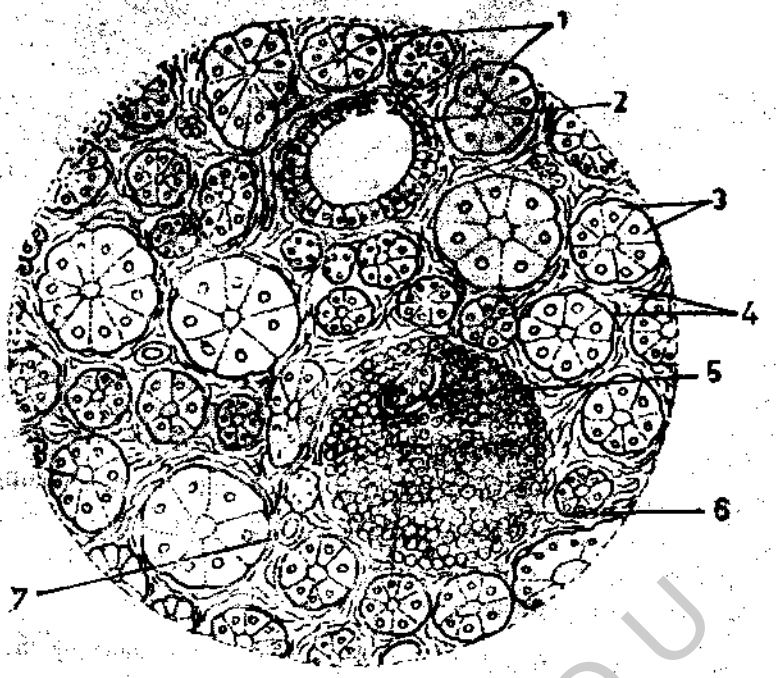


Fig. 32.3 T.S. Of the pancreas of rabbit. 1. Acini 2. Duct. 3. pyramidal cells of acini. 4 Connective tissue. 5. Blood vessel. 6. Islets of Langerhans. 7. blood capillary.

In an acinar cell the nucleus is spherical lies towards the base. The basal cytoplasm shows longitudinal striation, owing to the presence of numerous elongated mitochondria. The apical cytoplasm contains acidophilic secretions (zymogen) droplets or granules. The important function of the gland cells of the acini is the synthesis of the digestive enzymes (refer digestive system of rabbit). The pancreatic juice contains trypsin (protcolytic enzyme), amylopsin or amylase (Diastatic enzyme) and stepsin or lipase (Lipolytic enzyme) Pancreozymin a hormone acts on acinar cells, which release enzyme rich pancreatic juice.

Endocrine portion

Islet of Langerhans: The section of pancreas is identified by the presence of the Islets of Langerhans. They form the endocrine part of pancreas. They are spheroidal masses of cells. They are pale staining cells, in the form of irregular cords. between the cords of cells are capillaries. The islets of Langerhans is separated from the rest of surrounding exocrine acini, by a thin capsule of reticular fibres. Three types of cells are recognised in an Islet of Langerhans (Fig. 32.4) They are as follows:

α cells: Alpha cells secrete the hormone glucogon. It raises the blood sugar level, by promoting glycogenolysis.

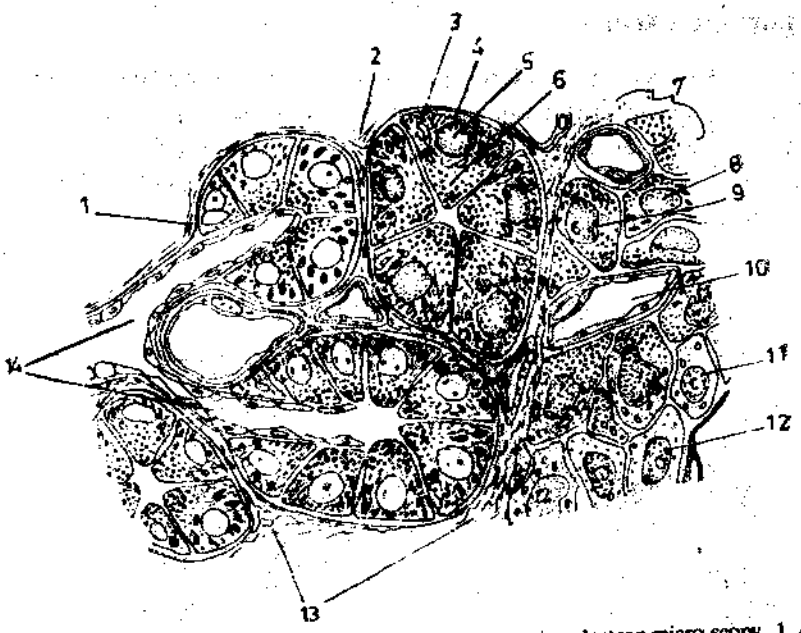


Fig 32.4. Diagram of a small portion of the pancreas as seen by low-power electron micro-scopy. 1. Acinous (exocrine). 2. Acinous. 3. Mitochondria. 4. Nucleus. 5. Nucleolus. 6. Zymogen droplets. 7. Endocrine Islet of langerhans. 8. Alpha cells. 9. Beta cells. 10.Capillary 11. 'c' cell. 12 Delta Cell. 13. Connective tissue. 14. Ducts.

β (Beta) cells: They occupy central position in an islet. Beta cells produce **insulin glocogenesis** conversion of glucose into glycogen and also Insulin promotes the transfer of glucose across cell membranes, particularly those in muscles and liver. Subsequently blood sugar level is lowered. Glucogon and insulin are antagonistic in their functioning.

δ (Delta) cells: These cells are found among alpha cells. Approximately they form 4% of the cells. They secrete **gastrin** in small amounts. It is similar to the gastrin severed by the stomach.

32.5 HISTOLOGY OF STOMACH

Stomach is the widest part of the alimentary canal (Ref. digestive system of Rabbit). Distinguished into three regions as the **cardiac, fundic** and **pyloric**. Histologically it consists of the following four regions (Fig. 31.5)

Inner most **mucosa** region is thick and forms a mass of the gastric gland which open on the surface by **gastric pits**. The gastric glands are simple tubular or branched tubular gland which extend deeply to reach the **muscularis mucosa**. The **lamina propria** (Aerolar connective tissue) spreads to occupy the spaces between glands. The most important glands of the stomach are the **fundic glands** in the fundic region. They produce the majority of the enzymes and hydrochloric acid and some mucous. The mucous is secreted by the mucous neck cell, between which are parietal cells oxyntic cells secreting hydrochloric acid. The base is composed mainly of chief or zymogenic or peptic cells which secrete the enzymes **pepsin** and **rennin**. Throughout the gastrointestinal tract there are endocrine mucosal cells that have been termed enterochromaffin cells. In the stomach one such cell type secretes the hormone **gastrin** (Ref. the physiology of Digestion). The **lamina propria** (connective tissue) is scanty, owing to the masses of cardiac glands. Muscularis mucosa is composed of the smooth muscles, arranged into inner circular and outer longitudinal layers. It is better developed in the stomach. Its contraction squeeses the gastic juice into the lumen.

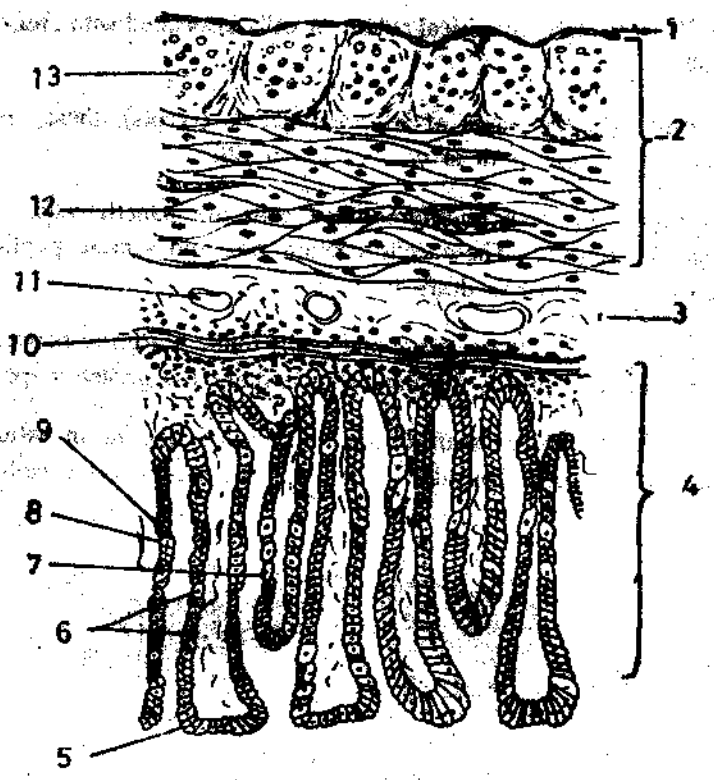


Fig. 32.5 A. T. S. of stomach. B. Portion of stomach (magnified). 1. Mucosa 2. Submucosa. 3. Muscularis. 4. Serosa. 5. Simple squamous epithelium. 6. Longitudinal muscle fibres. 7. Circular muscle fibres. 8. Blood vessel. 9. Muscularis mucosa. 10. :Peptic cells. 11. Tubular glands. 12. Oxyntic cells. 13. Simple columnar epithelium.

Sub mucosa: This is the fibro connective tissue region with collagenous, reticular and elastic fibres. The cells present in the mucosa are **fibroblasts, macrophages, plasma cells, lymphocytes** and some **fat cells.** The sub mucosa contains **blood vessels,** lymph and peripheral nerves.

Muscularis: The smooth muscle fibres are oriented in three different planes. The inner most layer is oblique, the middle one is circular and the outer most is longitudinal.

Serosa: The serosa is covered by a **mesothelial** layer of flat cells. The **peritoneum** is joined to the muscular coat by a thin sheet of loose areolar tissue. It contains vessels and nerves.

32.6 INTESTINE

Mucosa: The mucosa of the small intestine is specialised to form small finger like or leaf like projections of the mucous membrane called, villi (for increasing the surface area absorption). Each villus is covered by **columnar epithelium** and has a core of **lamina propria.** Crypts or intestinal gland (of Lieberkuhn) are tube like structure formed by the invagination of the interstinal epithelium and opening between the bases of villi. Between the crypts is the lamina propria.

To further increase the absorptive surface of the intestine, the columnar absorptive cells covering villi and lining crypts have numerous **microvilleous processes.** The epithelium of the intestinal mucosa is simple columnar in type. There are more than one cell type in it, consisting of the columnar cells with striated border, goblet cells, enterochromaffin cells and others as discussed below:

Columnar cells : These are tall, cylindrical columnar cells associated with absorption, particularly of macro molecules.

Undifferentiated cells : In the bases of intestinal glands (crypts), these are undifferentiated cells which replace other cells both in crypts and on villi

Paneth cells : Scattered between undifferentiated cells are paneth cells. They are present throughout the small intestine. These cells contain zinc and secrete peptidase and possibly lysozyme, an enzyme which breaks down bacteria.

Goblet cells: In interstinal villi, there are goblet cells found scattered between columnar cells. Due to the accumulation of mucus droplets, they acquire the goblet shape.

Enterochromaffin cells: Enterochromaffin cells which are endocrine in nature are found both in intestinal glands and on villi. in addition to other hormones, these cells produce **secretin** and **cholecystokinin.**

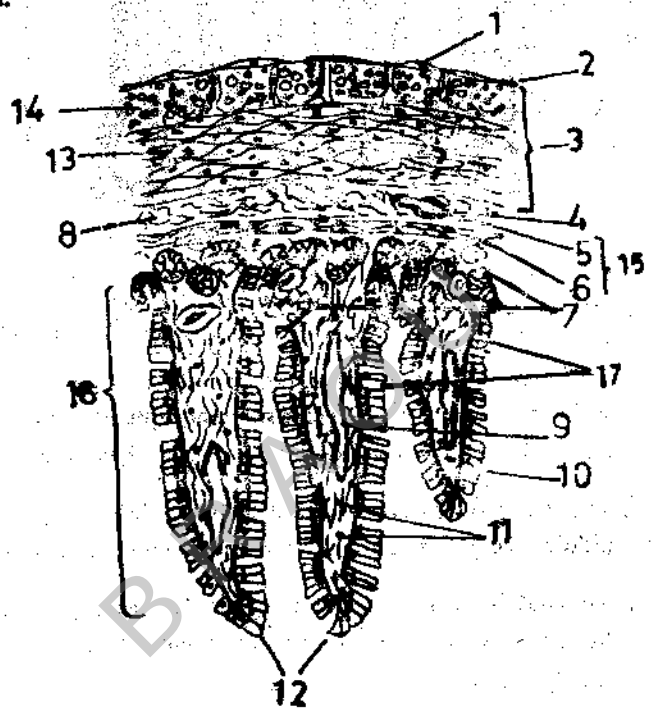


Fig. 32.6 A portion of duodenum magnified. 1. Simple squamous epithelium. 2. Serosa. 3. Muscularis. 4. Blood vessel. 5. Longitudinal layer. 6. Circular layer. 7. Crypts of Lieberkuhn. 8. Submucosa. 9. Lacteal. 10. Simple columnar epithelium. 11 Lymphocytes. 12. Villi. 13. Circular muscle fibres. 14. Longitudinal muscle fibres. 15. Muscularis mucosa. 16. Mucosa. 17. Goblet cells.

Sub mucosa: The sub mucosa is made up of the connective tissue. It contains blood vessels, nerve fibres and is already discussed in the section of stomach. The sub mucosa of the duodenum is having compound tubular duodenal glands, termed the **Brunner's glands.** They open into the crypts of Lieberkuhn. The secretions of these glands along with that of the crypts of Lieberkuhn forms the intestinal juice or **succus entericus.**

Muscularis: The muscular coat consists of the inner circularly oriented circular muscles and the longitudinally arranged longitudinal muscle fibres.

