SYSTEMATIC AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY (DZ0002) (MSC ZOOLOGY)

ACHARYA NAGARJUNA UNIVERSITY

CENTRE FOR DISTANCE EDUCATION

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M.Sc. Zoology (Distance Education Mode)

PAPER - II : SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

Syllabus

UNIT - 1

General Characters of the Phylum Chordates.

Protochordata in general : Hemichordata, Urochordata and Cephalochordata - comparison and specialised characters.

UNIT - II

Classification of fishes (upto classes) : Migration of fishes, Parental care

Amphibia : General characters and classification.

Reptiles : General characters and classification, poisonous and non-poisonous snakes.

UNIT - III

Aves : General Characters and classification (upto class only),

Common birds of India, Birds - Adaptation to flight, *Archaeopteryx* and its significance, flightless birds.

UNIT - IV

Mammalia : General characters and South Indian Mammals.

Aquatic adaptations and Adaptative radiation in mammals.

UNIT - V

Mammalia : General characters and South Indian Mammals.

Aquatic adaptations and Adaptative radiation in mammals.

LIST OF TEXT BOOKS :

1. T.J. Parker & W.A. Haswell, 1972. A Text book of Zoology, Vol.I, Invertebrates. (Eds.), A.J. Marshall & W. D. Williams ELBS. and Macmillan.
2. A. Sedgwick, 1972. A text book of Zoology. Vol. I&II, Central Book Depo, Allahabad.
3. J.Z. Young, 1978. The life of Vertebrates, Oxford University Press.
4. Nelson, O.E. 1983. Comparative Embryology, McGraw Hill, New York.
5. McEwen, 1957. Vertebrates Embryology, 4h ed. Hot, New York.
6. Dalinazy, B.I. 1964. Introduction to Embryology, Saunders, Philadelphia.
7. Berrill, N.J. 1971. Developmental Biology, Tata McGraw Hill New Delhi.

M.Sc., Degree Examination, December 2004

PAPER - II : SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

1st Year, Zoology

Time : Three hours Max. Marks : 100

All questions are compulsory
Each question carries 20 marks
Draw the diagrams wherever necessary

1. a) Compare the characteristics of Hemichordata and Cephalochordata. Identify their unique characteristics.

   or

   b) Write short notes on :
      i) Reproduction in urochordates
      ii) General characteristics of phylum chordata.

2. a) Give an account of the general characteristics of Phylum Amphibia. Classify it upto order level with examples.

   or

   b) Write shortnotes on :
      i) Migration of fishes.
      ii) Differences between poisonous and non-poisonous snakes.

3. a) Classify Aves upto class leel giving details about the general characteristics and exaples

   or

   b) Write shortnotes on :
      i) Significance of Archaeopteryx
      ii) Common birds of India.

4. a) Write in details the general characteristics of mammals with suitable examples.

   or

   b) Write shortnotes on :
      i) Two of South Indian mammals with their characters.
      ii) Aquatic adaptations of mammals.

5. a) Explain the mechanisms involved in different stages of fertilization.

   or

   b) Write shortnotes on :
      i) Patterns of cleavage
      ii) Oestrous cycle.

M.Sc., Degree Examination, December 2005

PAPER - II : SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

1st Year, Zoology

Time : Three hours Max. Marks : 100

All questions are compulsory
Each question carries 20 marks
Draw the diagrams wherever necessary

1. a) Compare the characteristics features of Hemichordata with those of Urochordata and explain their evolutionary significance.

   or

   b) Write short notes on :
      i) General characters of chordates.
      ii) Salient features of amphioxus.

2. a) What are the Reptilian characters? And how they are adapted to the terrestrial life?

   or

   b) Write shortnotes on :
      i) Classification of Amphibia.
      ii) Migration in fishes.

3. a) Give an account on the common birds of India, and add a note on the significance of Archaeopterix.

   or

   b) Write shortnotes on :
      i) General characters of Birds.
      ii) Significance of flightless birds.

4. a) Give an account on the general characters of mammals with suitable examples.

   or

   b) Write shortnotes on :
      i) Aquatic adaptations in Mammals
      ii) Importance of any three South Indian Mammals.

5. a) Compare the developmental events of spermatogenesis with those of oogenesis.

   or

   b) Write shortnotes on :
      i) Patterns of clevage
      ii) Physiology and evolution of placenta.

CONTENTS

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, MAY 2011.

Paper II — SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

All questions carries equal marks.

1. (a) Describe the general characters of phylum Chordata.

Or

(b) Give an account on comparison and specialized characters of Hemichordata, Urochordata and Cephalochordata.

2. (a) Describe Parental care and Migration in fishes.

Or

(b) Write an essay on poisonous and non poisonous snakes.

3. (a) What are the adaptations of birds to flight and add a note on flightless birds.

Or

(b) What is the significance of Archaeopteryx?

4. (a) Describe South Indian Mammals.

Or

(b) Write an essay on Adaptative radiation in Mammals.

5. (a) Describe Spermatogenesis.

Or

(b) Give an account on Physiology and evolution of Placenta.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, DECEMBER 2010.

Paper II — SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

All questions carry equal marks.

1. (a) Mention the specilised characters of hemichordate, urochordata, and cephalochordata.

Or

(b) Describe the general characters of phylum chordate.

2. (a) Describe the significance of parental care.

Or

(b) Illustrate the general characters or poisonous and non poisonous snakes.

3. (a) Write the general characters of birds.

Or

(b) Write short notes on

(i) Archaeopteryx.

(ii) Flightless birds.

4. (a) Describe the special characters of south Indian mammals.

Or

(b) Write short notes on

(i) Aquatic adaptations.

(ii) Adaptive radiation in mammals.

5. (a) Give an account on fertilization.

Or

(b) Write short notes on.

(i) Pattern of cleavage.

(ii) Oesterous cycle.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, JUNE 2010.

Paper II — SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.
Each question carries equal marks.

1. (a) Give an account on the general characters of Chordata.

Or

(b) Give a comparative study of Hemichordata, Urochordata and Cephalochordata.

2. (a) Give a detailed account on Migration of fishes.

Or

(b) Write short on :

(i) Poisonous and non-poisonous snake.

(ii) Classification of Amphibia up to orders.

3. (a) Briefly mention the common birds in India, write the adaptation of flight.

Or

(b) Write short on :

(i) Flightless birds.

(ii) Archaeopteryx.

4. (a) Describe the general characters of South Indian Mammals.

Or

(b) Write an account on Aquatic Adaptations and explain adaptive radiation in mammals.

5. (a) Describe the process of spermatogenesis.

Or

(b) Write short notes on :

(i) Types of animal eggs.

(ii) Physiology of placenta.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, DECEMBER 2009.

Paper II — SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.
Each question carries 20 marks.

1. (a) Give an account on characters and classification of cephalochordata.

Or

(b) Write short notes on

(i) General characters of chordata

(ii) Protochordata.

2. (a) Describe the parental care in fishes.

Or

(b) Write short notes on

(i) Non-Poisonous snakes

(ii) General characters of Amphibia.

3. (a) Give a detailed account on common birds of India.

Or

(b) Write short notes on

(i) Archaeopteryx

(ii) Flightless birds.

4. (a) Describe the adaptive radiation in mammals.

Or

(b) Write short notes on

(i) Aquatic Mammals

(ii) South Indian Mammals.

5. (a) What is Fertilization? Explain in detail.

Or

(b) Write short notes on

(i) Types of animal eggs.

(ii) Oogenesis.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, MAY 2009.

Paper II — SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

Each question carries equal marks.

1. (a) Give an account on the general characters of Chordata.

Or

(b) Describe general characters of Hemichordata, urochordata and Cephalochordata.

2. (a) Give a detailed account on Parental care.

Or

(b) Write short on :

(i) Poisonous and non-poisonous snakes

(ii) Migration of fishes.

3. (a) Give an account of classification of Birds, and write the significance of Archaeopteryx.

Or

(b) Write short on :

(i) Flightless birds

(ii) Adaptations of flight.

4. (a) Write an account on Aquatic adaptations, and explain adaptive radiation in mammals.

Or

(b) Describe the general characters of South Indian Mammals.

5. (a) Describe the process of Oogenesis.

Or

(b) Write short notes on :

(i) Gastrulation

(ii) Physiology of placenta.

M.Sc. (PREVIOUS, ZOOLOGY, EXAMINATION, DECEMBER 2008.

Paper II — SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

Each question carries 20 marks.

1. (a) Compare the subphylum urochordata and hemichordata taking the general and specialised characters.

Or

(b) Write short notes on :

(i) Cephalochordata

(ii) Salient features of chordates.

2. (a) Give the general characters and classification of reptiles.

Or

(b) Write short notes on :

(i) Parental care in fishes

(ii) General characters of Anurans.

3. (a) Enumerate the general characters of Aves.

Or

(b) Write short notes on :

(i) Adaptation to flight

(ii) Archaeopteryx and its significance.

4. (a) Give an account of South Indian mammals.

Or

(b) Give an account of aquatic mammals.

5. (a) Write short notes on :

(i) Types of animal eggs and patterns of cleavage.

(ii) Evolution of placenta.

Or

(b) Write short notes on :

(i) Compare Spermatogenesis and Oogenesis.

(ii) Gastrulation.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, MAY 2008.

Paper II — SYSTEMATICS AND ANATOMY OF CHORDATES AND GAMETE BIOLOGY

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

Each question carries 20 marks.