Serosa: As in stomach, serosa is composed of mesothelium (peritoneum) and connective tissue.

32.7 KIDNEY

Kidneys are the **excretory** and **osmoregulatory** organs of rabbit. There is a pair of dark red bean shaped kidneys, lying close to the dorsal body wall, one on either side of the dorsal aorta in the abdominal cavity.

A cross section of the kidney reveals that it is enclosed within a connective tissue capsule. The interior of the kidney is differentiated into a peripheral or outer **cortex** region and an inner or central **medulla** region with striated appearance. The glandular part of each kidney is composed of a complex system of coiled **uriniferous tubules** or nephrons. There are as many as 1,00,000 nephrons in each kidney of rabbit. Nephron is an excretory unit. (For diagrams refer unit 29).

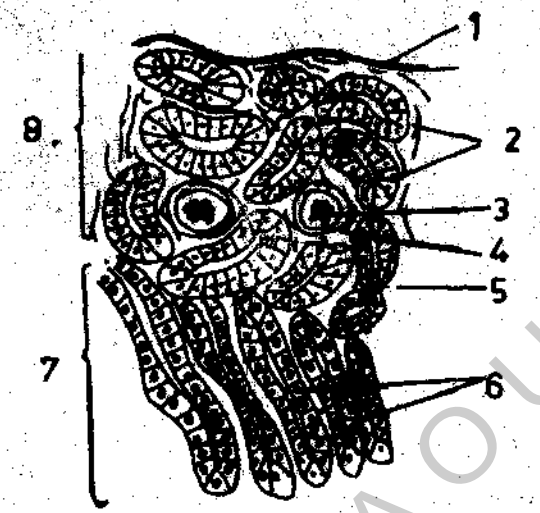


Fig. 32.7. T.S. of Kidney (a portion magnified) 1. Capsule. 2. Sections of convoluted parts of uriniferous tubules 3. Glomerulus. 4. Bowman's capsule. 5. Connective tissue with blood capillaries. 6. looped region of uriniferous tubules. 7. Medulla. 8. Cortex.

Each uriniferous tubule starts as a double walled globular **Bowman's capsule** (with squamous epithelium) from the cortex region. The cavity of the Bowman's capsule contains a bunch of capillaries known as the **glomerulus.** the bowman's capsule and a glomerulus together constitute a **Malphighian body.** From the Malphighian body the uriniferous tubule continues as a **proximal convoluted tubule** (with cuboidal ciliated epithelium). Then it is continued in the medullary region as the U shaped **Henle's loop.** From other limp of the loop of Henle forms the **distal convoluted** portion in the cortex region. After this the uriniferous tubules join with one another to form the **collecting tubules.** The collecting tubules converge at a point to form a **conical pyramid. The** pyramid is applied to the expanded beginning of the **ureter** called the pelvis of the kidney.

The important function of the kidney is the separation of the urea (manufactured in liver) from the blood and its removal from the body (Refer unit 29 for anatomical details.)

32.8 TESTIS

A section of the testis shows the presence of many seminiferous tubules. Each one enveloped by a **germinal epithelium** composed of cuboidal cells with few **pyramidal sertoli** or **subtentacular**

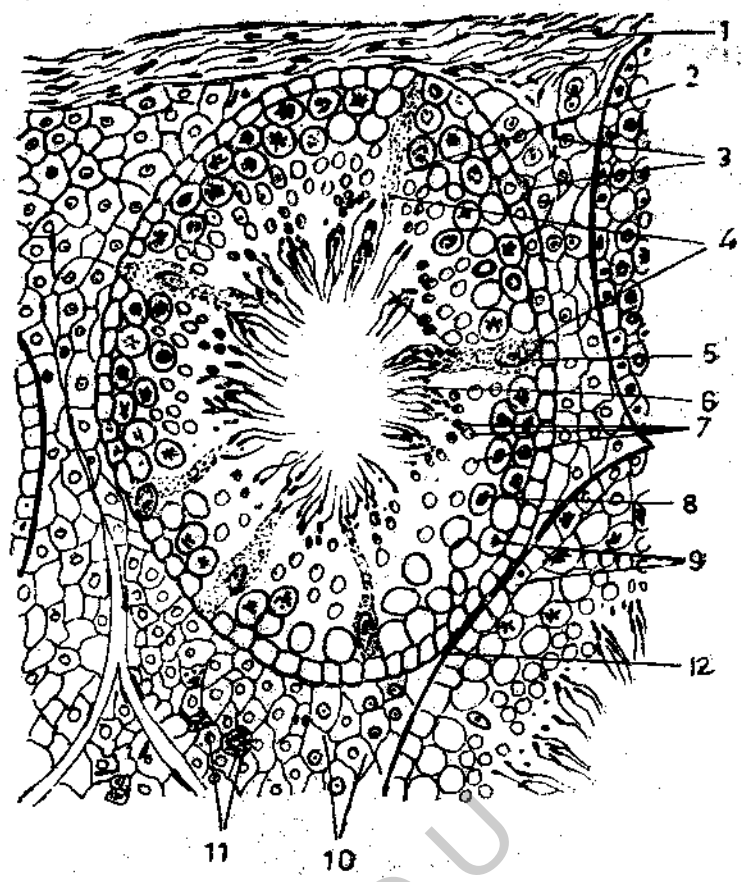


Fig. 32.8. T.S. of Testis. 1. Tunica albuginea. 2. Seminiferous tubule or crypt. 3. Connective tissue. 4. Sertoli cells. 5. Nucleus of sertoli cell. 6. Spermatozoa. 7. Spermatids. 8. Primary spermatocytes. 9. Spermatogonia. 10. Interstitial cells (of leydig). 11. Capillaries. 12. Basement membrane.

nutritive cells among them. Mitotic division of the germinal epithelium produces rounded cells, the **spermatogonia.** They multiply by mitosis for some time and develop into primary spermatocytes. The meiotic division of each primary spermatocyte forms two haploid **secondary spermatocytes** and from each secondary spermatocyte two haploid spermatids are produced. The latter attach to the sertoli cells and undergo metamorphosis to form **spermatozoa** by a process called spermatogenesis. In the cross section, various cellular layers exhibiting the different stages of spermatogenesis described above are seen within the germinal epithelium.

32.9 MAMMALIAN OVARY

The mammalian ovary is solid, small, round or oval body. It is situated behind kidneys one on each side nearer to the dorsal body wall. It is covered by visceral peritoneum. Inner to the peritoneum is the **germina epithelium** of cubical cells. Interior is differentiated as the peripheral **cortex** with follicles and deeper **medulla.** The stroma is composed of fibrous connective tissue with a little unstriped muscles. The stroma contains blood vessels, nerve fibres, **Graffian follicles** in various stages of development, **corpus luteum** or its degenerating stages called **corpus albicans.**

Germinal epithelium undergoes mitotic division to form new cells the oogonia towards the stroma. The oogonia in the form of **ovigerous tube** or **egg tube** project into the stroma. It

later detaches from the germinal epithelium as a mass of cells, the egg nest. One central cell of the mass becomes the **primary oocyte.** The remaining cells form a regular layer of the **follicular epithelium** round the oocyte and nourish it. This structure so formed is called the young or **primary follicle.** The follicular epithelium becomes several layered thick by the continued division of its cells. The developing follicle sinks to occupy a deeper postion in the medulla.

There develops a cavity in the follicle-the follicular cavity or antrum, filled with a semiviscous fluid the **liquor folliculi** secreted by the follicular cells. The follicular cavity widens and is surrounded by a compact granular cells forming **membrana granulosa** at the periphery. The membrana granulosa contains **theca interna**, consisting of spindle shaped cells, dense connective tissue and small blood vessels. The inner rounded cells form theca interna with connective tissue and a net work of capillaries.

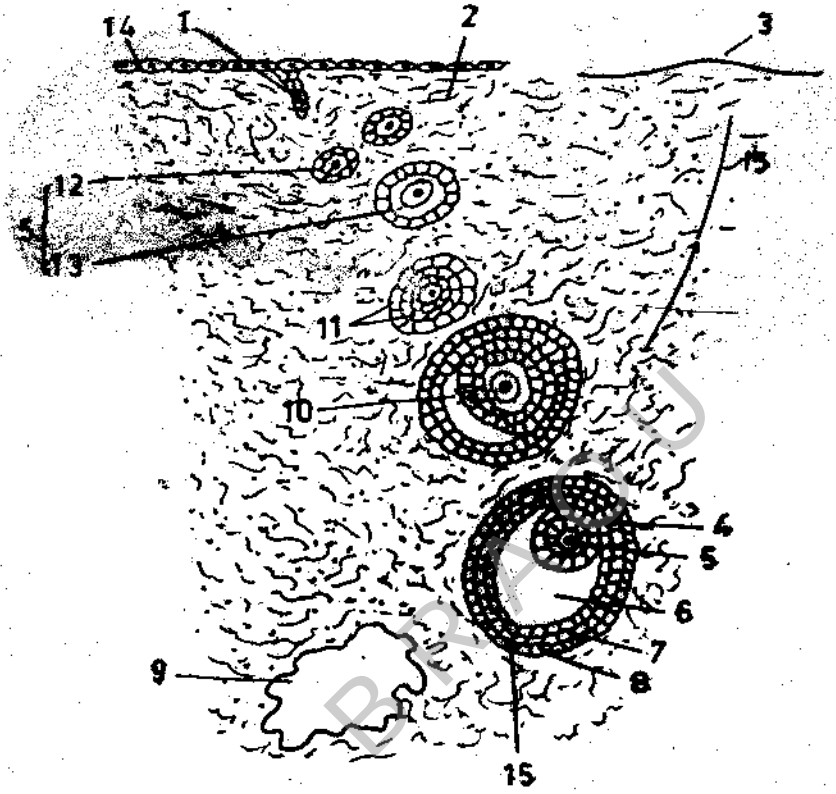


Fig. 32.9 Section of the ovary 1. Ovigerous tube epithelium. 2. Stroma. 3. Stigma. 4. Germ cells. 5. Oocyte. 6. Follicular cavity. 7. Membrane granulosa. 8. Basement membrane. 9. Corpus luteum. 10. Follicular cavity. 11. Many layers of cells. 12. Follicular cells. 13. Young Graffian follicle. 14. Germinal epithelium. 15. Mature Graffian follilcle.

The oocyte along with a few layers of follicular cells is found attached to the membrana granulosa on one side by a stalk of follicular cells, the **discus proligerus** or **cumulus proligerus** or **cophurus** or simply **germ hill.** Such a follicle is a **matured Graafian follicle.** The mature Graafian follicle being lighter (due to accumulation of watery fluid) rises to the surface of the cortex and occupies the entire width of the pit in cortex. It bulges at a point called **stigma.**

The oocyte acquires two membranes. The inner thin **vitfelline membrane** and the outer thick, clear non-cellular **zona pellucida.** The latter is surrounded by **corona radiata** made up of enlarged follicular cells with fine processes between them. It imparts a striated appearance to the corona radiata and allows passage for nourishment to the developing oocyte.

32.10. NERVE

Each peripheral nerve comprises of hundreds of nerve fibres. Each nerve fibre is made of a centraly placed **axon** surrounded by **myelin sheath** and **neurilemma.** Single fibre is enclosed within a thin connective tissue covering called the **endoneurium.** Many such fibres are grouped to form **perineurium** or **internal perineurium** which is also made up of connective tissue and forms **fasciculum.** The connective tissue enclosing together numerous such fasciculi is known as **epineurium** or **external perineurium.** The connective tissue contains sections of arteries and veins.

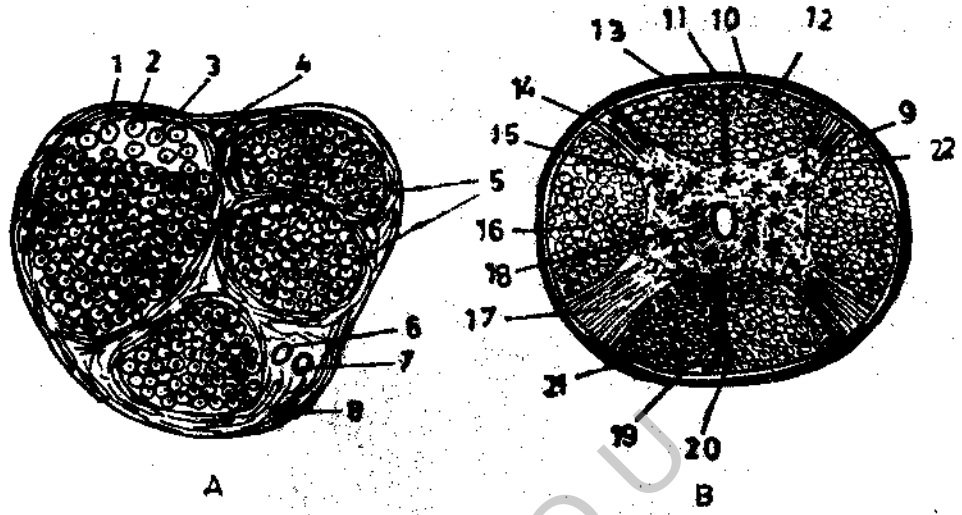


Fig. 31.10. A T.S. of nerve. B. Transverse section of spinal cord. 1. Axon 2. Myline and neurilemma. 3. Endoneurium. 4. Perineurium. 5. Fascicules. 6. Vein 7. Artery. 8. Epineurium. 9. Pia mater. 10. Arachnoid membrane. 11. Dura mater. 12. Dorsal funiculus. 13. Dorsal septum. 14. Dorsal horn. 15. Grey matter. 16. White matter. 17. Ventral horn. 18. Central canal. 19. Ventral fissure. 20. Blood vessels 21. Ventral funiculus. 22. Lateral funiculus.

(Ref. Nervous tissue 31)

32.11 SPINAL CORD

Spinal cord is the posterior continuation of the brain (medulla oblongata). It is a long cylindrical structure, which passes through the neural canal of the vertebrae.