1. (a) Give an account on protochordata and its classification.

Or

(b) Write an account on the general characters of phylum chordate.

2. (a) What are the general characters of amphibians? Give the classification till orders.

Or

(b) Write short notes on :

(i) Migration of fishes.

(ii) Comparison of poisonous and non-poisonous snakes.

3. (a) Give the classification of Aves upto classes and comment on the significance of Archaeopteryx.

Or

(b) Write short notes on :

(i) Flightless birds.

(ii) Common birds of India.

4. (a) What are the general characters of mammalia.

Or

(b) Define adaptive radiation. Explain it taking mammalian examples.

5. (a) Explain the process of Oogenesis.

Or

(b) Write short notes on :

(i) Oesterous cycle.

(ii) Patterns of cleavage.

UNIT - I

LESSON 1.1

GENERAL CHARACTERS OF THE PHYLUM CHORDATA

INTRODUCTION

- Chordates are the highly developed triploblastic organisms in the process of evolution.
- The phylum includes diversified organisms from simple ascidian (*Herdmania*) to Man (*Homo sapiens*).
- Diversity is also observed in their morphology, metabolic activities and modes of life.
- Possession of the following three important features viz., (a) The Notochord, (b) Dorsal tubular nerve cord, and (c) Pharyngeal gill slits either singly or in toto is the main character of this phylum.
- Chordates with these features in their adult condition are called pro-chordates. Others with vertebral column as the supporting skeleton, on the mid-dorsal side in the adult stage are the vertebrates.

CONTENTS

1.1.1 OBJECTIVES

After going through this unit, you should be able to

* Understand the general characters of Chordata
* Differentiate Chordates from invertebrates (non-chordates)
* know the outline classification
* Explain the origin of Vertebrates

1.1.2 GENERAL CHARACTERS

Besides the above three main features, Vertebrates also possess the following characters in common. They are:

a) Bilateral symmetry
b) Axiation
c) Triploblasticity
h) Heart
i) Blood
j) Limbs for locomotion

d) Cephalization
e) Sense organs
f) Coelome
g) Mouth & anus
k) Tail
l) Excretory system
m) Reproductive system & development
n) Phosphogens and endocrine glands

These characters are discussed in detail hereunder:

Main Features: These are the prime characters of chordate organisms.

a) **Notochord**: (Gk. Noton = Dorsal ; Chord = rod)

- The name chordata is derived from the possession of the notochord as a supporting rod on the mid dorsal side of the body.
- It is formed from chordamesoderm.
- It is formed of closely packed notochordal cells having vacuolated cytoplasm.
- This rod is covered by a sheath of connective tissue.
- It lies in between the dorsal tubular nerve cord and digestive system
- It is replaced by vertebral column in Vertebrates.

b) Dorsal tubular nerve cord:

- It is a hollow tubular structure formed from ectoderm.
- Its cavity is filled with cerebrospinal fluid.
- It enlarges into brain at the anterior end and terminates posteriorly as a fine filament called filum terminale.
- It constitutes the central nervous system.

c) Pharyngeal gill slits:

- These are located in pairs on either side of the pharynx.
- These may be retained in adults as in prochordates and fishes. In others, they seen only in embryonic stages.
- They are formed by the fusion of pharyngeal evaginations and ectodermal invaginations. The gill slits are supported by gill arches.
- Gills are the aquatic respiratory structures.
- In highly developed vertebrates, they transform into endocrine glands and other associated structures such as hyoid, mandible etc.

General features: These are seen mostly in Vertebrate organisms.

d) Bilateral Symmetry:

- The organisms can be cut into two equal parts through the sagittal plane passing from anterior to posterior end of the body. Each half is the mirror image of the other.
- Paired organs such as nerves, blood vessels, ribs, kidneys etc., are present on either side of the median axis, thus exhibiting segmentation.

e) Axiation:

The median axis from anterior to the posterior end of the body brings about the arrangement of paired organs on bilaterally symmetrical fashion. Organisms show organ system grade of body construction.

f) Triploblasticity :

Organisms are triploblastic : The three germinal layers formed during the development are the ectoderm, endoderm and mesoderm. They contribute for the formation of various organs and organ systems.

g) Cephalization:

- Anterior part of the neural tube enlarges into Brain.
- Brain is protected by cranium. Brain and its associated organs constitute the head. Complexity of cephalic region progresses from cyclostome fishes to man.

h) Sense Organs:

Formation of the head is associated with the congregation of main sense organs such as eyes, nose, tongue and ears in the cephalic region.

i) Coelome:

- A true coelome is the body cavity lined on either side by mesodermal layers viz., somatic and splanchnic mesothelia.
- It is formed by enterocoelous method in primitive chordate organisms and by enterocoelic and schizocoelic method in higher chordates.
- Viscera is seen in the body cavity

j) Mouth and Anus:

- Mouth is anteriorly located and is secondarily formed.
- The first formed blastopore of the embryo turns to anus in the adult. Hence these organisms are called deuterostomes.

k) Heart:

- It is formed from mesoderm and is pulsatile.
- Heart is primitive and single chambered one in prochordates.
- In higher vertebrates, it is muscular, pulsatile and ventral.
- It possess two to four chambers.
- It aids in pumping the blood to different organs of the body.

l) Blood and Blood vascular systems:

- Blood is composed of plasma and blood cells
- Most of the organisms possess haemoglobin as the chief respiratory pigment.
- Blood vascular system is of closed type. It consists of arteries, veins and capillaries.
- Presence of portal system in the body is a special feature.

m) Locomotory organs:

- Locomotion is brought about by either fins as in fishes or limbs as in other tetrapods.
- Fins are supported by fin rays.
- Limbs are paired and pentadactyle
- Limbs are variously structured to suit their mode of life.

n) Tail:

- Tail is the post anal extension of the body.
- Certain adult organisms may not possess tail but it is formed in their embryonic condition.
- Nerve cord, notochord or vertebral column extends into the tail.
- It helps in locomotion and equilibrium besides protection in some organisms.

o) Excretory system:

- This consists of paired kidneys formed from mesoderm.
- Nephrons are the structural and functional units of the kidney.
- Kidneys may be of pronephric, mesonephric or metanephric types.

p) Reproductive system & Development:

- All chordates are unisexual. Most of them are sexually dimorphic.
- Gonads are formed from mesoderm.
- Gonads also act as endocrine glands.
- Gonads and gonoducts are well developed in adult forms.
- Fertilization may be external or internal.
- Organisms may be oviparous or viviparous.
- Development may be direct or indirect.

q) Phosphagens and Endocrine glands:

- Phosphagens are the biochemical substances released during muscle contraction.
- Phosphocreatine and phosphoargenine are the major phosphagens.
- These two are released during muscle contraction in prochordates.
- All higher chordates release only phosphocreatine during muscle contraction.
- Endocrine glands are well developed in association with internal organ systems.
- They secrete and release hormones into the blood.
- They are the bio-chemical messengers to regulate various metabolic activities.
- Pituitary, thyroid, parathyroid, pancreas, adrenal gland and gonads are the main endocrine glands in vertebrates.

1.1.3 MAIN DIFFERENCES WITH INVERTEBRATES (Non-chordates)

Chordates differ from invertebrates in the following features viz.,

- Possession of notochord.
- Presence of dorsal tubular nerve cord.
- Single hollow nerve tube.
- Muscular, chambered heart on the ventral side.

- Blood flow towards posterior direction in dorsal blood vessel or arteries and anterior direction in ventral blood vessel or veins.
- Pharynx with gill pouches and gill slits.
- anteriorly differentiated brain.
- unisexual nature except ascidians which are bisexual.

1.1.4 ORIGIN OF CHORDATES

- Continuous changes occurred in the enviroment necessiated the formation of variations.
- Geological time scale explains the conditions prevailed for the evolution of chordate organisms.
- The first vertebrates appeared during ordovician period of palaeozoic era were the jawless fishes.
- First gnathostomes originated during silurian period of palaeozoic era are the true fishes.
- Amphibians took origin from fishes during misricipian age of palaeozoic era.
- Reptiles took origin from amphibians in Pensylvanian period of palaeozoic era.
- Reptiles ruled the entire universe during tirassic period of mesozoic era.
- First birds appeared from reptiles in jurassic period of mesozoic era.
- Mammals originated from reptiles during quaternary period of coenozoicera.
- Garstring, Wikely, Semper, Gregory and Bevil proposed different conclusions about the origin of chordate organisms.
- Annelidan, Arachnidan, Echinoderm theories proposed by different scientists explain the invertebrate origin of chordates.
- Similarities in the larval features and phosphagens of echinodermates and hemichordates reveal the bipinnarian precocity. This validates the proposal of echinoderm origin.
- It is also said that other chordates took their origin from hemi-chordates.

All the above views are only hypothetical as there is no clearcut evidence to substantiate the origin of chordates.

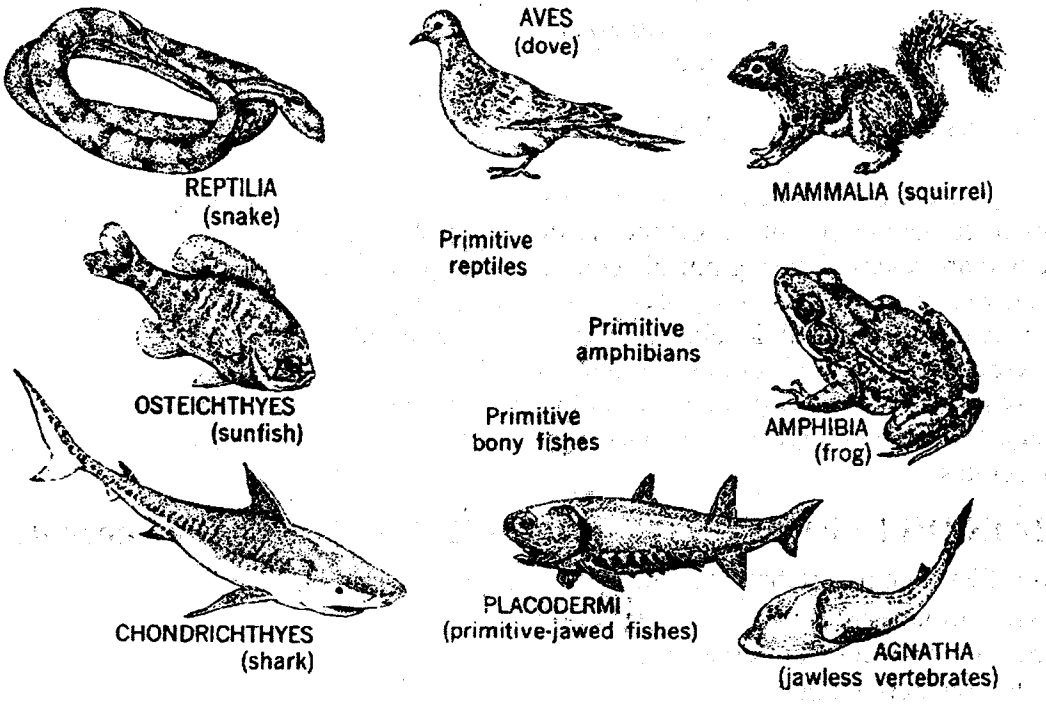
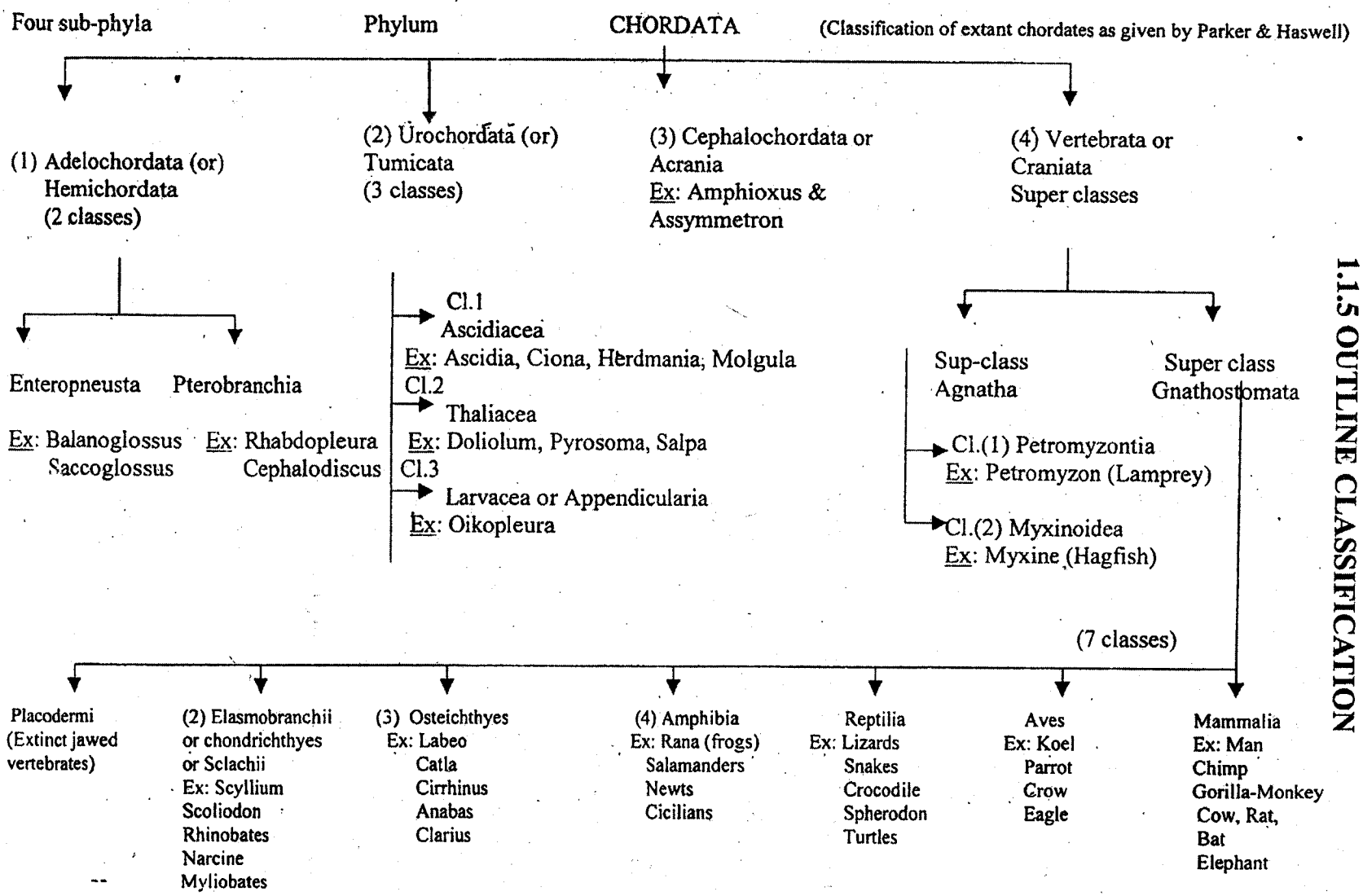


Fig. 1.1 Some Chordate Representatives

1.1.5 OUTLINE CLASSIFICATION



1.1.6 SUMMARY

- Chordates are the highly developed triploblastic deuterostome organisms with a dorsal tubular nerve cord, notochord and gill slits as their prime characters.
- General organisation shows similarity between different chordates in various features and organ systems.
- Chordates are classified as protochordates and vertebrates basing upon the retention of the notochord in adult condition.
- Vertebrates are further classified into agnathans and gnathostomes taking the possession of jaws into consideration.
- The origin of chordates was explained by several scientists by proposing annelidan, arachnidan and echinoderm theories. The concept of the origin of chordate organisms is only hypothetical as there is no clear evidence to substantiate.

1.1.7 SELF ASSESSMENT QUESTIONS

a) Fill in the blanks with suitable answers:

i) Agnathans are the organisms having _____ .

ii) Notochord is rod like and lies between _____ & _____ .

iii) Post anal extension of the body is called _____ .

iv) Deuterostomes have _____ as their first formed opening.

v) Extinct, jawed vertebrates are included under class _____ .

b) Write brief answers for the following :

i) Notochord, ii) Deuterostomes, iii) Subphyla of phylum chordata.
iv) Enterocoelous, v) Bilateral symmetry

1.1.8 REFERENCE BOOKS

1. **A Text Book of Zoology, Vol. II** by Parker & Haswell.
2. **A Student Text Book of Zoology, Vol. II,** Adam Sedgwick.
3. **Vertebrate Biology** by R.T. Orr.

Dr. K. Kondaiah

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UNIT-I

LESSON - 1.2

PROTOCHORDATES IN GENERAL

Study of the first lesson has given you an overview on the general characters and origin of chordates besides their outline classification. Let us now see the protochordates in general through their general and specialised characters.

Introduction

- Protochordates are the first formed chordate organisms formed in the process of evolution.
- These organisms possess notochorol, dorsal tubular nerve cord and pharyngeal gill slits in their adult condition except in ascidians.
- They are the triploblastic deuterostomes with anus as the first formed opening.
- Previously hemi, uro and cephalochordates were called as protochordates.
- Hyman separated hemicordates from protochordates as they are more related to invertebrates than to chordates.
- Protochordates show affinity with some invertebrates on one side and with chordates on other side besides having some specialized features.
- All the protochordates are marine living either singly or in colonies. Their body is covered by a single layered epithelium or test. Internally they lack the bony skeleton.
- They possess paryngeal basket supported by branchial skeleton.
- These organisms are the mucociliary feeders. Endostyle helps in driving the food into the oesophagus.
- Heart is undivided.
- Excretory system is formed of nephridia, glomerulus and neural gland.
- They are mostly unisexual (except ascidians) and oviparons with indirect or direct development.

CONTENTS

1.2.1 Objectives

After studying this lesson you would be able to understand

(a) general and specialized characaters of Hemichordates, urochordates and cephalochordates.

(b) affinities of these three groups with other related phyla of animal kingdom and their systematic position.

(c) the features of comparison amongst the protochordates.