A cross section of the spinal cord shows a central canal in it, which is continuous with the ventricles of the brain. It is lined by cuboidal epithelial cells with few cilia forming the **ependyma.** Central canal contains the **cerebro spinal fluid.** It is surrounded by two types of nervous tissue. Inner gray mater and the outer white matter. The gray mater is H-shaped in cross section and is composed of **multipolar** nerve cells in groups, **non-medullated** nerve fibres and **neuroglial cells.** The anterior and posterior limbs of the 'H' are called the **anterior** and **posterior horns.** They extend into the surrounding white matter and are continued into the spinal nerves. The white matter, formed by medullary nerve fibres and neuroglia surrounds the gray matter and is divided into three such **funiculi:** a dorsal funiculus on the dorsal side of the spinal cord, ventral funiculus between the ventral dorsal horns, and pair of lateral

funiculi between the dorsal and ventral horns on each side. In the mid dorsal region the white matter has a dorsal septum and another situated mid ventrally, the **ventral fissure.**

Meninges

Three protective membranes (meninges), the inner vascular **pia mater,** the middle **arachnoid** and the outer thick **dura meter** enclose the brain and spinal cord. Space between the pia mater and arachnoid membrane is filled by the nutritive cerebro-spinal fluid.

32.12 LUNG

The lungs are paired organs situated one on each side of the thoracic cavity. They are invested by the visceral pleura. On entering a lung the bronchus undergoes repeated divisions to form a branching system. It consists of bronchioles **terminal bronchioles, respiratory bronchioles, alveolar ducts, alveolar sacs and alveoli.** This branching shows a retrogression in the size of the tubules and their histological structure.

The epithelium changes gradually from a **pseudostratified** variety to **ciliated columnar** type in the terminal bronchiole. The connective tissue around the epithelium is rich in elastic fibres. There is a region of smooth muscle fibres surrounded by the adventitia consisting of a thin layer of fibro elastic connective tissue. Distally in the respiratory bronchiole, there is cuboidal epithelium. outside the mucosa, the wall is very thin. Containing elastic fibres and scattered smooth muscle cells. At the distal end the respiratory bronchioles divide into two or more short cone shaped, thin walled, irregular alveolar ducts. The simple squamous epithelium is supported by a very small amount of fibrous tissue. The alveolar sacs consists of a cluster of respiratory of pulmonary alveoli. The wall of the alveoli is formed of a single layer of moist, squamous epithelium and is covered by a network of capillaries. The alveoli capillaries other blood vessels and branches of the bronchus are all held together by an elastic connective tissue having smooth muscle.

32.13 SPLEEN

Spleen is the largest of the **lymphoid organs.** It is the only organ specialised for filtering blood. It consists of a soft pulpy mass surrounded by a **capsule,** which itself is composed of a dense fibrous connective tissue containing numerous elastic fibres and smooth muscle fibres. From the inner side of the capsule, strands extend into the pulpy moss as trabeculae and divide it into compartments or lobules. Artery, vein and nerve also accompany the trabeculae.

The pulpy substance is of two types: the **white pulp** and the **red pulp.** The bulk of the pulpy mass is made up of the red pulp in which are the patches of white pulp. Both the pulps are formed of reticular tissue and splenic cells. Comparatively the red pulp is having less of reticular tissue but more of free erythrocytes which give it red colour. In the white pulp the reticular tissue is dense and contains white corpuscles. Splenic cell act as phagocytes and destroy worn out red corposules. It is an important haemopoietic organ, producing lymphocytes. It acts as a storage organ for red cells. it filters the blood. The production of anti-bodies is another important function of the spleen.

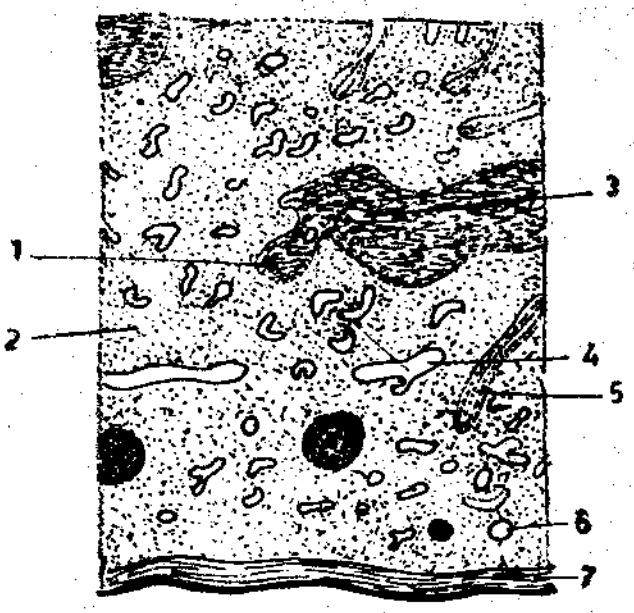


Fig. 32.11 T. S. of spleen. 1 White pulp. 2. Red pulp. 3 Artery of malphighian venous corpuscle. 4. Sinus 5. Fibrous trabecula 6. Penicilli of white pulp. 7. Capsule.

32.14 SUMMARY

In this unit, the microscropic detailed structure of the various organs is discussed. The mammalain liver is composed of 5 lobes, each lobe consists of several rows of cords of parenchyamal cells (hepatocytes). Each lobule is covered by a fibre-connective tissue called **Glisson's capsule.** Glisson's capsule is absent in man. Kupffer's cells are found lining the sinusoids which are phagocytic i.e., engulf the degenerating erythrocytes, pigment granules and iron containing granules. Liver is an important organ regulating various chemical metabolic activities and is often described as chemical work shop of the body. Pancreas is a endocrine organ and consists of several acini (lobules) and islands of cells called langerhan's islets with 3 types of cells viz., α, β & γ. The wall of the digestive tract consists of 4 layers viz., Serosa, muscularis, Submucosa and mucosa. Lamina propria is well developed in the stomach wall. Tubular gastric glands contain chief and oxyntic cells in addition to goblet cells. oblique muscles only seen in the stomach. The intestinal mucosa consists of column, paneth, goblet & enterochromaffin cells. Villi crypts of lieberkun, payers' patches are characteristic of intestinal wall. Kidney is differentiated into outer cortex and inner amedulla. The Malphighian capsules and ascending convoluted lobule lie in the cortex while the descending convoluted lobule, the Henle's loop and the collecting tubules lie in the medulla.

The testis is formed of the seminiferous tubules consisting of cuboidal cells with cells of setroli.

There also lie the interstitial cells (leydigs cells) in the stroma which are endocrines in function. The ovary again contains outer cortex studded with graffian follicles with maturing and matured ova while the medulla with the vascular stroma.

Theca interna seems to secrete estrogens. The graafian follicles after ovulation produces corpus luteum which in turn produces progesterone.

The lung alveoli are lined by the squamous epithelium. Spleen is the largest lymphoid organ.

The spleen pulp is composed of white and red pulps. The spleen is haemopoietic as well as the phagocytic organ for the worn out cells.

32.15 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Describe the histology and enumerate the functions of liver or pancreas of rabbit.
2. Sketch and label the section of the mammalian ovary describing the process of maturation.

II. Answer the following in about 10 lines.

1. What is the endocrine part of pancreas?
2. Sketch and label the section of stomach or intestine. Write a note on its characteristic features.
3. Describe the microscopic structure of the testis.
4. Describe the minute structure of spinal cord.
5. Write a note on the histology of rabbit lung.
6. Write a note on the spleen.

BLOCK - III
EMBRYOLOGY

Unit – 33 TYPES OF EGGS, FERTILIZATION, CLEAVAGE AND GASTRULATION

Contents

33.1 OBJECTIVE

- This unit describes the kinds of eggs, process of fertilization and later development of Zygote.

33.2 INTRODUCTION

Organisms develop, grow and die. In nature however, their number is maintained for perpetuation of the race. This multiplication is possible by way of reproduction in several successive processes like gametogenesis, fertilization, cleavage, organogenesis and growth. Thus the transformation of a single fertilised Zygote cell into the multicellular, well-organised adult like its parents [**ontogeny**] constitutes an important branch of biology, **embryology**. This study of development of a species i.e., ontogeny reveals the evolutionary path way [**phylogeny**]. This paved the way for the Muller and Haeckel's **biogenetic or recapitulation** law which is popularly stated **"ontogeny recapitulates phylogeny"**. Embryology now a days is called as **'Developmental Biology'**. To a medical student, developmental biological studies are of particular interest.

33.3 TYPES OF EGGS

The ovary has an epithelial layer consisting of **germinal cells**. Each germinal cell undergoes the stages of proliferation, growth and maturation in a sequence which has been understood in the foundation course already, as the **oogenesis**. During the growth and maturation stages, the egg cell accumulates reserve food materials, in particular the yolk, which consists of proteins and lipids. The volume of nucleus increases hence it is known as **germinal vesicle**. This increase is because of the deposition of large amount of nucleoplasm in the nucleus. When two successive maturation divisions take place, the homologus chromosomes exchange their genetic components and reduce half to original number specified for a species. Consequently, only one set of chromosomes, the **haploid**, remains in the egg. Second polar body is extruded soon after the fertilization takes place. All polar bodies disintegrate and disappear. Thus only mature ovum remains at the end of **oogenesis**.

An egg-cell is enclosed by a **thin vitelline membrane**, containing **ooplasm** and a **large nucleus**.

The ooplasm is filled with **yolk** or **deuteroplasm** which is meant for nourishing the growing embryo. A large **nucleolus** or several **nucleoli** are often present in the nucleus.

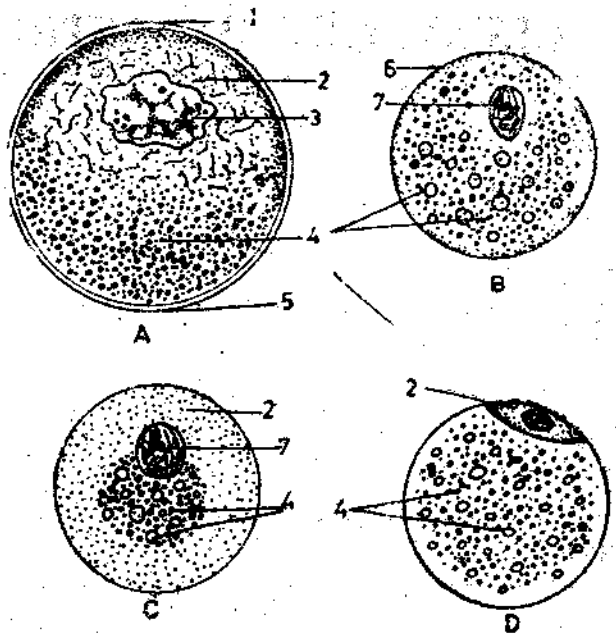


Fig.33.1. Types of eggs. A.Mesolecithal (Telolecithal) B.Microlecithal(Isolecithal or homolecithal) C. Centrolecithal D. Macrolecithal(Discoidal) 1. Animal pole 2.Vegetal pole 3.Germinal vesicle (Nucleus) 4.Yolk 5.Ooplasm 6.Vitelline membrane 7.Nucleus.

On the basis of amount of the yolk and its distribution in ooplasm there are chiefly three types of eggs namely **microlecithal, mesolecithal** and **macrolecithal** (Fig.33.1 A.D.) When yolk quantity is less the egg is said to be microlecithal. In such eggs if the distribution of yolk in the ooplasm is uniform the type of egg is **homolecithal** or **isolecithal** eg. *Ascidia, Amphioxus,* **eutherian mammals. Mesolecithal egg** contain moderate quantity of yolk as in Amphibia and lung fishes in which yolk is concentrated at vegetal pole of the egg hence the **term telolecithal** is applied to such eggs. **Macrolecithal eggs** possess a very large amount of yolk almost filling the ooplasm entirely leaving only a small amount of ooplasm with nucleus at the animal pole like a minute disc. Such eggs are otherwise known as **discoidal eg. Reptiles and Birds.** In insects heavy amount of yolk accumulates in the centre of the egg when it is called as the **centrolecithal.** The ooplasm envelops the yolk in this case.

The egg is surrounded by egg membranes. Immediately outside is **primary egg membrane** or **vitelline membrane** which is secreted by follicle cells or ooplasm itself. In tunicates and fishes this is called as **chorion. Zona radiata** and **zona pellucida** are the primary membranes which develop in mammals.

Secondary egg membranes are secreted by oviduct which include the **shell,** secreted by shell glands of oviduct as in sharks, reptiles and birds. In Amphibia the egg is surrounded by layers of jelly to make the egg to adhere to one another, and to submerged objects in water. In birds many secondary membranes are formed as seen in a hen's egg. The outer most membrane is a porous shell, next two are thin shell membranes followed by thin and dense albuminous layers (White of egg) surrounding the vitelline membrane.

33.4 FERTILIZATION

Fertilization is a process involving the approximation of male and female gametes followed by the fusion of their nuclei and cytoplasm (Fig.33.2 A.C.). According to the place and medium there are two kinds of fetilization processes: **external fertilization** occurs in water outside the bodies of parents e.g. Frog. In reptiles, birds and mammals sperms are discharged into the oviduct where the eggs are **internally fertilized.** On coming in contact with the ovum, the spermatozoan attaches its head to the egg and becomes motionless. The ovum produces a glycoprotein called **fertilizin** (species specific) and another species specific protein called **antifertilizin** is produced by the sperm. Both react like antigen antibody and form a chemical-lock between the two. Thus process is called **'capacitation'** and as a result many sperms adhere to the surface of the ovum. The sperm's acrosome now produce an enzyme, **hyluridinase** which seems to dissolve the egg membranes. A **fertilization cone** protrudes from the egg and receives the nucleus of sperm along with its middle piece. Both pronuclei (sperm and egg nuclei) fuse with each other (amphimiris) to form a **zygote nucleus.**

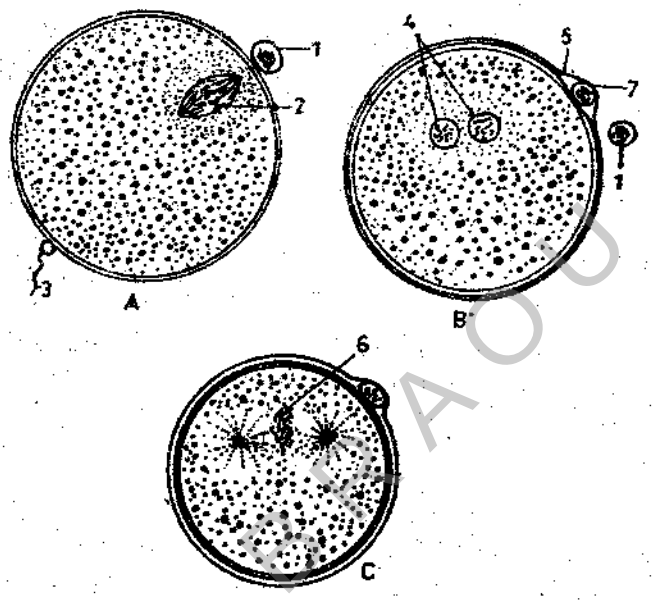


Fig.33.2. Process of fertilization. A.sperm approaching the egg B.Fusion of male and female pronuclei C.Zygote 1.First polar body 2.Egg nucleus 4.Male and female pronuclei 5.Fertilization cone 6.Zygote nucleus 7.Second polar body.

Fertilization activates the egg to start further development. The fusion of male and female pronuclei ensure the specific **diploid number** of the animal species, further introduces genetic variations in the species.

33.5 CLEAVAGE

Immediately after fertilization, the activated zygote passes through a series of cleavages through successive mitotic cell divisions. The result of the cleavage is the formation of a complex multicellular body from a unicellular zygote. During the whole process the general shape of embryo does not change. There is an increase in the number of cells whose size decreases progressively.

The cleavage of fertilized egg is initiated by the division of nucleus and is followed by the division of cytoplasm so that the zygote divides into two daughter cells known as **blastomeres.** In each division cleavage furrows appear in various planes. First few cleavage planes are vertical passing through animal-vegetal axis. Later on cleavage planes are formed equatorially or transversely.

The plane of cleavage is decided by the position of miotic spindle formed during the cleavage. As a rule the place of cleavage remains always at right angle to the long axis of the spindle. If the spindle is oriented transversely to polar axis, cleavage will be vertical, conversely if the spindle is parallel to polar axis the divisions will be **horizontal or transverse.**

Usually the plane of first cleavage is vertical passing through central axis of the zygote. The second is also vertical but at right angles to the first plane giving rise to **four blastomeres** in the same lane. The third cleavage plane is transverse which is at the right angles to the first two planes and polar axis. Thus **eight blastomeres** are formed-four usually of smaller size at the top (animal pole) the **micromeres** and four usually of large size at the bottom (the vegetal pole), comprising the **macromeres** (Fig.33.3 A.F).

The arrangement of blastomeres in a cleaving egg show various patterns. When upper tier of blastomeres lies over corresponding blastomeres of the lower tier, the cleavage is said to be **radial** eg. Echinoderms and Amphibians. **Spiral cleavage** when all blastomeres of upper tier come to lie over junctions between each two of the vegetal blastomeres. This is because of the oblique position of the mitotic spindles. During third cleavage four oblique spindles are arranged in a spiral manner in respect, to the main axis of zygote. Spiral blastomeres tier may take a turn in a clockwise or anticlockwise direction when they are said to be **dextral** and **sinitral** cleavages respectively eg. Annelids, Molluscs, Nemerteans, Polycladia.

The differences in the size of blastomeres in the first two divisions establish in some animals **bilateral cleavage.** Two of the first blastomeres may be larger than the other two. These two establish bilateral symmetry which becomes more obvious in subsequent cleavages eg. Tunicates, Nematodes.

On the basis of total range of developmental potentialities of the blastometres cleavage is defined as **determinate** and **indeterminate.** The formation of blastomeres with fixed embryonic development is known as **determinate cleavage.** When such blastomeres are separated, each blastomere is capable to develop only fixed part of the embyro eg. Annelida, Mollusca. On the contrary in indeterminate cleavage such separated blastomere has the capacity to form a complete embryo eg. Echinoderms, chordates.

The role of yolk can not be underestimated in the process of cleavage as it is always present in the egg in lesser or greater amounts. Cleavage occurs rapidly in eggs containing less yolk. When yolk quantity is more in an egg. It retards the process of mitosis and prevents the cleavage plane to extend over dense regions. Thus the yolk influences the course of cleavage. The result of this influence is that the zygote nucleus is displaced owing to the heavy deposition of yolk at the vegetable pole. The cleavage rate in this area falls which results in unequal sized blastomeres. When zygote undergoes total division forming separate blastomeres right from animal to vegetal pole at a time, it is called as **total or holoblastic cleavage** eg. Amphioxus, Placentals. This occurs in microlecital egg. In highly telolecithal or macrolecithal eggs, the cleavage remains restricted to the discoidal area of cytoplasm of the egg at animal pole eg. Bony fishes, Reptiles, Birds. Such type is termed **meroblastic.** In centrolecithal eggs, superficial cleavage occurs; the cleavage planes are restricted to the surface

layer of the egg cytoplasm as observed in insects.

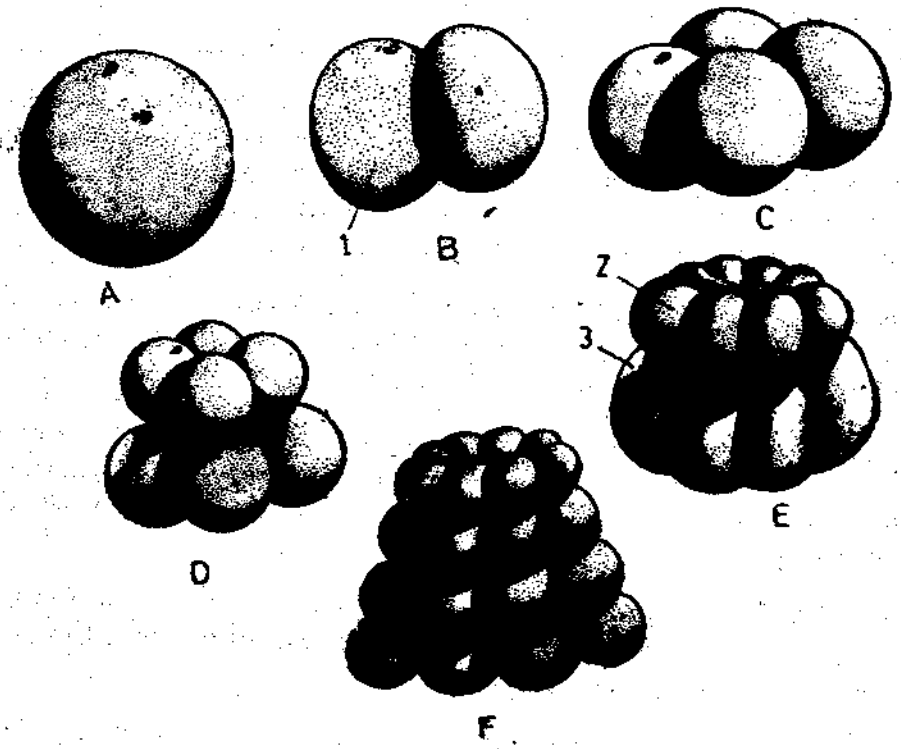


Fig.33.3.Cleavage. A.Zygote B.Two-cell stage C.Four cell stage D.Eight cell stage E.Sixteen cell stage F.Thirty two cell stage 1.Blastomere 2.Micromere 3.Macromere.

33.6 BLASTULATION

The repeated cleavages result in a mass of blastomeres which form into a ball of minute cells. As the cleavage proceeds further, the blastomeres arrange themselves into a single cell thick layer known as **blastoderm.** Inside the blastoderm a cavity appears, the blastocoel, which is filled with a fluid. This hollow, spherical embryonic stage consisting of single layer of cells is called as **blastula** (Fig.33.4 A), and the process of its formation is called the **blastulation.** The blastula of different animals are named differently. Blastula of Echinoderms and Amphioxus is called **coeloblastula** and that of Amphibians as **amphiblastula** and that of insects **superficial blastula** and that of fishes, reptiles and birds as **discoblastula.**

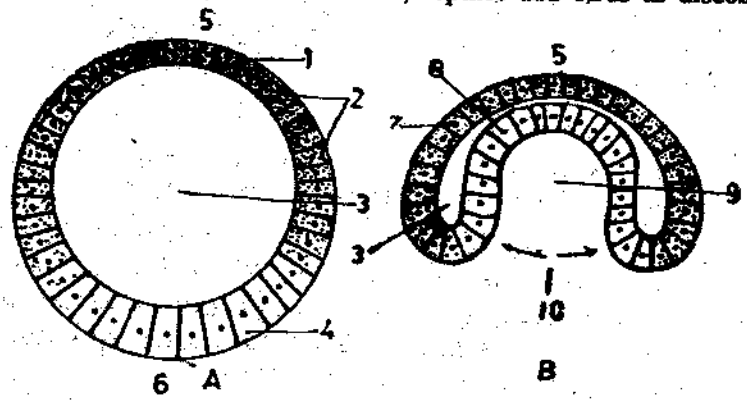


Fig.33.4. A.Blastula B.Gastrullation Invagination 1.Micromeres 2.Blastoderm 3.Blastocoel 4.Macromere 5.Animal pole 6.Vegetal pole 7.Ectoderm 8.Endoderm 9.Archenteron 10.Blastopore.

33.7 GASTRULATION

Gastrulation is the process during which the single layered blastula is transformed into two layered form known as **gastrula.** In higher forms of vertebrates (discoblastula) three distinct germinal layers are established by the end of gastrulation. The process involves the displacement of the cells (blastomeres) of the blastoderm by morphogenetic movements, from one place to another. These movements can be grouped under two heads :

(A) Epiboly: These morphogenetic movements occur in ectodermal blastomeres (micromeres) which flatten, divide rapidly, expand, eventually spread over and envelop inwardly migrating blastomeres of prospective endodermal and mesodermal cells.

(B) Emboly: These morphogenetic movements are concerned with inward migration of future notochord-mesoderm forming and endoderm forming blastomeres from the blastodermal surface of blastula and their extension to form the main axes of the embryo. In different groups of animals this may occur in the following ways which are very common:

(i) Invagination: This term implies 'in tucking' or 'insinking' of layer of endodermal cells (vegetal region) into the blastocoel, the process resembles to that of a balloon which has been pushed in with a finger in a region (Fig.33.4 B).

(ii) Ingression: The endoderm forming cells migrate from the surface of blastula inwardly in a simple manner by amoeboid types of movements. i.e., several different and separate inward migrations of one or more cells. Hence it is also called **polyinvagination** (reptiles, birds and mammals).

(iii) Delamination: Endodermal cells either bud off or separate as a whole sheet into the interior of blastula from the blastoderm as seen in meroblastic eggs (Fig.33.5 B).

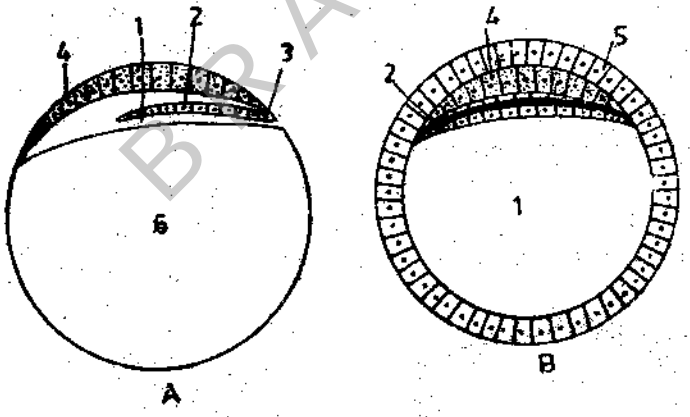


Fig.33.5. Gastrulation A.Involution B.Delamination 1.Archenteron 2.Endoderm 3.Blastoporal lip 4.Ectoderm 5.Trophoblast 6.Yolk

(iv) Involution: This method involves rolling of endodermal blastomeres from vegetal region of blastula and spreading of such layer underneath the surface layer of blastula. The cells of outside surface of blastula converge towards external margins of the blastoporal lips wherefrom the cells gradually roll inwards. This can be well illustrated in the movements of chordamesoderm cells in *Amphioxus*, birds and frogs (Fig.32.5 A).

Ultimate result of emboly is the production of an embryonic stage in which the embryo is two layered - an external ectoderm and an internal endoderm. Further morphogenetic movements of endodermal cells bring about a new interior cavity, the **archenteron** (primitive

gut), roof of which possesses chorda- mesodermal cells. Exterior opening of the archenteron is known as the **blastopore** whose dorsal, ventral and lateral margins are named as **'lips'** which particularly play an important role in the morphogenetic movements and mesoderm formation. As a consequence of gastrulation blastocoel is obliterated. In late stage of **gastrula** all the three primary germ layers appear along with notochord. By staining with vital colours to moving cells, charts are drawn up, named **fate maps,** showing in particular, the fate of each part of the embryo at late blastula stage. These maps show the limits of organ forming substances.

The three germ layers give rise to the various tissues of the adult. Ectoderm gives rise to the integumentary system, nervous system, sense organs, anterior pitutary, having of stomodaeum and proctodaeum, endoderm gives rise to the lining of digestive tract, liver, pancrease, respiratory system, bladder, certain endocrine glands (parathyroid, thyroid, thymus), lining of vagina, urethra and associated reproductive glands, auditory tube and middle ear etc. And the remaining tissues like skeletal, circulatory, excretory, gonads, genital tracts, coelom, dermis and muscles develop from mesoderm.