1.2.2 General and specialised features of Hemichordata

- Hemichordates or Adelochordates are the worm like primitive organisms exhibiting the following characteristic features.
- Worm like marine organisms leading either solitary or colonial life.
- Body is long, slender, unsegmented and triploblastic and brittle.
- They live in 'U' shaped burrows and hence are tubicolous. Their body is well suited for burrowing mode of life.
- They show bilateral symmetry.
- Body is divided into three parts viz., proboscis, collar and trunk.
- Some organisms may possess tentaculated arms in their collar region.
- body cavity or coelome is not continuous and is seen in proboscis as a single cavity. It is paired in collar and trunk. The cavities of the trunk are closed while those of the collar and proboscis open out through small pores.
- Body wall is encircled by unilayered ectoderm with mucous secreting cells. Such cells are largely located in proboscis.
- Phanynx may possess either single or paired gill slits opening out through gill pores.
- Blood vascular system is of open type and hence definite blood capillaries are absent. Body possess a number of blood lacunae. Heart is vesicular.
- Excretion is conducted by glomerulus or proboscis gland.
- Intra-epidermal nerve net constitutes the nervous system. It has a middorsal and a ventral nerve cord connected with each other by circular nerve fibres.
- Gonads are located in linear rows in the genital wings present behind the collar.
- Most of the organisms are unisexual.
- They can reproduce asexually by budding and regeneration.

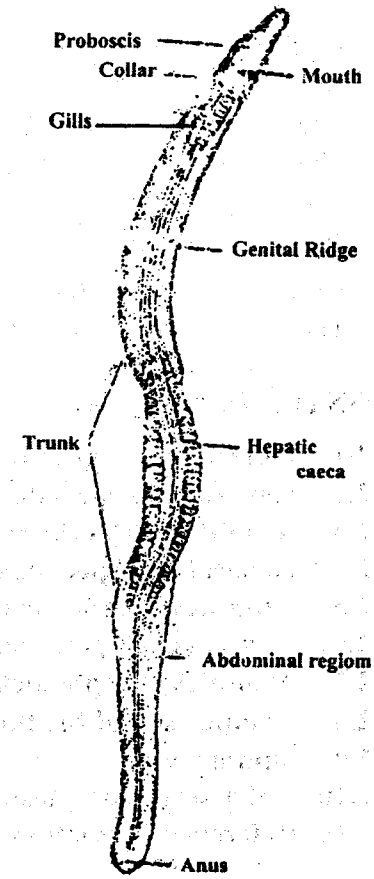

Fig. 1.2 *Balanoglossus*

- Fertilization is external. Organisms are oviparous. Tornaria larva is formed in the life history.
- Organisms of the class enteropneusta are the acorn / tongue worms without tentacular arms at the collar region. They are unisexual with indirect development involving **Tornaria** as larval form. Development is direct in saccoglossus. These cannot reproduce asexually. **Ex:** *Balanoglossus, Saccoglossus, Ptychodera.*

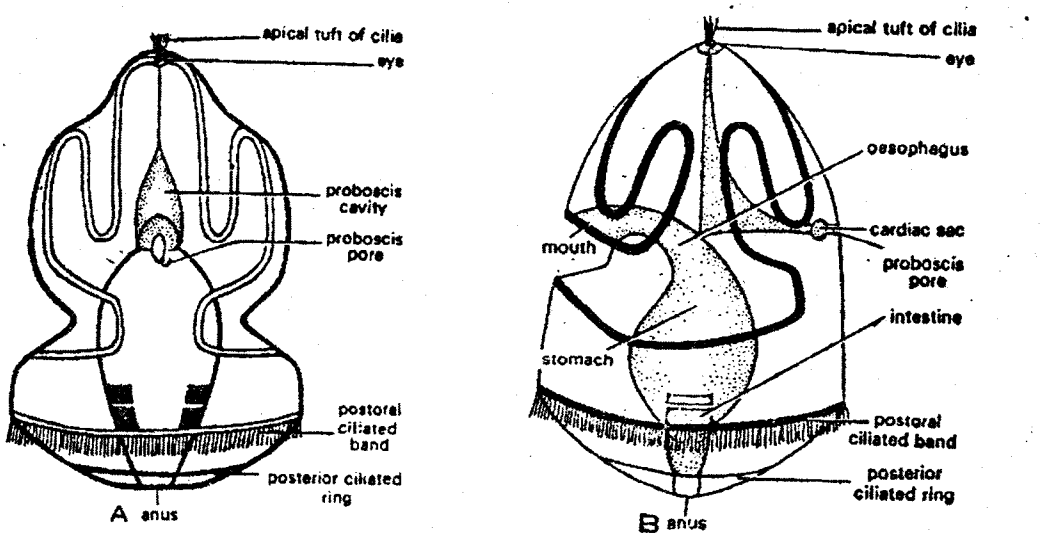

Fig. 1.3 Tornaria larva of *Balanoglossus*

- Organisms of class pterobranchia are small, colonial with a shield like proboscis. Tentacular arms of the collar form lophophore. They possess either single or one pair of gonads. They may be unisexual or bisexual. Development is either direct or indirect. **Ex:** *Rhaddolpleura, Cephalodiscus. Atubaria.*

1.2.3Affinities and systematic position

Adelochordates show affinities with chordates, echinoderms and Annelids.

(i) Resemblances with other chordates: Presence of

- gill slits and their origin, structure, function
- dorsal tubular nerve cord without any ganglea.
- buccal diverticulum or stomochord with vacuolated cells arising from the foregut and extending into the proboscis. This can be compared with the notochord of other protochordates.

Differences with chordates:

- Chordates have lateral gill slits while hemichordates possess them on their dorsal side.
- Notochord is dorsally placed and extends antero posteriorly in chordates. Hemichordates possess a short notochord or buccal diverticulum.

- Buceal diverticulum is located ventral to the dorsal blood vessel. In other chordates, it is located dorsal to the dorsal blood vessel.
- Notochord is not covered by any connective tissue sheath while in chordates, it is encircled by two sheaths.
- Buccal diverticulum is formed from the anterior end of the foregut and it is separated while in chordates, it gets separated.
- Large sized vacuolated cells of notochord differ from the small sized cells of the buccal diverticulum. These cells are considered as epithelial cells by many scientists.
- Hemicordates possess dorsal tubular nerve cord limited to the collar region. Rest of the body possess intra epidermal nerv net. While chordates possess anteroposteiorly extended dorsal tubular nerve cord whose anterior end enlarges into brain.
- Chordates have one pair of gonads while hemichordates possess many gonads.
- Blood flow in dorsal blood vessel is from posterior to anterior end as seen in invertebrates.
- Heart is dorsal in hemichordates while it is ventral in chordates.
- Single layered ciliated epidermis differs from chordates having multilayered epidermis.
- Serological tests reveal their resemblance with echinoderms in particular and invertebrates in general.

ii) Resemblances with Echinoderms

More resemblances can be eluted between the bipinnaria larva of Asterias and tornaria larva of Balanoglossus.

- cleavage and the gastrulation are similar in both the groups.
- arrangement of ciliated bands in the larval forms is closely similar.
- coelome is formed in enterocoelic way
- Mouth is ventral and anus is posteriorly located
- Anus is formed from the place of blastopore (Deuterostomes)
- Poorly developed nervous system in adult condition.
- Madreporic vesicle of tornaria larva is comparable with the heart vesicle of echinoderms.
- Phosphagens released during muscle contraction are similar.
- Organisms of both the groups are marine living.
- The larval forms show bilateral symmetry though the adults differ.

The main difference here is that the echinoderms have spiny skin while the hemichordates possess ciliated epidermis.

iii) Resemblances with Annelids

- Organisms are tubicolous and live in burrows. They feed on decaying organic material and release castings during egestion.
- Blood vascular system of echinoderms resemble that of annelids. Heart is dorsal.
- Blood flows in anterior direction in dorsal blood vessel and in posterior direction in ventral blood vessel.
- Tornaria larva can be considered as the modified trochophore larva of annelids.

Differences with annelids:

- Nervous system basically differs in both the groups.
- Nephridia of annelids cannot be equalled to the glomerulus of hemichordates.
- Pharyngeal basket as seen in hemichordates is not similar to the muscular pharynx of annelids.
- Buccal diverticulum as seen in hemichordates is not present in annelids.
- Ciliary mode of feeding in hemichordates differs from that of annelids.

Systematic position

- Hemichordates, the entero coelic group of organisms, present many resemblances with invertebrates.
- Biochemical resemblances with echinoderms place these organisms nearer to invertebrates
- The annelidan characters of hemichordates might have formed due to divergent evolution.
- Phanyngeal basket of hemichordates place them nearer to chordates.
- Several invertebrate organisms show gill slits and pharyngeal openings.
- It can be presented that the common anchestor might have evolved into echinoderms on one side and hemichordates and chordates on the other side.
- Position of the hemichordates in animal kingdom became a controversial point for the scientists.
- Sedzwick and Huxley related these organisms with chordates.
- Bateson (1885) treated hemichordata as a subphylum in phylum chordata.
- Vander Horst (1939), Danrydoff (1948), Marcus (1958) and Hyman (1959) opined that the hemi chordates be given the status of a phylum amongst the invertebrates.

Hence, Hemichordata is given the phylum status amongst the other invertebrate phyla.

1.2.4 General and specialized characters of UROCHORDATA

Urochordates are generally called as sea squirts. They are distributed worldwide and are marine. They are also named as tunicates as their body is encircled by test or tunic made of a type of cellulose, tunicin. Ascidian was first described by Aristotle (384-322 B.C.). The name tunicate was

confirmed by Lamarck (1816) after examining the tunic. Most of the information about urochordates was provided by Herdman, Bateson, Dass, Bevil and Garstang.

Kowaleysky included these organisms in true chordates.

i) General characters:

- Organisms may be solitary or colonial.
- Adult organisms are sedentary while the larval forms are freeliving.