33.8. SUMMARY

In this unit certain general principles of embryology discussed in brief. The eggs are broadly classified into 3 types viz., microlecithal, mesolecithal and megalecithal depending upon the quantity of yolk present in the egg. The amount of yolk present will determine the cleavage furrow [holoblastic or meroblastic] after fertilization or amphimixis. The acrosomal part of the sperm produces an enzyme called hyaluridinase paving its way to make entry. The position of the mitotic spindle determines the type of the cleavage viz., radial or spiral cleavage results in the morula, a ball of mass of cells which transform into a hollow ball of minute cells, blastula with the cavity blastocoel. The blastula now converts into gastrula, obliterating the blastocoel. The gastrula encloses archenteron [primitive gut] lined by endoderm, opening out by blastopore with dorsal, ventral and lateral lips. Soon there develops mesoderm in between the outer ectoderm and inner endoderm. Thus now the gastrula is with all the three germ layers which give rise to the various tissues of the future adult.

33.9. MODEL EXAMINATION QUESTIONS

I. **Answer the following in about 30 lines.**

1. Describe the structure of various types of eggs with regard to quantity and distribution of yolk.
2. What is cleavage? Discuss its various types.

II. **Answer the following in about 10 lines.**

1. Explain the process of gastrulation in general.
2. Write a note on fertilization.
3. Blastula & Blastulation
4. Morphogenetic movements and Gastrulation.

Unit – 34 : DEVELOPMENT OF AMPHIOXUS

Contents

34.1 OBJECTIVE

- This lesson describes the basic embryology of a primitive chordate, being very simple. The study will throw light on all basic stages of development.

34.2 INTRODUCTION

Amphioxus is a marine chordate living in shallow sea waters forming burrows in sandy coasts. Though it is not a vertebrate, yet the process of its development reveals enough of basic features of any vertebrate embryology, it also exhibits resemblance to the development of echinoderms.

As in all higher chordates the sexes in *Amphioxus* are separate but are in distinguishable externally. In both sexes gonads, the **testis** and **ovaries,** develop from the antero-ventral parts of the somites, in two rows. These two rows are situated one on either side of the body. Germ cells develop,undergo gametogenesis and differentiate into spermatozoa or ova according to the sex. Spermatozoan of Amphlioxus is of very minute size (18 microns) contains a head possessing a beadlike **acrosome** in front, a short **middle piece** and a **long vibratile slender flagellum or tail.** The egg is **small** (0.12 mm) and **spherical.** It contains a very small amount of yolk and is said to be **microlecithal - homolecithal.** It is surrounded by a vitelline membrane only, secondary membrane being absent (Fig.34.1 B).

34.3 FERTILIZATION

The gametes are shed by contractions of muscles of body wall, first into the atrium then into sea waters through atriopore. A sperm enters the egg which is at the secondary oocyte stage.

The entry of the sperm causes activation of egg. The ooplasm contracts, plasma membrane separates from vitelline membrane, a fluid is secreted in between these two memberanes when the latter is known as fertilization membrane which bars then entry of more sperms from outside. The egg which is in a secondary oocyte stage undergoes maturation by extrusion of a second polar body near the animal pole. The sperm and egg nuclei enlarge and become male and female pronuclei. These two pronuclei migrate towards the equator of eggs and fuse to form zygote nucleus. This nucleus is surrounded by yolk free, transparent nucleoplasm.

34.4 ORGANIZATION OF ZYGOTE

Soon after fertilization the cytoplasm of the zygote rearranges its substances into various regions. Near the vegetal pole there is greatest amount of yolk and hence it is dark. The animal hemisphere of the egg having less amount of yolk, is transparent. On the posterior side of the egg there is a crescentic cytoplasm. Opposite to this crescent there are two more crescentic areas. On the basis of these four presumptive areas fate maps have been drawn which reveal the presence of their respective organ forming substances.

(i) The dark area, containing more yolk develops into endoderm.

(ii) Clear cytoplasm develops mainly epidermis.

(iii) Posterior crescentic area forms mesoderm.

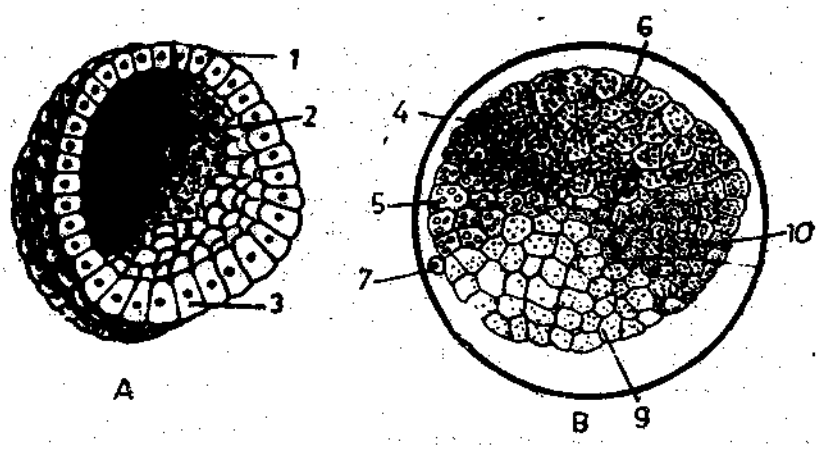
(iv) Out of the two areas opposite to mesodermal crescent the one below develops nervous system and the one above notochord. In addition, bilateral symmentry and orientation of the main body axis is also established as exhibited by the cleavage.

34.5 CLEAVAGE

The first vertical cleavage is holoblastic which passes through animal vegital axis bisecting the mesodermal crescent (Fig.34.3). It is of indeterminate type. First two blastomeres which are equal in size establish bilaterel symmetry of the adult. Each blastomere produces either right or left of the adult. The second vertical cleavage at right angles to the first gives rise to 4 blastomeres. Out of these four two belong to the anterior and the other two to the posterior part of the adult. The third cleavage is horizontal as usual, passing slightly above the midregion, dividing the blastomeres transversely into four small micromeres at the top and four large macromeres placed below them. A fourth vertical, fifth transverse and a sixth vertical cleavages in the zygote produce 64-blastomeres when the cleavage pattern becomes irregular and cannot be followed systematically, as micromeres divide rapidly.

34.6 BLASTULATION

As the cleavage is going on, the inner surface of blastomeres which are in close contact start secreting a semifluid, jelly like substance. TThis material gradually accumulates in the centre of the mass of the blastomores. This jelly serves to push all the blastomeres outward so to as to arrange them in a single layer of cells (monoblastic) called the blastoderm. The interior space, blastocoel or segmentation cavity is filled with fluid. Blastula has one cell



34.1. Amphioxus. A. V.S. of early blastula B.Late blastula showing presumptive areas and symmetry 1.Blastocoel 2.Micromeres 3.Macromeres 4.Notochord 5.Neural plate 6.Endoderm 7.Second polar body 8.Vitelline membrane 9.Ectoderm 10.Mesodermal cresecent.

thick wall consisting partly of micromeres and partly of macromeres (Fig.34.1.A). It is slightly pear shaped. Its pointed and being posterior. The distribution of organ forming substances (presumptive areas) which are destined to produce organs and systems in future embryo are destined are shown in the fate map of blastula(Fig.34.1.B).

34.7 GASTRULATION

As gastrulation begins, six hours after fertilization, the dorsal surface of the blastula flattens to form an **endodermal plate.** This then invaginates into the blastocoel to such an extent that it almost meets the future **ectodermal layer** (Fig.34.2A). Blastocoel is obliterated owing to the invasion of endodermal cells. Thus a two layered **gastrula** is formed with a new cavity, the **archenteron** which open exteriorly through is known as the **blastopore.** Its edges are termed as **lips of blastopore** (Fig.34.2B). At this stage the ectodermal cells (micromeres) of the animal hemisphere divide rapidly and spread out by epibolic process over the invaginating blastomeres. The blastoporal lips now become main centres of morphogenetic movements of the blastomeres. The chorda cells at the dorsal lip roll in by the process of involution to form the roof of archenteron. Ventral and lateral lips of blastopore involute nearby the

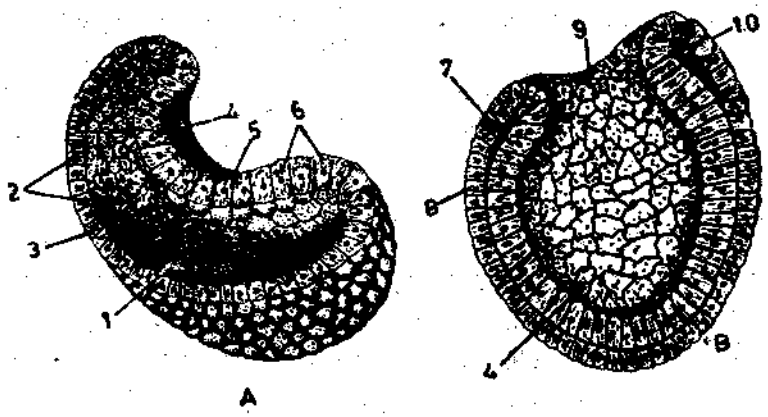


Fig.34.2. Amphioxus A. Gastrula in vertical section B. Late gastrula in vertical section 1.Blastocoel 2.Micromeres 3.Anterior face 4.Archenteron 5.Posterior face 6.Macromeres 7.Endoderm 8.Ectoderm 9.Blastopore 10.Blastocoel(reduced).

mesodermal cells, which migrate up dorsally to a position on either side of the chorda cells forming a part of roof of archenteron. Thus epiboly brings coordination between invaginating and involuting cells, result being the shifting of blastopore to a more posterior position (from early antero-dorsal) and its reduction in size. It eventually reduces into an insignificant fraction of original wide opening.

Now, the late gastrula is slightly elongated and two layered. Outer layer is the **ectoderm** which spreads all over except a broad band of presumptive **neural plate dorsally.** The inner layer consists of future **notochord** middorsally, flanked on both sides by mesoderm bands and endodermal cells spread out laterally and ventrally. Blastocoel completely disappears due to close contact of these two layers.

34.8. ORGANOGENESIS

The three germ layers, **(Ecto, Endo and Mesoderms)** formed by the end of gastrulation, are the sources for the development of all the organs of adult animal. The **organogenesis** is a side by side continuous process of shaping different organ systems. Therefore, for a convenient understanding each organ system is individually described under separate heading.

34.8.1 Formation of neural tube

The neural tube is formed by the band of presumptive ectodermal cells dorsally. At first these cells flatten and thicken and separate from the rest of the epidermal cells as **neural plate.** This plate sinks below so that its sides rise up as neural folds enclosing neural groove. Soon these folds grow towards each other and meet together and give rise to the **neural tube** with internal cavity, the **neurocoel.** The meeting of the folds begins from the posterior end and gradually extends forwards. For sometime the neural tube communicates with the hinder end of archenteron by a short neuroenteric canal. Later the blastopore closes. Anteriorly the neurocoel opens to the exterior through an aperture called the **neuropore.** Later this also closed by the end of embronic period (Fig.34.3). The process is termed **neurulation.**

34.8.2 Induction

In the formation of neural tube and in many other organs, a basic process is involved known as the **induction.** One embryonic tissue layer induces the adjacent one so that the latter develops in a particular way. In all chordates the chordamesoderm(dorsal lip of blastopore) lies in the roof of archenteron of the late gastrula. It is called as **neural inductor** as it induces the neural plate to become neural tube. This is possible when these two layers (chordamesoderm and neural plate) come in physical contact with each other. Some chemical substances diffuse from the chordamesodermal cells into neural plate cells. These substances are called **evocators (stimulators).**

The anterior part of neural plate induces head organs hence called as the **head inductor.** The posterior part becomes the **trunk or spinocaudal inductor** which differentiates trunk organs and tail- bud. The head inductor in turn induces forebrain, eyes, ears etc. The chemical nature of these substances is still not known.

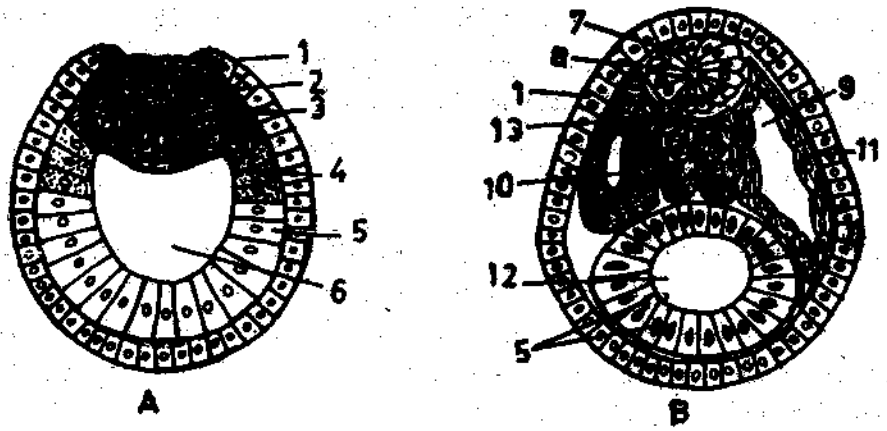


Fig. 34.3 Amphioxus-Formation of neural tube, notochord and mesodermal sacs. A.Early stage. B.Late stage
1.Ectoderm 2.Neural plate 3.Notochordal cells 4.Mesoderm 5.Endoderm 6.Archenteron 7.Neural tube
8.Neural canal 9.Myocoel 10.Notochord 11.Mesodermal sac 12.Enteron 13. Mesodermal somite.

34.8.3 Formation of notochord or Notogenesis

Side by side with the neural tube formation, the chordal cells forming the roof of archenteron stretch and become arched over archenteron by rolling down movements or evagination. These cells then separate off from the archenteron, their edges meet with each other in an interdigitating manner to form the notochord. This is solid rod with vacuolated cells containing jelly like supporting system (Fig.34.3). and this rod is covered by a fibrous tissue called notochordal sheath. This rod extend through out the length of the body.

34.8.4 Formation of mesodermal sacs

While the above described processes are going on, the mesodermal cells arranged on either side of notochordal cell in dorsolateral portion of the archenteron evaginate. Their edges roll in gradually till they meet with each other and cut away from the archenteron as **mesodermal sacs,** Each sac contains a part of archenteron as its cavity, hence they are also named as **enterocoelic sacs.** These sacs further grow down between ecotoderm and endoderm layers, till the right and left sacs meet each other in the midventral line below the archenteron or gut. The fusion wall between the sacs soon breaks down to form one continuous cavity, the **coelom or the enterocoel.** This process of formation of coelom is called as **enterocoelic** method. It is bounded by two mesodermal layers, namely, the **somatopleur** made up of ectoderm and **somatic layer** of mesoderm outside and the **splanchnopleur** consisting of endoderm and visceral layer of mesoderm inside. The mesoderm which covers the dorsal part of coelom, remains intact as mesodermal somites. The somites contain a cavity known as **myocoel.** The wall of each somite nearer the notochord and nerve cord becomes thickened and gives rise to muscle cells forming the myotomes. The outer wall or myocoel which is thin forms the dermatome, from which develop the parts of skin below the epidermis. From the ventral ends of myocoel form the sclerotomes which give rise to thick connective tissue membranes, **like myosepta or myocommata.**

34.8.6 Formation of allimentary canal

After the formation of notochord and mesodermal sacs from the wall of archenteron a gap is left on its dorsal side. The margins of the endoderm move up in middorsal line and fuse. Now the endoderm is a closed tube. From this tube arise the major part of the alimentary canal and its anterior **diverticulum** (Fig.34.3 and Fig.34.4).

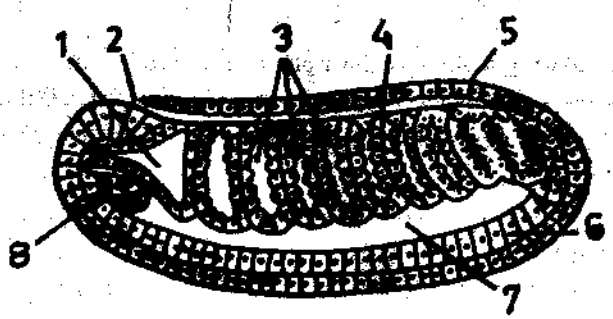


Fig.34.4. Amphioxus - Formation of alimentary canal. 1.First somite 2.Neuropore 3.Mesodermal somites 4.Neural canal 5.Epdermis 6.Endoderm 7.Gut 8.Anterior diverticulum of gut.

34.9. Development after hatching

The larva of Amphioxus hatches out by the rupture of vitelline membrane when it has completed the formation of nerve cord, 13-18 hours after the fertilization. Long flagella cover the body of larva which aid in swimming freely in the surface waters. It has no mouth or anus and therefore, it is often referred to as **free embryo** rather a larva as it is incapable of feeding. To become adult the larva undergoes the following post-hatching changes, almost in a sequence :

A **mouth** appears at the anterior end on the left side of the midventral line but soon shifts on to the mid ventral line. The anterior diverticulum transforms into **wheel organ, Hatschek's pit** and Hatschek's nephridrum.

An **anus** appears in a similar manner at extreme posterior end of the gut near the region of blastopore. A small area of endoderm fuses with the ectoderm. At the point of fusion of the two a perforation occurs the anal opening. It shifts on to the left side.

There arises on right side a diverticulum from the anterior end of the pharynx which grown out into a coiled tube to form a club- shaped gland.

In front of the club-shaped gland an invagination of ciliated glandular cells develops on the right side of archenteron - the larval endostyle. Feeding begins at this stage.

By the fusion of endoderm of archenteric wall with ectoderm in the pharyngeal region midventrally, fourteen **primary gillslits** appear. Eventually they shift to right side, the first and last five close up leaving only eight called primary gill slits. Dorsal to this set appears another set of eight secondary gill slits. Now the primary slits remarkably migrate to the left side of the pharynx. Thus eight gill slits are left on either side. Further more gill slits are added afterwards on both sides.

Nephridia appear as **blind sacs** at the dorsal ends of the gillslits and acquire openings to outside. **Hatscheck's nephridium** develops as a small blind tube.

On the ventral side of the larva, a pair of solid ectodermal **metapleural** folds arise posteriorly enclosing a groove. These folds grow anteriorly enclosing the gill slits. They develop solid medium shelves, called **epipleura,** which grow towards mid- ventral line to fuse and form the **atrium.** At first it has both open ends but later on the posterior opening is retained as the **atriopore.** Finally it grows upwards and surrounds the pharyngeal region. Due to its growth, the coelom is pushed up and becomes restricted on the dorsal side of the pharynx. The metaplenral folds soon become hollow enclosing lymph spaces in them.

Most remarkable feature of the larval development is its characteristic asymmetry. (i) mouth up the left side (ii) 2 diverticulae left diverticulum smaller while right one is large sized;

(iii) Primary, Secondary gill slits on the right of the body .With regards to this asymmetry no satisfactory explanation has been suggested. * The asymmetrical larva feeds on planktonic food material for about three months and undergoes metamorphosis to become bilaterally symmetrical adult.

34.10 SUMMARY

The development of Amphioxus reveals the enough basic features of any vertebrate embryolog, Oogensis is peculiar in the sense the maturation divisions occur after ovulations. The unfertilised ovum is microlecithal 10 to 12 mm] and covered by plasma membrane and another mucopolysaccharide layer called vitelline membrane. Fertilisation is external. The fertilised egg shows well marked cytoplasmic organisation. The ovum attaches to ovary by 'animal pole' side and according to Conklin, this is in contrast to the condition seen in invertebrates. Conklin further suggests that this reversal may also signify the reversal of the ventral position of the nerve cord to dorsal side. * Gastrulation begins after 6 hrs. of fertilisation and the balstodermal cells show various types of morphogenetic movements like epiboly, invagination and involution. The gastrula now comes to contain two layers i.e., the outer epiblast[neural & epidermal ectoderm] and inner hypoblast [prospective notochord, mesoderm and endoderm]. Later, neurulation, notogenesis, mesogenesis, enterocoelic pouches[coelom] etc., occur making out a well formed 'free embryo'. At this stage, the mouth and anus are yet to be formed and hence it is not a true larva, as it cannot feed.

Mouth and anus appear at 16-18 pairs of somites are formed. Simultaneously, other structures like wheel organ, Hatschek's pit and nephridium, midgut diverticula, primary and secondary gill slits on right side[asymmetry], nephridia, ectodermal atrium with atriopore and hollow metapleural folds with lymph spaces develop. The 'larva' swims freely for about 3 months feeding on plankton and metamorphoses. * Embryologically, it is interesting to note the influence of certain tissue inductors to induce the adjacent one to develop in a particular way, eg. neural inductor.

34.11 MODEL EXAMINATION QUESTIONS

I. **Answer the following in about 30 lines.**

1. Describe the early development of **Amphioxus** upto the formation of gastrula.
2. What is organogenesis? Give an account of formation of the nerve cord and notochord in **Amphioxus.**

II. **Answer the following in about 10 lines.**

1. Discuss the method of formation of coelom and mesoderm in **Amphioxus.**
2. Write a note on induction and its influence on the process in of development **Amphioxus.**
3. Describe briefly the process of development after hatching in **Amphioxus.**
4. Fate map
5. Archenteron.

UNIT – 35 FOETAL MEMBRANES IN CHICK

Contents

35.1 OBJECTIVE

- To make the student aware of the protective and nutritive devices in a chick embryo

35.2 INTRODUCTION

Lower vertebrates in their evolutionary process left water and invaded land for food and protection. The amphibians have to a large extent succeeded in their attempt to come on to the land and move with their well organised pentadactyle limbs. However, they failed to breed their progeny on land because of the adverse environmental conditions, like dryness,mechanical injury less protection from temperature, air currents and enemies. Naturally there is no other way for them than to return to waters. This problem has been successfully meted out by their successors in the line of evolution, the reptiles, birds and mammals, by developing protective membranes from the structures lying outside the embryo. These structures are extra-embryonic hence they are called as **extra-embryonic membranes.** Since these membranes are enveloping the embryo all around they are named as **embryonic** or **foetal membranes** (mammals). The above named three classes of vertebrates which develop such membranes are grouped together under amniota in contrast to the anamnia such as fishes and frogs.

Foetal membranes are auxiliary organs which have arisen partly for protection of the embryo and more specially to provide for its nutrition, respiration and excretion until the embryo becomes independent. The embryos of fishes and amphibians remain immersed in water during development. In these embryos large endodermal cells contain yolk which is used for nourishment and is quite sufficient to last until independent life is ensured carried on. In reptiles, birds and mammals foetal membranes are formed which are of use during the period of embryonic development alone.

The fundamental set of embryonic or foetal membranes in amniotes include (1) the yolk sac; (2) chorion (Serosa); (3) amnion, and (4) allantois. The following descriptions is mainly concerned to the chik embryo.

35.3 YOLK SAC

Yolk sac is formed by a layer of extra-embryonic splanchnoplure (endoderm - visceral mesoderm) which spreads over the yolk mass. This layer ultimately encloses the entire yolk and forms

the yolk sac. This is connected to the embryo by a narrow yolk stalk which is continuous with the gut of the embryo. The endodermal cells are in contact with the yolk, The surface of this layer is further increased by a series of septa which penetrate deep into the yolk. The endodermal cells of yolk sac secrete digestive enzymes, which make the yolk soluble. This predigested yolk is now transported to the embryo of chick by its viteline veins. A large amount of yolk is utilised by the time of hatching. Lastly the yolk sack is sucked into the gut of the embryo and the walls of the abdominal cavity close behind it. The development of yolk sac begins before the egg is laid (Fig.35.1.A).

35.4 AMNION AND CHORION

At about 30 hours of incubation amnion and chorion are developed simultaneously. The extra embryonic somatopler (Ectoderm + Somatic mesoderm) in front of the head of embryo rises up as the head fold of the amnion. This essentially consists of a double fold of somatopleur drawn out upon itself. On the third day, the tail fold of amnion arises in the same manner. These two folds start growing over the embryo in opposite directions, They are soon joined by similarly formed lateral folds of amnion. Thus all these folds meet with each other over the back of the embryo. Head and tail folds meet behind the middle of the embryo; this junction is called **seroamniotic connection.** After the meeting both amnion and chorion become separated (Fig.35.1.A.B.).

The amnion encloses the embryo. Its wall has the ectoderm inside and somatic mesoderm outside. It contains nutritious amniotic fluid in which the embryo floats.

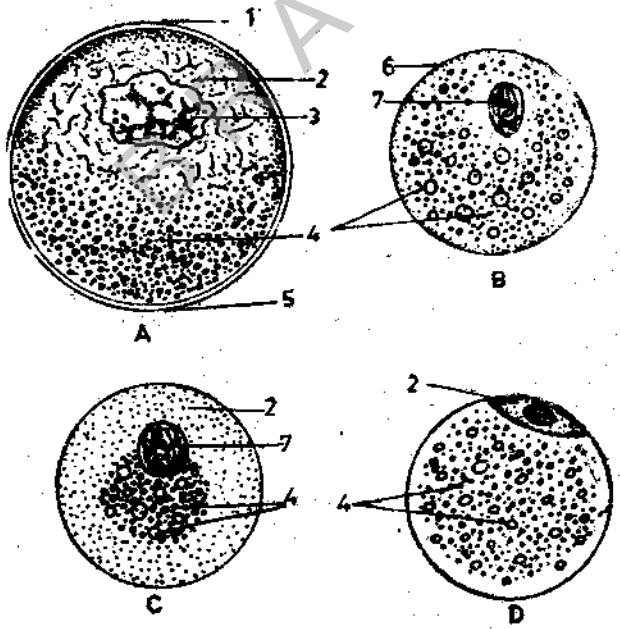


Fig. 35.1 Diagrams illustrating the development of the extra embryonic membranes in chick (sagittal plane). 1.Embryo. 2.Ectoderm. 3.Mesoderm. 4.Endoderm. 5.Yolk Sac. 6.Gut. 7.Amniotic folds. 8.Allantois. 9.Extra embryonic coelom or Exocoel. 10.Amniotic cavity. 11.Amnion. 12.Exocoel. 13.Chorion. 14.Seroamniotic connection.

The chorion ultimately surrounds the embryo and the amnion also. Its wall has ectoderm out side and somatic mesoderm inside. The space between the amnion and choron is called chorionic cavity since the chorionic cavity is lined by somatic and splanchnic mesoderm it also known as)extra embryonic cavity. It contains a fluid. The chorion at a later stage becomes pressed against the shell membranes and plays an important role in gaseous exchange through the porous shell.

Functions

1. Even though the hen lays its eggs on dry land the developing embryo lies in the amniotic fluid and hence is protected from the danger of desiccation.
2. The chick embryo is protected from the mechanical shocks which are absorbed by the amniotic fluid.
3. The amnion and chorion isolate the embryo from the shell to avoid adhesion or friction of the embryo with the shell surface.
4. The chorionic cavity or extra embryonic coelom provides a space for the allantois to expand.

35.5 ALLANTOIS

Allantois develops as a blind evagination from the floor of the hind gut which grows downwards into the extra embryonic coelom. This arises on the third day of incubation. It is formed of splanchnopleur, having endoderm on the inner and splanchnic mesoderm on the outer side. It grows very rapidly from a pear shaped structure to a very large organ which extends into chorionic cavity and almost fills the latter. The mesoderm of allantois fuses with that of the chorion forming a composite mesodermal membrane, the **allantochorion.** Allantochorion becomes pressed against the shell membranes and receives a pair of allantoic blood vessels. Allantois is connected to the hind gut by a narrow, hollow allantoic stalk. Later the allantoic stalk and yolk-sac stalk are surrounded by a common somatepleur of ventral body wall, forming the **umbilical cord.** The allantochorion continues to expand and surrounds the albumen substance of the egg and forms in it an albumen sac and aids in absorption of water and albumen. At the time of hatching the umbilical cord breaks and allantois dries up.