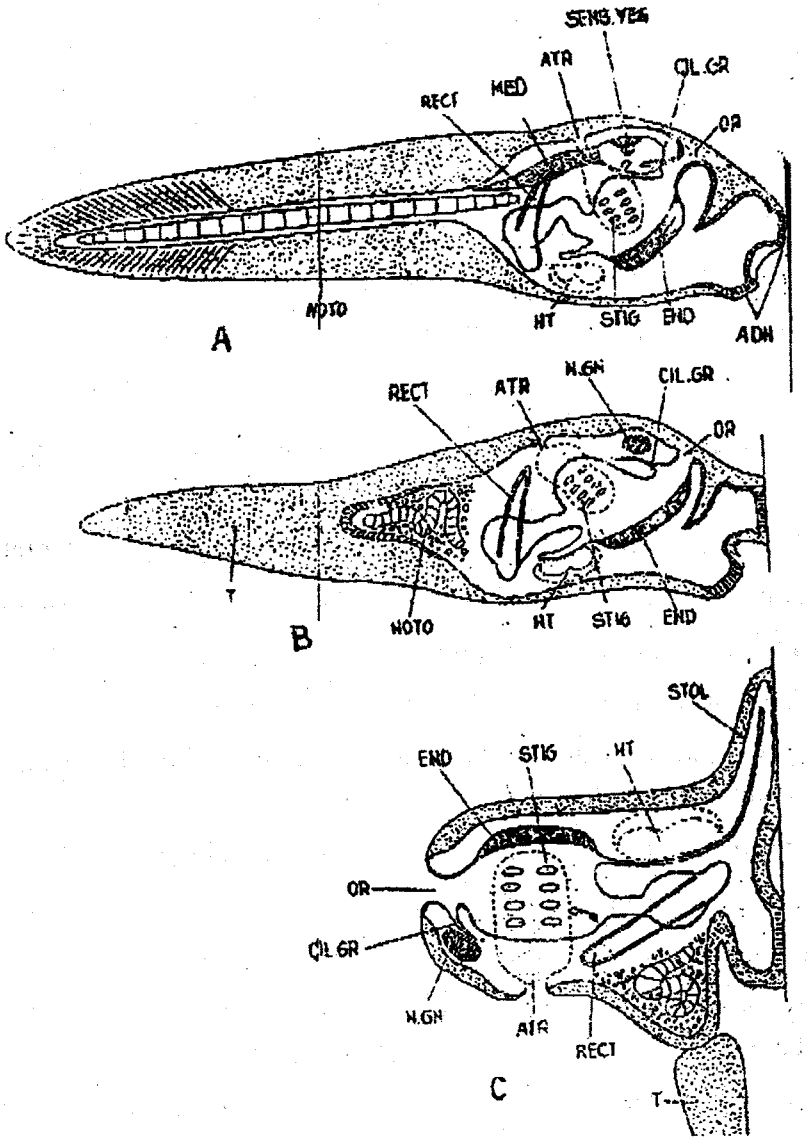

Fig. 1.4 Metamorphosis of ascidian tadpole

A-free-swimming larva; B-larva recently fixed; C-older fixed stage ; ADH-adhesive papillae, ATR-atrial cavity; IL-GR-ciliated diverticulum, becoming ciliated funnel; END-endostyle HT-heart; N GN-nerve-ganglion; NOTO-notochord; OR-oral aperture;REC T-rectum; SENS VES-sense vesicle; STIG-stigma; STOL-stolon; T-tail.

- ❖ Body is differentially coloured and may be transparent or translucent or opaque. Size and shape differs.
- ❖ Basket shaped body is covered by protective test or tunic made of tunicin.
- ❖ The organism possess a branchial siphon at its anterior end and an atrial siphon on its dorsal side.
- ❖ Water flow into the body is through branchial opening and exits through atrial opening.
- ❖ Water helps in the transport of food and oxygen into the body. Outgoing water takes away the excretory products, undigested materials, carbon dioxide and germ cells.
- ❖ Visceral organs are located in wide peribranchial or atrial cavity.
- ❖ Pharynx bears a number of small respiratory openings called stigmata. They inturn open into the atrial cavity.
- ❖ Pharynx has a dorsal lamina or hyper pharyngeal fold and a ventral endostyle.
- ❖ Nervous system is absent and is represented by a ganglaon in between the siphons. Dorsal to it is a neural gland.
- ❖ Heart is tubular 'U' shaped and ventral. Pulsations of the heart show reverse periodicity. Hence the single blood vessel acts as both artery and vein alternatively. It carries both oxygenated and deoxygenated blood simultaneously. Heart is Myogenic Blood possess special type of cells called vanadocytes containing vanadium.
- ❖ Organisms can reproduce by asexual and sexual methods. Asexual reproduction is by budding. Ascidians exhibit hermaphroditism. Each lobe of the gonad possess both male and female reproductive parts.
- ❖ Ascidians also exhibit regeneration and polymorphism.
- ❖ fertilization is external. Development is indirect. Tadpole larva formed from the zygote is a free living one with the three prime characters viz., notochord, dorsal tubular nerve cord and pharyngeal gill slits.
- ❖ Notochord is located in the tail region of the larva and hence the name urochordata.
- ❖ Larva undergoes retrogressive metamorphosis.
- ❖ Neoteny or paedogenesis is observed in some organisms.
- ❖ These are the only chordates lacking excretory system.

ii) Special Characters:

- Presence of notochord in the tail region of the larva.
- Body covered by hard tunicin made test or corona.
- Sedentary habitat
- Neural gland and a single nerve gangleon.
- Branchial and atrial siphons with openings for water flow besides well expanded atrium depleting the body cavity.

- Tubular ventral heart showing reverse periodicity
- Blood vessel acting both as artery carrying oxygenated blood and vein carrying deoxygenated blood.
- Hermaphroditism in each lobe of the gonad.
- Well developed larva undergoing retrogressive metamorphosis.

1.2.5. Affinities of urochordates with other phyla :

Urochordates have notochord in their tail region of the larva besides the other two prime characters. Disappearance of these characters in the adult organism due to retrogressive metamorphosis is a special feature of these forms. They show resemblances with chordates.

Resemblances with chordates

- Branchial tentacles of urochordates can be compared with the wheeler tentacles of Amphioxus.
- Presence of gill slits giving a basket appearance to the pharynx.
- Muco-ciliary mode of feeding of urochordates is comparable with the feeding mode of cephalochordates and Ammocoetus larva of petromyzon (a cyclostome fish).
- Endostyle is homologous with that of the thyroid gland of higher forms.
- The neural gland and the nerve gangleon of urochordates combinedly resemble the pituitary gland of vertebrates.
- Anterior opening of the tubular nerve cord is homologous to the neuropore of higher chordate forms.
- Presence of tail with fins on either side as post anal extension of the body of the larval form.
- Pericardial membrane surrounding the heart.
- Blood vascular system is much similar to that of blood vessels in fishes.
- Typhlosole in the intestine is in similarity with the scroll valve of fishes.
- Tadpole larva of ascidians resembles the tadpole larva of frogs.
- Similarities in the development of zygote can also be observed.

Comparison with Amphioxus

Resemblances:

- Conchlin proposed a number of resemblances in the structure of egg and different embryonic stages of ascidians and amphioxus.
- Formation of notochord and dorsal tubular nerve cord is similar in both the forms.
- Pharynx with endostyle, gill slits, supra and peripharyngeal ciliary bands in both the organisms.
- Presence of atrium and atrial opening as an exhalent aperture.
- Ciliary mode of feeding.
- Presence of tail at least in the larval form of urochordates.

Differences:

The following important differences observed in between urochordates and amphioxus over weigh the similarities. Absence of:

- ❖ protonephridia as organs of excretion.
- ❖ segmentally arranged coelomic pouches and paired myotomes.
- ❖ heart and pericardium in amphioxus.
- ❖ tunicin made test or corona in amphioxus.
- ❖ asexual reproduction and regeneration in amphioxus.
- ❖ gonoducts and hermophroditism in amphioxus.

Comparison with Balanoglossus:

Presence of

- gill slits in the pharynx.
- notochord in the tail as compared to the stomochord of Balanoglossus.
- almost similar nervous system

Differences: Absence of the following features in Balanoglossus overweigh the superficial similarities. They are the absence of

- tunicin made test or corona
- sedentary mode of life
- expanded atrial cavity
- true notochord
- hermophroditism and retrogressive metamorphis.

Systematic position:

Reduced coelome and metamerism in urochordates support the view that the adult ascidian is primitive to amphioxus. Garstang was of the opinion that the anchestors of the chordates led sedentary life with ciliary mode of food collection. This view was subsequently supported by Berril and Romer.

Over looking the features like test, gill slits, dorsal tubular nerve cord, Borradile kept these organisms in invertebrates for long time. The establishment of animal nature in ascidians by Aristotle, identification of compound ascidian by Schlosser and Ellis, detailed study of internal organisation by Savigney helped Lamarck to create a separate class called **'Tunicata'**.

Research studies of Kowaleysky proved the fact that urochordates are the protochordate organisms. The special characters limited to these organisms alone made the scientists to assign the status of the subphylum to urochordata.