Functions

1. It acts as a reservoir of embryonic excretory wastes, such as uric acid.
2. Allantochorion membrane acts like a respiratory surface of the embryo.

Thus the four foetal membranes are devices which provide adequate nutrition, protection and meet the metabolic requirements of the developing chick embryo.

35.6. SUMMARY

In course of evolution of vertebrates, right from the stage of fishes onwards, attempts to invade land have had been made and ultimately succeeded in adapting to the terrestrial mode of life. One of the severest problems faced by the land vertebrates is the development during the most delicate embryonic life. Desiccation, mechanical shocks, nutrition, respiration and excretion are some problems the delicate embryo meets during its course of development.

As a measure to counteract the problems, the foetal membranes have evolved. The walls of amnion and chorion are formed of somatopleur while the yolk sac and allantois are composed of splanchnopleur. Since the chorionic cavity contained between the amnion and chorion is lined by the mesoderm and hence it is also called as extraembryonic coelom. The amnion surrounds and bathes the embryo with its amniotic fluid which provides nutrition and protection to the embryo. The mesoderm of the chorian and the allantois fuses to form chorio-allantois which eventually forms the albrumen sac for absorption of albrumen and water. Allentois also stores nitrogenous, wastes and hence is also called as **'precocious urinary bladder'**. The chorioallantois also provides respiratory surface for gaseous exchange through the porous shell. The endodermal lining of the yolk sac secretes enzymes for dissolving and absorption of the nutriments.

35.7 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Name various kinds of foetal membranes of chik. Describe their development and significance.

II. Answer the following in about 10 lines.

1. Amnion
2. Chorion
3. Allantois
4. foetal membranes.

UNIT – 36 PLACENTATION IN MAMMALS

Contents

36.1 OBJECTIVE

- To explain the embryonic adaptations in the mammal's during development.

36.2 INTRODUCTION

In all viviparous mammals (Theria) the development takes place inside the uterus of the mother. Eggs of such animals are microlecithal having less amount of yolk which is not sufficient for the development of embryo till it can lead an independent life. Therefore, the embryo has to depend on the mother for nourishment and oxygen supply. Such embryos get attached with the uterine wall to draw their required substances from the mother by means of an organ called placenta. In other words, placenta is an organ built up of maternal and foetal tissues jointly. It serves for the exchange of nutrients and gases between the tissues of the mother and the embryo.

Mammalian placenta is a compound structure consisting of foetal part and maternal part. The foetal part of placenta is furnished by chorion, and allantois whereas maternal part is contributed by the wall of uterus consisting of its compact and spongy layers. In between these two parts, a huge blood sinus known as intervillous space is present which contains a large number of chorianic villi and crypts in the uterine wall. The distribution of substances between mother and foetus is done by diffusion which include oxygen, carbondioxide, water, inorganic compounds, hormones, vitamins and waste products such as urea. Placenta serves as a barrier against transmission of bacteria. It also serves to store iron fat and glycogen. As an endocrine gland it releases relaxin (in rabbits) and other hormones which aid in the birth of young one. It also checks on the passage of harmful substances into foetus like sex

hormones, blood proteins etc.

I. There are three types of placenta on the basis of the nature of foetal membranes taking part in its formation: the yolk sac, allantoic or chorion.

36.3 YOLK SAC PLACENTA

Consists of yolk sac and chorion as the allantois is either absent or degenerated. The yolk sac grows very large and almost surrounds the embryo. The placenta supplies materials from the uterus through foetal vitelline vessels. This type is found in metatheria (Kangaroo) (Fig.36.1.A).

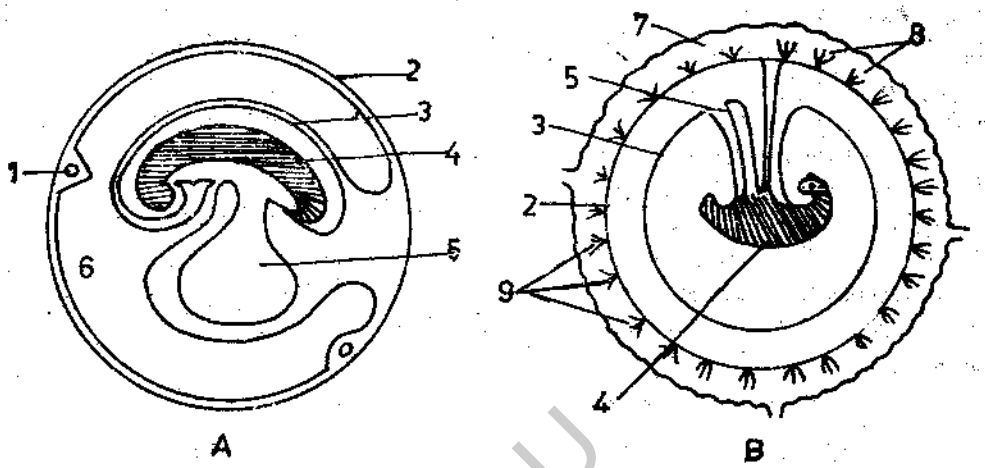


Fig.36.1.A. Yolk sac placenta. B.Chorionic placenta. 1.Blood vessel. 2.Chorion. 3.Amnion. 4.Embryo. 5.Allantois. 6.Yolk sac. 7.Wall of uterus. 8.Placenta. 9.Chorianic villi.

36.4 ALLANTOIC PLACENTA

Allantoic Placenta is composed by allantois and chorion or allantochorion. Here the allantoic blood vessels of embryo carry the supplies from the mother through allantochorion. In advanced condition the allantochorion is found in all Eutheria. It is firmly connected to uterus by an interlocking system of villi, small processes on chorion, and the crypts, depressions in uterine wall to fit the villi.

36.5 CHORIONIC PLACENTA

Consists of only chorion, allantois being small and degenerated. Allantoic blood vessels grow and vascularise chorion. The villi appear on the chorion and penetrate crypts in uterine wall forming chorionic placenta. This type is found in human beings (Fig.36.1.B).

II. As far the distribution pattern of chorionic villi and intimate connection between foetal and maternal parts are concerned there are five types of placentas, grouped as deciduate and non-deciduate. In the former case when placenta is cast off at the time of birth there is loss of both embryonic and maternal tissues with extensive haemorrhage. In the latter form since foetal and maternal tissues have no intimate connection and do not fuse, no bleeding occurs during the birth.

On the basis of distribution pattern of chorionic villi the following types of placenta under deciduate group have been recognised:

36.6 ZONARY PLACENTA

In carnivores (Cats, Dogs) the villi develop in one or two transverse bands or girdles around the chorionic surface (Fig.36.2.A).

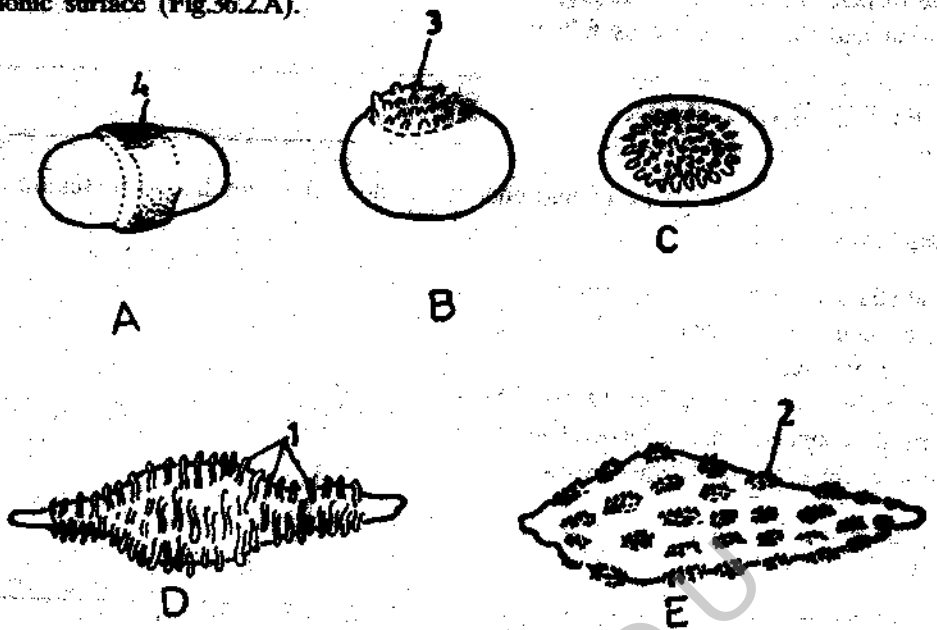


Fig.36.2. Types of placenta in mammals. A.Zonary. B.Discoidal. C.Metadiscoidal. D.Diffuse. E.Cotyledonary. 1.Chorionic villi. 2.Cotyledon of branching villi. 3.Placenta with villi. 4.Band of villi.

36.7 DISCOIDAL PLACENTA

The discoidal placenta bears villi on a small disc shaped area of the chorion. It occurs in rabbits, bats, insectivores and rodents(Fig.36.2.B)

36.8 METADISCOIDAL PLACENTA

The metadiscoidal placenta, found in human being and apes is characterised in developing villi all around on chorion of implanted embryo, but soon the villi disappear on the surface exposed in the luman of uterus during development of the embryo (Fig.36.2.C)

Under non-deciduate group there are two types of placentae exhibiting variety in the arrangement of villi:

36.9 DIFFUSE PLACENTA

In diffuse placenta chorionic villi remain scattered all over the surface of chorion. This is seen among horses and Pigs (Fig.36.2.D).

36.10 COTYLEDONARY PLACENTA

In cotyledonary placenta villi on the surface of chorion are grouped into small patches or cotyledons. For their insertion small thickened areas, the caruncles, are formed by the uterine wall. Remaining Chorionic surface is smooth. eg. Cattle, Sheep (Fig.36.2.E).

III Types of placentae based on the degree of contact and minute histological relations between the chorion and the uterus are as follows:

36.11 EPITHELIO - CHORIAL PLACENTA

In this type of placenta exchange of nutrients etc. is done from mother to foetus through the following tissues (Fig.36.3.A):

i) Endothelium of uterine blood vessel
ii) Uterine connective tissue
iii) Uterine epithelium
iv) Allanto-chorionic edpithelium (Trophoblast)
v) Chorionic connective tissue (Foetal mesoderm)
vi) Endothelium of foetal blood vessels

There is no erosion of maternal or foetal tissues hence this is of diffuse type. eg. Horse, Pig. (Fig.36.3.A.) etc.

36.12 SYNDESMOCHORIAL PLACENTA

In syndesmochorial placenta the uterine epithelium is eroded, hence chorionic villi come into direct contact with the maternal connective tissue. Only five barriers lie between foetal and uterine blood streams. This non-diciduate type of placenta is found in cattle and sheep which have coteledonary type of distribution of villi (Fig.36.3.D)

36.13 ENDOTHELIC CHORIAL PLACENTA

In this case two tissues, the uterine elpithelium and uterine connective tissue are eroded therefore, there are only four barriers between foetal and meternal blood streams. Histologically this is the characteristic of the zonay placenta. Hence this is a deciduate type, eg.Cat, Dog. (Fig.36.3.C)

36.14 HAEMOCHORIAL PLACENTA

Due to more intimate placental relationship all the three maternal tissues i.e., the uterine epithelium, uterine connective tissue and endothelium of uterine blood vessels are eroded. Thus foetal villi are directly batched in maternal blood flowing into sinuses. Consequently the exchange is done through three tissues only. This, to some extent, is the characteristic of discoidal type of placenta under deciduate group. This occurs in some rodents bats and primates (Fig.36.3.B)

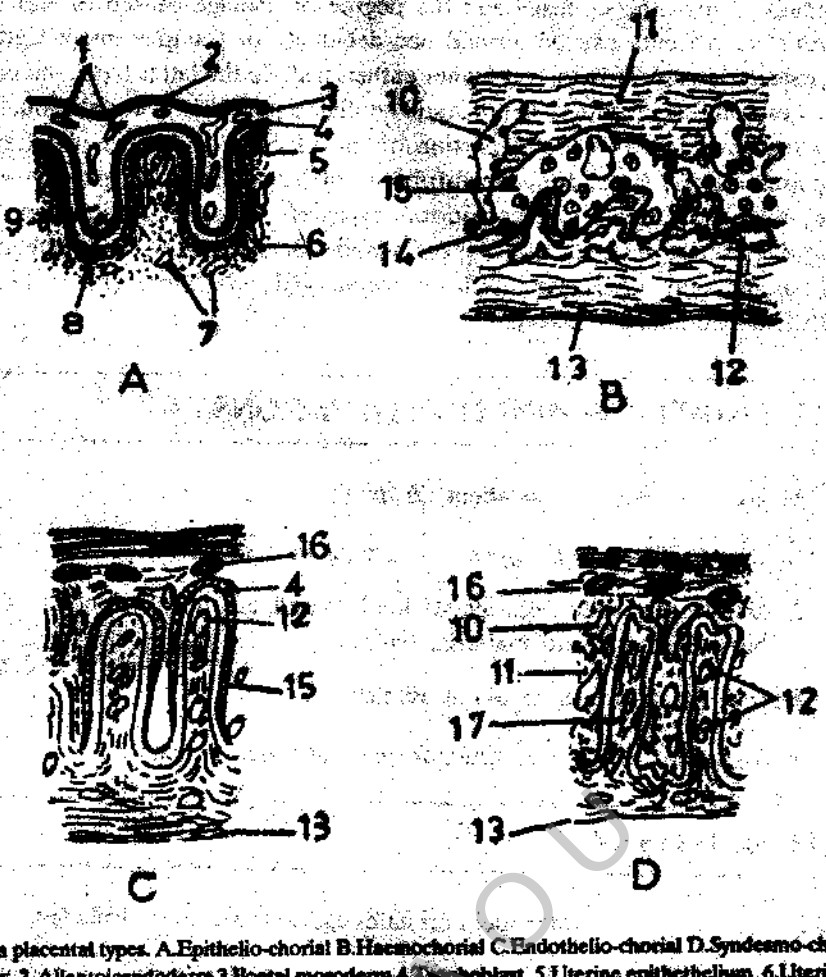


Fig.36.3 Mammalian placental types. A.Epithelio-chorial B.Haemochorial C.Endothelio-chorial D.Syndesmo-chorial 1.foetal capillaries. 2. Allentoicendoderm 3.Foetal mesoderm 4. Trophoblast. 5.Uterine epithethelium .6.Uterine connective tissue. 7. Uterine capillaries. 8. Crypt. 9.Villi.. 10.Uterine blood vessel. 11.Maternal connective tissue. 12.Embryonic blood vessels. 13.Allantois. 14.Villi. 15.Maternal blood sinus. 16.Uterine gland. 17.Trophoblastic villus.