Phylogeny

Ascidians were thought to have evolved from pterobranchs of hemichordata. The tailed larval forms after leading free swimming life attach with the substratum and trasnform into a sedentary adult. Some scientists opined that these larvae exhibit neoteny by forming gonads and then transformed into adults. These might have migrated to the estuarine regions and underwent tremendous changes to live successfully in the changed environment. Thus these sedentary organisms might have developed into free living forms.

According to Garstang, it was presumed that the ascidian tadpole took its origin from auricularia larva of echinoderms. Subsequently, ascidians have evolved into different types of chordates in three ways:

a) Larval forms of some anchestral organisms undergone retrogressive metamorphosis and developed into adult ascidians.

b) Certain anchestral larvae migrated to estuaries, entered into fresh water and evolved into primitive free living organisms like fishes by developing locomotory structures, muscles etc.

c) Certain other larvae reentered the sea water and slowly evolved into amphioxus like organisms.

These are only hypothetical conclusions. There are neither clear evidences nor fossil records to work out the phylogeny of urochordates.

1.2.6 General and specialized characters of Cephalochordates

Cephalochordates are the advanced protochordates having all the three basic characters of chordates viz.,

- anteroposteriorly extended rod like notochord
- dorsal tubular nerve cord, located dorsal to the notocord has an anterior enargement, probably the primitive brain, and
- sac like pharyngeal basket with about 200 pairs of gill slits in the adult condition.
- The best example is the amphioxus identified by Pallas in 1774 who considered it as a slug. Yarren proposed the name amphioxus in 1836.
- Costa in 1884 described amphioxus as a primitive chordate organism.
- Amphioxus, a small fish like marine organism measuring 76 mm is generally called as a lancelet. It prefers to live in burrows, though capable of swimming through undulations. These exhibit primitive, specialized and degenerative characters besides the common general features as discussed below:

i) General characters of cephalochordates

☆ Solitary organisms leading free swimming or burrowing life and universal in distribution.

☆ Fish like organisms showing bilateral symmetry except assymmetron.

☆ Anterior part of the body lacks definite head, brain, sense organs, jaws and paired appendages. Hence body is divisible into trunk and tail.

☆ Dorsal fin is a short and hollow fold while tail fin is in the form of lobes.

☆ Anteriorly skin extends as a oral hood with 10-20 pairs of ciliated buccal cirri.

☆ Oral hood encloses a wide cavity called vestibule.

Ventral to the vestibule is a sphinctored septum called velum bearing velar tentacles.

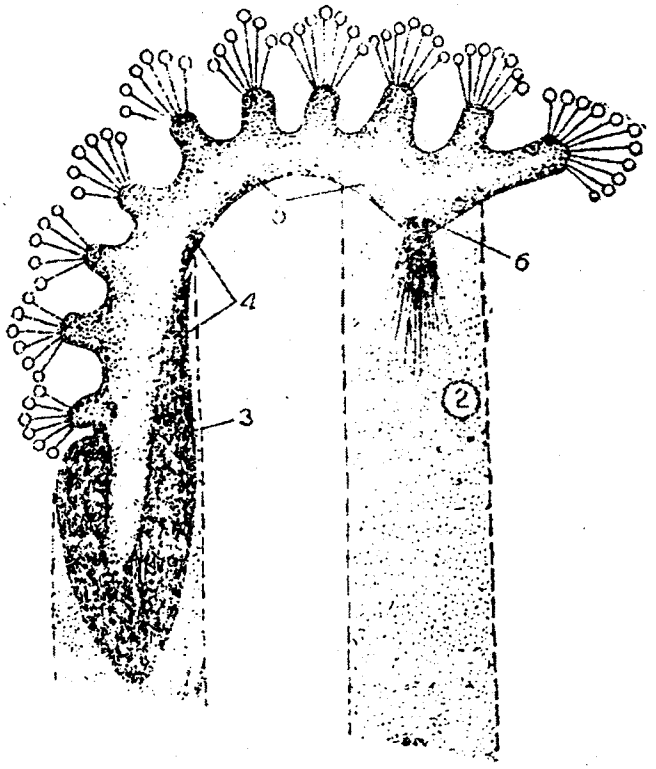

Fig. 1.5 *Amphioxus*-Nephridium with a primary and a secondary gill-bar
1. Primary gill-bar; 2. Secondary gill-bar; 3. Coelomic space in primary gill-bar; 4. Vertical limb of nephridium; 5. Horizontal limb; 6. External opening of nephridium; 7. Solenocytes.

✦ Exoskeleton is lacking. Laterally body has 50-85 pairs of 'V' shaped myotomes.
✦ Persistant notochord extending from anterior rostrum to the posterior tail.
✦ Coelome is reduced because of expanded atrial cavity in which viceral organs are located.
✦ Many pairs of gill slits on the lateral sides of the pharynx to help in feeding and branchial respiration. They open into atrial cavity.

- ✦ Fiter feeding or mucociliary feeding mechanism for food collection.
- ✦ Alimentary canal has the liver diverticulum or hepatic caecae as only digestive gland.
- ✦ Blood is colourless and blood vascular system is on chordata plan, having hepatic portal system also.
- ✦ Excretory system consists of solenocytes or nephridia as seen in annelids.
- ✦ Dorsal tubular nerve cord is located dorsally to notochord. It slightly enlarges anteriorly paving way for the formation of brain.
- ✦ Unisexual organisms having metamerically arranged gonads. Gonoducts are lacking.
- ✦ Fertilization is external development is indirect with an asymmetrical larval form.
- ✦ Coelome is formed in enterocoelous way.

ii) Primitive characters:

- Body is covered by thin and transparent skin having neither pigmentation nor glands. Epidermis is unilayered as seen in annelids.
- Anterior wheel organ with its ciliary buccal cirri helps in filter feeding or muco-ciliary mode of feeding besides creating continuous water current.
- 'V' shaped myotomes arranged in pairs on the lateral sides of the body.
- Lack of distinct head, jaws, teeth, tongue, eyes and auditory organs.
- Straight tubular and undifferentiated alimentary canal.
- Slight enlargement at the anterior end of dorsal tubular nerve cord as a precursor to the brain.
- Nervous system is primitive. Ganglea are not clear. Peripheral nerves are naked (without myelin sheath).
- Sense organs are represented as Kolliker's pit, Hatcheck's pit, buccal cirri and eye spot.
- Persistant antero posteriorly extended notochord.
- Blood vascular system has blood vessels. Blood is colourless. Neither heart nor pericardium are seen.
- Excretory system is represented by proto-nephridia or solenocytes.

Gonads are many and paired but gonoducts are lacking as seen in invertebrates.

Development is indirect involving an assymmetrical larval form.

iii) Special features:

- Antero-posteriorly extended notochord, longer than nerve cord.
- Wide phanynx with several pairs of gill slits.
- Well developed vestibule and oral hood in front of month.
- Well expanded atrium around pharynx and other visceral organs.
- Formation of primary and secondary gill bars made of chitin.

iv) Degenerative features:

- Poorly developed brain and sense organs
- Wheel organ, Kolliker's pit and eye spot as substitutes of sense organs.
- Lack of paired appendages

v) Systematic position:

Systematic position of cephalochordates is still controversial and their place in animal kingdom is not clearly specified. They show resemblances with urochordates and agnathan fishes on one side and invertebrates on other side.

3.7. Affinities of cephalochordates with other phyla :

Resemblances with Urochordates : Presence of

large number of gill slits and endostyle in pharynx.

atrium around phanynx and visceral organs

supra and peripharyngeal ciliated bands

notochord, tubular nerve cord which are similar in their structure and formation.

Differences with urochordates:

Unlike sedentary urochordates, cephalochordates are free living.

Body is not covered by tunicin made test as in urochordates.

Absence of gonoducts as against urochordates having gonoducts.

Unisexual nature of cephalochordates against the bisexual nature of urochordates.

Presence of straight alimentary canal which is 'U' shaped in urochordates.

c) Resemblances with agnathan cyclostomes:

- Presence of endostyle which is similar to the subpharyngeal gland of ammocoetus.
- Absence of gonoducts
- Large number of gill slits.
- Persistant notochord in adult forms
- Similarity in the formation of myotomes and their arrangement.
- Oral hood of amphioxus in comparison with buccal funnel of cyclostomes
- Protonephric type of kidneys
- Ammocoetus larva of cyclostomes is comparable with the adult cephalochordates as both of them have fish like body with expanded vertical caudal fin.
- Lack of paried fins
- Lack of jaws and feeding is by filter feeding mode
- Posteriorly directed blood flow in dorsal aurta and anteriorly directed in ventral aorta.
- Straight and uncoiled alimentary canal opening out through anus.

d) Differences with cyclostomes:

- Amphioxus is marine while ammocoetus larva lives in fresh water.
- Paedogenesis is observed in some cephalochordates while the larvae of cyclostomes under go metamorphosis.
- Notochord in cyclostomes is represented in between vertebrate.
- Absence of photoreceptive cells as seen in amphioxus.
- Pharynx is shorter in cyclostomes
- Lack of gill lamellae in the walls of pharyngeal pouches as seen in cyclostomes.

Conclusion

Because of the above resemblances and differences cephalochordates were considered as developing fishes. Because of their burrowing mode of life, several of the characters have degenerated and hence was considered as a degenerating fish like chordate. Gregory described them as degenerating agnathans. These were thought to have resembled with silurian fishes which have given rise to modern fishes. Newell stated that had amphioxus was not discovered, it must be created. This emphasizes the general chordata plan of cephalochordates. Because of the primitive and specialized characters, cephalo chordates were given the status of a subphylum in the taxonomy.