36.15 HAEMOENDOTHEILAL PLACENTA

In haemoendothelial placenta the three uterine tissues and two foetal tissues are eroded thus the number of barriers is reduced to just two. Only the endothelium of foetal blood vessels thus lie directly in the blood sinuses of the uterus. The exchange of material now takes place only through the endothelial layer of foetal capillaries. This type of deciduate is found in some higher rodents like rats and rabbits.

36.16 SUMMARY

Placenta is an organ that forms an intimate connection between the foetal and maternal tissues for purposes of nutrition, gas transport and excretion. The period of gestation varies from species to species. Placenta can also be seen in other than mammals like peripatus, salpa [Ternicata], some elasmoloranchs and snakes, but defers markedly yolk sac type.

Placenta can be classified based on several criteria. Broadly, mammalian placenta is of 2 kinds : (i) Choriovitelline eg. Didelphys, Macropus & (ii) Chorioallantoic eg. parameles, Dasyurus & all eutherians based upon the source of Chorionic vascularisation.

Depending upon the intimacy and the degree of damage caused to either side at the time of parturition, placenta can be termed non-deciduate or semiplacentaeg.Cattle and deciduous or placenta vera[true placenta – eg. higher eutherians]. In the latter type, the maternal tissues will be tern away causing bleeding. There is still another type called contradecidiuale placenta where not only maternal but also foetal portion of the placenta is lost as in paramoles [marsupial] & Talpa[insectivors]. Based upon the distribution of the Chorionic villi, placenta is classified into diffuse [Pig, horse, lemur etc.], cotyledenary[cattle, sheep, deer], Zonary [car[carnivores], discoidal[insectivores, bats, rodents] and metadiscoidal [monkeys, apes & man]. Based on histology, it is classified into 5 types viz., epitheliochorial, syndesmochorial, endotheliochorial, haemochorial and haemoendothelial placenta.

36.17 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines.

1. Discuss the various types of placenta in mammals.
2. Define placenta. Describe its kinds based on the distribution of villi and connection between foetal and maternal parts.

II. Answer the following in about 10 lines

1. Describe the general structure and functions of placenta.

36.18 GLOSSARY

Apes	:	Anthropoid primates eg. Chimpanzee, Gorilla etc.
Chorda cells	:	Cells of vertebrate embryo which give rise to notochord.
Crypts	:	Small pits in the walls of uterus into which fit the villi.
Club-shaped gland	:	First gill-cleft which forms glandular tube and disappears afterwards in Amphioxus larva
Endostyls	:	Glandular ciliated groove on the floor of pharynx. Mucous produced by it helps in feeding. Thyroid gland has evolved from it.
Endothelium	:	A layer of thin cells lining the blood-vessels
Embryonic adaptations	:	Protective devices of embryos (in reptiles, birds and mammals) which also aid in nutrition and respiration.
Eutheria	:	(Placentalia) Higher mammals whose embryos develop allantoic placenta.
Extra embryonic coelom	:	Coelom outside the limits of embryo i.e., between the amnion and the chorion.
Haemorrhage	:	Bleeding of blood vessels.
Hatscheck's nephridium	:	An unpaired excretory organ of Amphioxus consists of numerous flame-cells and fine tubules.

Insectivora	:	Small mammals, molars with conical cusps eg. Shrews, moles, hedgehogs.
Metazoa	:	All multicellular animals.
Metatheria	:	(Marsupialia) Mammals usually having a pouch on the belly to carry and nurture the immature young eg. Kangaroo.
Myocommata	:	(Myosepta) - Anterior and posterior walls of the envelope enclosing the body muscles or myotomes of
Ooplasm	:	The cytoplasm of the egg.
Organogenesis	:	The formation and differentation of the organs in embryo.
Plankton	:	Floating microscopic organisms on the surface of waters.
Polar axis	:	Imaginary central axis connecting the animal and vegetal poles of the egg.
Presumptive area	:	Part of an embryo, cells of which become a particular organ or tissue later.
Primates	:	Mammalian order comprising monkeys, apes and humans.
Pronucleus	:	The nucleus of a male or female gamete containing haploid chromosomes.
Rodents	:	Gnawing mammals which include rats,mice, squirrels etc.
Trophoblast	:	A layer of cells enclosing early mammalian embryo which develops villi for implantation of foetus in the wall of uterus.
Villi	:	Fine finger-like projections arising on foetal placenta which fit into the corresponding crypts in the uterine wall.
Wheel organ	:	A complex system of ciliated ridges with grooves in the buccal cavity, under the oral hood in Amphioxus.
Zona radiata	:	(Zone pellucida) - striated layer which normally surrounds the ovum of a mammal, is formed by the follicle cells. It is replaced by zona pellucida at a later stage.

36.19 SUGGESTED BOOKS

1. Agarwal & Varma : Chordate Embryology
2. Balinsky, B.I. : An Introduction of Embryology
3. Charles J.Price FAO & Josephine E. Reed : Histology
4. Dhami P.S.& Dhami J.K. : Chrodate Zoology volume - II ; R. Chand & Co Daryaganj, New Delhi.
5. Freeman, W.H. & Bilan Bracegirdle : An Atlas of History : The English Language Book Society & Heinemann Educational Books, London.
6. Grom & Newell : Animal Biology, University Tutorial Press Ltd.
7. Lesson & Lesson : Histology; W.H. Saunders Company, Philadelphia/London/ Toronto/Holf-Saunders Japan Ltd./Tokyo.

8. Mc Ewen, R.S. : Vertebrate Embryology

9. Roberts, M.V.B. : Biology-a functional approach. The English Language Book Society & Nelson.

10. Saxena, K.R. : A Text Book of Zoology, Vol.II, Sri Saraswathi Book Depot, Hyderabad.

11. Vidyarthi, R.D.: A Text Book of Zoology. Agrasia Publishers Daresi 2, Agra 4.

12. Waddington,C.H. : Principles of Embryology.

13. William, A, Haswell Revised by Marshall : Text Book of Zoology Vol.II, Vertebrates: English Language Book Society & Macmillan.

Dr. B. R. AMBEDKAR OPEN UNIVERSITY

Faculty of Science

ZOOLOGY

COURSE – 2 CHORDATA, HISTOLOGY AND EMBRYOLOGY

B.SC., II YEAR

SYLLABUS

SUB PHYLUM VERTEBRATA

General characters and classification of vartebrates with a brief note on the origin and evolution of different vertebrate groups.

CLASS CYCLOSTOMATA

General characters and classification and affinities of cyclostomes.

PISCES

General characters and classification.

CLASS ELASMOBRANCHIA

Classification of elasmobranchia upto order with examples.
Morphology and exoskeleton of Dogfish
Skeleton and Viscera of Dogfish.

CLASS OSTEICHTYHYES

General characters and classification upto sub classes with suitable examples.
Common edible fishes of Andhra Pradesh.
General characters and affinities of Dipnoi.

CLASS AMPHIBIA

General characters and classification upto orders with suitable examples.
Important South Indian amphibians.

CLASS REPTILIA

General characters and classification upto orders with suitable examples.
Calotes (Morphology and Anatomy excluding skeleton).
Skeleton of Varanus.
Poisonous and non-poisonous snakes (with a note on the importance of snake poison).
Dinosaurs.

CLASS AVES

General characters and classification upto sub classes with suitable examples.
Pigeon – Morphology and exoskeleton.
Skeleton of Pigeon.
Anatomy of Pigeon.
Flight adoptations and migration of birds.

CLASS MAMMALIA

General characters and classification upto sub classes and the diagnostic features of prototheria, metatheria and eutheria.

Rabbit morphology, structure and function of skin.

Skeleton of Rabbit.

Digestive system of Rabbit and Physiology of digestion.

Nervous system of Rabbit.

Functions of different parts of brain.

Nerve impulse transmission.

Respiratory system of Rabbit and Physiology of respiration.

Respiratory pigment and its role in the transport of O2 and CO2.

Circulatory system of Rabbit. Physiology of regulation of heart beat.

Urinogenital system of Rabbit. Physiology of regulation of heart beat.

Urinogenital system. Physiology of excretion, with a note on Urea formation.

Endocrine glands and their functions.

HISTOLOGY (Rabbit as an example)

Epithelial, connective, muscular and nervous tissues.

Histology of liver, pancreas, stomach, intestine, kidney, testis and ovary, spinal cord and nerve, lung and spleen.

EMBRYOLOGY

Types of eggs, fertilization, cleavage and gestation.

Development of Amphioxus.

Foetal membranes in chick.

Placentation in mammals.

Dr. B.R.AMBEDKAR OPEN UNIVERSITY

Faculty of Science

ZOOLOGY

COURSE – 2 CHORDATA, HISTOLOGY AND EMBRYOLOGY

B.SC., II YEAR

MODEL EXAMINATION PAPER

Time : 3 Hours Max. Marks : 75

Section – A

Answer any 3 questions.
Each question carries 15 marks.
Answer the following in about 30 lines each.

1. Describe the general characters of Vertebrates.
2. How do you differentiate poisonous snakes from that of non- poisonous snakes.
3. describe the structure of the brain of rabbit. Enumerate the functions of its various parts.
4. Describe the histology and enumerate the function of liver of rabbit.
5. What is organogenesis? Give an account of formation of the nerve cord add notochord in Amphioxus.
6. Discuss the various types of placenta in mammales.

Section – B

Answer any 5 questions.
Each questions carries 6 marks.
Answer the following in about 10 lines each.

1. General characters of class Petromyzontia.
2. Outline the female urinogenital organs of Dogfish.
3. Gymnophiona.
4. Describe air sacs of pigeon. Add a note on their significance.
5. Describe the structure of bone
6. Describe the structure of tooth.
7. Give a brief account on Metatheria.
8. Explain the process of gastrulation in general.
9. Amnion and Chorion.
10. What is nerve impulse? How is it transmitted ?

Dr. B.R.AMBEDKAR OPEN UNIVERSITY

Faculty of Science

ZOOLOGY

COURSE – 2 CHORDATA, HISTOLOGY AND EMBRYOLOGY

B.SC., II YEAR

ASSIGNMENT – 1

N.B.

1. Do not copy the answer directly from any of the books.
2. As far as possible try to answer the questions independently in your own words.
3. If it is necessary to quote from any source give the correct reference.
4. Use your own foolscap pages for writing the assignment.
5. Leave sufficient margins for the comments of the evaluator.
6. Completion of this assignment should not take more than two hours time.

I. Answer the following in about 30 lines.

1. Describe the general characters of Cyclostomes.
2. Describe the alimentary canal of Dogfish.
3. Outline the general characters of Dipnoi.

II. Answer the following in about 10 lines.

1. Write an account on 'Placoid Scales'.
2. Types of jaw suspension in Vertebrates.
3. Describe the origin and evolution of amphibians.

cut here

Dr. B.R.AMBEDKAR OPEN UNIVERSITY

Faculty of Science

ZOOLOGY

COURSE – 2 CHORDATA, HISTOLOGY AND EMBRYOLOGY

B.SC., II YEAR

ASSIGNMENT – 2

N.B.

1. Do not copy the answer directly from any of the books.
2. As far as possible try to answer the questions independently in your own words.
3. If it is necessary to quote from any source give the correct reference.
4. Use your own foolscap pages for writing the assignment.
5. Leave sufficient margins for the comments of the evaluator.
6. Completion of this assignment should not take more than two hours time.

I. Answer the following questions in about 30 lines.

1. Mesozoic era is called the "The Golden Age of Reptiles" comment.
2. How do you differentiate poisonous snakes from theat of non- poisonous snakes.
3. Describe the exoskeleton of birds.

II. Answer the following in about 10 lines.

1. Differentiate between Lacertilia and Opnidia.
2. Causes of birds migration.
3. Describe the temporal fenestrae in reptiles and explain how the classification of reptiles is based on this character.

Dr. B.R.AMBEDKAR OPEN UNIVERSITY

Faculty of Science

ZOOLOGY

COURSE – 2 CHORDATA, HISTOLOGY AND EMBRYOLOGY

B.SC., II YEAR

ASSIGNMENT – 3

N.B.

1. Do not copy the answer directly from any of the books.
2. As far as possible try to answer the questions independently in your own words.
3. If it is necessary to quote from any source give the correct reference.
4. Use your own foolscap pages for writing the assignment.
5. Leave sufficient margins for the comments of the evaluator.
6. Completion of this assignment should not take more than two hours time.

cut here

I. Answer the following in about 30 lines.

1. What is nerve impulse? How is it transmitted.
2. Describe the digestive system of rabbit.
3. Sketch and label the section of the mammalian ovary.
4. Write a note on evulation.

II. Answer the following in about 10 lines.

1. Describe the structure of retina.
2. Describe briefly the process of cleavage.
3. What is the endocrine part of pancreas?