1.2.8. Comparison of the three subphyla

Hemichordata	Urochordata	Cephalochordata
Free living or burrowing forms with worm like body	Free living or sedentary organisms with barrel shaped body	Free living or burrowing forms with fish shaped body
Body is divided into proboscis, collar and trunk	Body has no definite head and tail. Body is undifferentiated	Lancelet organism is divided into head, trunk and tail
Notochord is limited to collar region only. It is represented as buccal diverticulumn or stomcord	Notochord is located only in the tail region of larval forms. It is not seen in adult organisms.	Notochord is a rod like one extending from anterior to the posterior end of the body. It is longer than tubular nerve cord.
Gill slits vary from one pair to many pairs	Gill slits are many in number and harynx is like a basket	Many pairs of gill slits giving the appearance of a basket to the pharynx
Besides a dorsal tubular nerve cord, there is a ventral cord also embedded in the skin	Nerve cord is present in the anterior part of the tail on the dorsal side and opens out through anterior neuropose. It is represented as a reduced gangleon and neural gland in adults	Dorsal tubular nerve cord is entire and elongated. It is located dorsal to the notochord and opens out through antero dorsal neuropore in the adult. It enlarges anteriorly to form a primitive brain
Anus is postero terminal. While mouth is antero ventral lying between proboscis and collar	Anus is absent. Alimentary canal opens into atrium. Mouth is represented as a opening on the branchial sifhon.	Anus is present at the postero ventral side. Mouth is located in the centre of the wheel organ at the anterior end and is surrounded by buccal cirrhi.
Exhibit bilateral symmetry without any external covering	Assymmetrical organisms. Body is covered by a tunicin made cyst or tunica	Bilateral symmetry without any external protective layer
Body cavity is divided into five parts	Body cavity is reduced due to the expansion of atrium	Body cavity is reduced by the development of atrium
Open type of blood. vascular system with a vesicular heart for pulsations	Closed blood vascular system. Heart is tubular and show alternative reverse pulsations. Blood sinuses are seen.	Closed type of blood vascular system. Heart is not specific. No blood sinuses
Proboscis gland is meant for excretion	Neural gland is the main excretory organ	Solenocytes or flame cells are the proto nephridia involved in the process of excretion
Gonads are arranged in linear rows in the genital wings	Gonads are lobed and each lobe has both tests and ovary	Gonads are metamerically arranged. Gonoducts are lacking.
Organisms may be uni or bisexual	Organisms are bisexual and exhibit di/polymorphism	Organisms are unisexual but not dimorphic

Hemichordata	Urochordata	Cephalochordata
Reproduce asexually by budding	Reproduce asexually by budding	Cannot reproduce asexually
Power of regeneration is more	Power of regeneration is more	Cannot regenerate the lost body parts
Fertilization is external	Fertilization is external	Fertilization is external
Development involves a free swimming larval form called Tornaria	Development involves a free swimming bilaterally symmetrical Tadpole larva	Development involves a free swimming assymmetrical larval form
Branchial skeleton is formed of tongue bars	Branchial skeleton is not specific	Branchial skeleton is formed of primary and secondary gill bars
Ciliary bands of the larvae are retained in the adult	Ciliary bands are absent in larval forms	No ciliary bands in the larval forms
Larva is bilaterally symmetrical. Metamorphosis of progressive type	Larva undergoes retrogressive metamorphosis and transforms into an asymmetrical barrel shaped adult	Larva is asymmetrical and undergoes progressive metamorphosis and transforms into a symmetrical fish like adult

1.2.9 SUMMARY

Protochordates are the primitive chordates having notochord, dorsal tubular nervecord and pharyngeal gill slits as chordata characters in the adult condition. These are the triploblastic duterostomes with coelome developed in enterocoelic method. They are marine and are adopted for ciliary or mucociliary mode of feeding. They lead either free living or tubicolous or sedentary life. Organisms are mostly unisexual. Bisexual organisms are also found. They reproduce both by asexual and sexual methods. Development is external and indirect. Prochordates have three subphyla viz., Hemichordata, urochordata and cephalochordata. Subsequently, Hemichordata has separated and given the status of minor phylum. This is more related to invertebrates.

Hemichordata:

It is represented by free living or tubicolous organisms. Their body is divided into proboscis, collar and trunk. Body is covered by a unilayered ciliated epidermis. Mucus glands secrete mucus which forms a cementing layer in the burrow. Body cavity is a five chambered one with annocboid cells in the coelomic fluid. Body has proboscis skeleton, buccal diverticulum, branchial skeleton formed of tongue bars, circular and longitudinal muscles, liver diverticula, digestive glands, 'U' shaped gill slits, open type of blood vascular system, dorsal sinus as heart, blood lacunae, proboscis gland as excretory organ, nerve plexus in the epidermis, uni or bisexual nature, tornaria larva in development as special features.

Urochordata:

This is represented both by free swimming pelagic and sedentary forms covered by tunicin made test or corona. They possess branchial and atrial siphons and openings for water flow. Heart is ventral and show reverse periodicity. Blood vessels are seen but capillaries are absent. Phanyx is

basket like with a dorsal lamina and endostyle. It bears a number of gill slits. Neural gland is the excretory organ. Reproduces both by asexual and sexual methods. Life cycle includes a free swimming well developed, bilaterally symmetrical larva. It undergoes retrogressive metamorphosis.

Cephalochordata:

Organisms possess well formed notochord longer than neural tube. They lead solitary free swimming or tubicolous life. They have a well formed wheel organ with a number of tentacles, buccalcirri, velum and velar tentacles. Organisms are unisexual but are not sexually dimorphic. The systematic position of these groups is highly controversial and much debated. Basing on the special features of the organisms their position in animal kingdom s decided as subphyla of phylum chordata except hemichordates which were given the rank of mino phylum and included along with invertebrates.

1.2.10 Self assessment Questions

(a) Enumerate the general and specific characters of hemichordata. Discuss its systematic position.
(b) Discuss the affinities of urochordates.
(c) Write an account on the general characters and affinities of cephalochordata.
(d) Compare the three protochordate groups in relation to their general body organization.

1.2.11 Reference Books

1. **A Text Book of Zoology, Vol. II** by Parker & Haswell.
2. **A Student Text Book of Zoology, Vol. II**, Adam Sedgwick.
3. **Vertebrate Biology** by R.T. Orr.

Dr. K. Kondaiah

UNIT II

Lesson - 2.1

CLASSIFICATION OF FISHES

INTRODUCTION: Fishes are the swimming vertebrates limited mostly to the aquatic environment. They are popularly named as **moving water flowers.** These possess well-suited body to lead successful life in their habitat.

As **devonian** is represented well by all types of fishes, which enjoyed the supremacy over all other organisms of that period, it is considered as the **golden age of fishes.** This branch of study is generally named as **ICHTHYOLOGY.**

Fishes possess a number of common characters in general. This lesson is dealt on the following plan:

Contents:

2.1.1 OBJECTIVES:

After studying this lesson, you should be able to

- Appreciate the evolution of fishes as successful aquatic organisms
- Understand the origin, supremacy and distribution of fishes during different periods of geological time scale.
- Enumerate the general characters of fishes
- Classify the living reptiles up to order level
- List out the scientific names of commonly occurring fishes

2.1.2 GENERAL CHARACTERS OF FISHES :-

- These are aquatic vertebrates having toothed and hinged jaws for the first time. Hence they are the gnathostomes. Tongue is immovable.
- They have spindle shaped streamlined body with slimy skin covered by dermal scales.
- Special appendages are the bilaterally symmetrical paired fins and median unpaired fins helping in locomotion and equilibrium in water. Tail fin is of varied types .

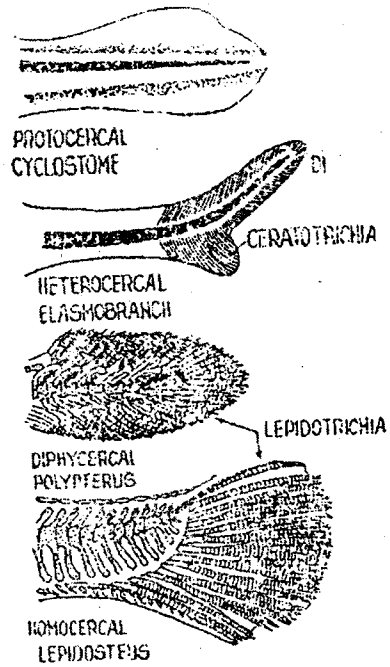

Fig. 2.1 Tail -fins of fishes

- Poikilothermous or cold blooded organisms capable of changing their body temperature in relation to the environment.
- Generally they respire through gills. Dipnoi fishes have lung like endodermal air sacs for aerial respiration. Some fishes possess accessory respiratory organs

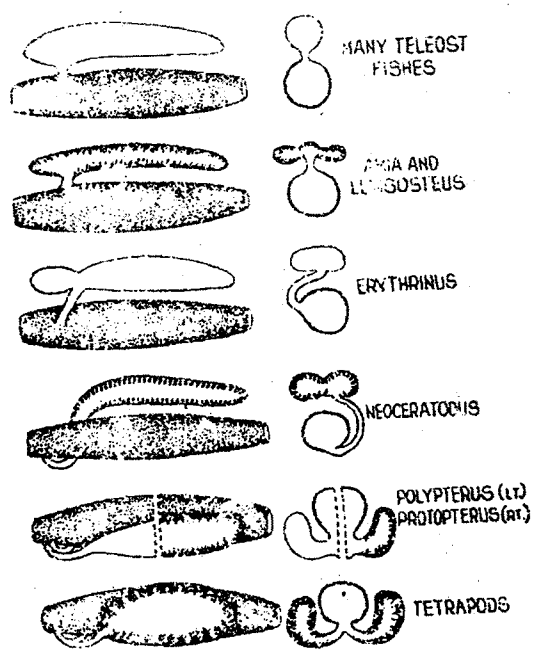

Fig. 2.2 Types of air bladders in fishes

- Body is well suited for swimming, aquatic respiration, food collection, protection and reproduction in aquatic environment.
- Paired nostrils never open into pharynx except in lung fishes.
- Digestive system has a wide stomach, lobed liver and pancreas.
- External ear and tympanum are absent. Internal ear is represented by membranous labyrinth having semicircular canals.
- Venous heart has only two chambers viz., one auricle and one ventricle. Partially divided ventricle is seen in dipnoi fishes.
- Brain is protected by cranium and notochord is replaced by vertebral column. Ten pairs of cranial nerves arise from the brain.

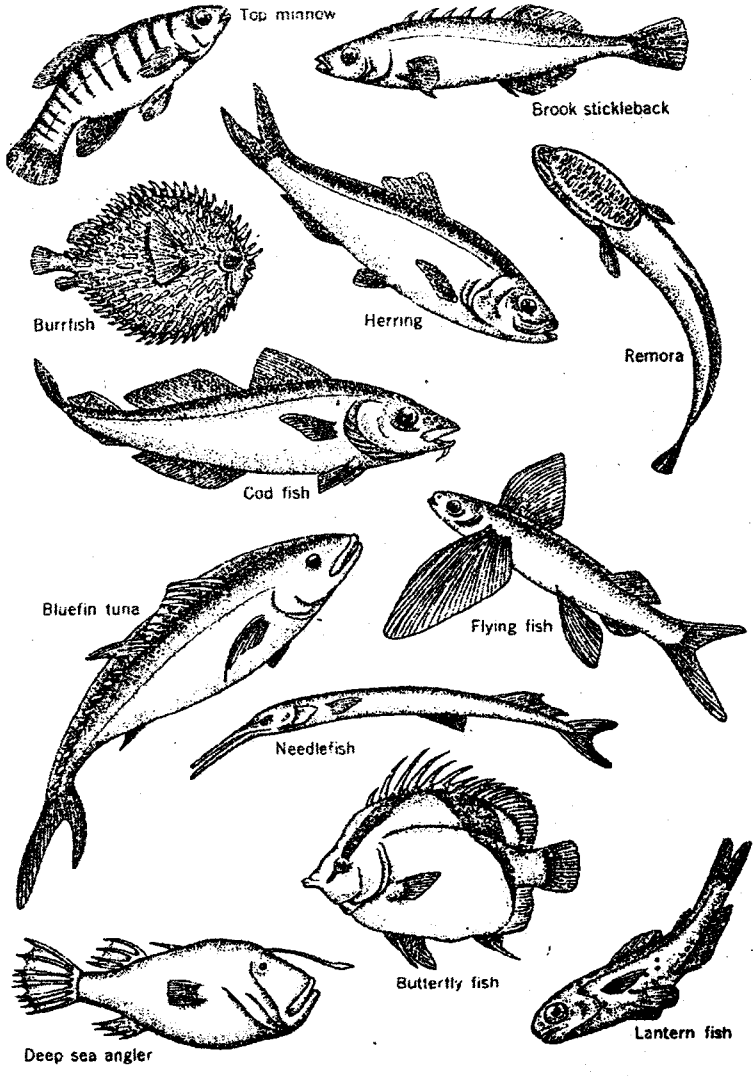

Fig 2.3 Some Bony fishes

- All the spinal nerves are mixed and medullated.
- Pituitary gland is small and is in association with the brain.
- Lateral line sense organs are well developed extending from the head region to the posterior end of the body on either side of the organism. They open out thorough small openings located in between the scales on the body.
- Muscles are in the form of '<'on either side of the body and help in causing body movements.
- Kidneys are mesonephric except in cyclostomes where they are pronephric. Urinary bladder is absent. Gonads are paired and the true gonoducts open into cloaca.
- Unisexual and sexual dimorphism may or may not be seen.
- Oviparous organisms except some elasmobranchs, which are viviparous. Fertilization and development occur in water.
- Fishes are anamniotes, as the amnion is not formed during the development.

2.1.3 CLASSIFICATION OF FISHES UNDER SUPER CLASS GNATHOSTOMATA:

The group Fishes is classified into three Classes viz:

Class 1 **PLACODERMI**:

- First formed gnathosto. es of devonian and silurian times and became extinct during permian period
- Body is covered externally by hard bony plates forming into an armor.
- Jaw suspensorium is of primitive aphetohyoidan type
- The first gill slit looking like a gill is represented as spiracle.
- Though they are fresh water in origin, they subsequently migrated to sea water
- This group is considered to be intermediate between cyclostomes and gnathostomes

Ex: Climatis, Cacosteus, Micropetalithyes, Terichthoidea and Jemendina

Class 2. **CHONDRICHTHYES or ELASMOBRANCHII**

- This class includes marine sharks, rays and chimeras having jaws and fins.
- Some fishes are also seen in fresh as well as in brackish waters
- Head is covered by dermal plates in some fishes.
- Endoskeleton is totally cartilaginous.
- Notochordal remnants are present
- Tough skin impregnated with placoid scales is valuable as leather and shagreen
- Voracious carnivores with mouth on the ventral side of the snout.
- Intestine possess spiral valve for secreting enzymes
- External nostrils are half moon shaped and are purely olfactory.

- *Five to seven pairs of gill slits are present on either side of the pharyngeal region.*
- Heart is a two chambered one with a contractile conus arteriosus.
- Heterocercal tail fin-having continuation of the vertebral column in the dorsal lobe.
- Urinary and genital ducts open into the cloaca.
- Eggs are released in less numbers and are with high quantities of yolk.

  Some organisms are viviparous.

This class is divided into two sub classes viz.,

1. **Sub Class Selachii**: This includes sharks and rays. Jaw suspensorium is of hyostyli or amphistylic type. Jaws are toothed. Gills open out directly through gill slits. This has three orders viz.,

   i. Cladoselachii: Boat shaped paired lateral fins. One pair of dorsal fins. Notochord is undivided. Small scales surround eyes.

   ii. Protoselachii: Pectoral fins have a notch on their posterior side. Pelvic fin bear copulatory styles in males Ex: *Heterodontus*

   iii. Euselachii: Pectoral fins have three basal plates from which arise a number of fin rays. Ex: *Scoliodon, Pristis, Tigrina, Torpedo*

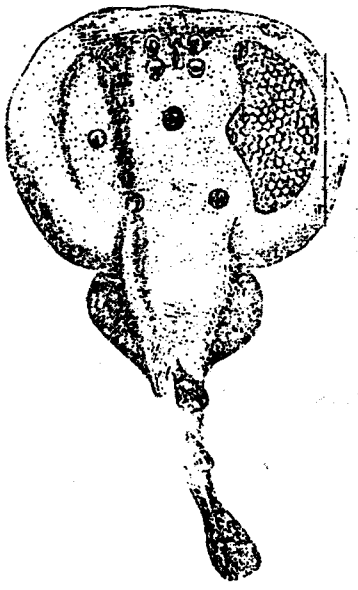

Fig. 2.4 The Electric ray, *Torpedo*

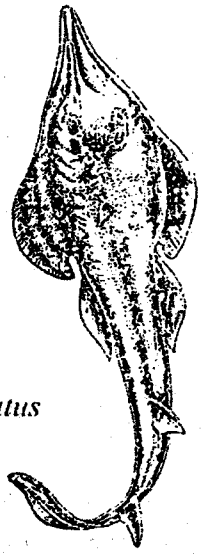

Fig. 2.5 *Rhinobatus*

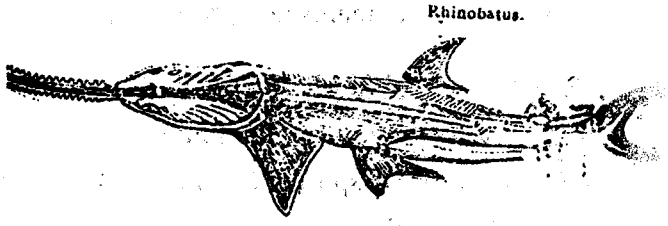

Fig. 2.6 The Saw - fish, *Pristis*

2. **Sub Class Bradyodonti** having two orders viz.,
   - i. Eubradyodonti with wide teeth Ex-*Hilodus.*
   - ii. Holocephalii having fishes with operculum. Spiracles are absent. Tail is long and filamentous. Scales are absent. Jaws possess large number of teeth. Urino genital openings and anus are separate. Ex: *Chimaera, Callorhynchus.*

Class 3. **OSTEICHTHYES:**

- Fishes of devonian origin having completely ossified endoskeleton
- Ancestors possessed bony covering. Modern fishes have their skin impregnated with cycloid, ctenoid and ganoid scales.

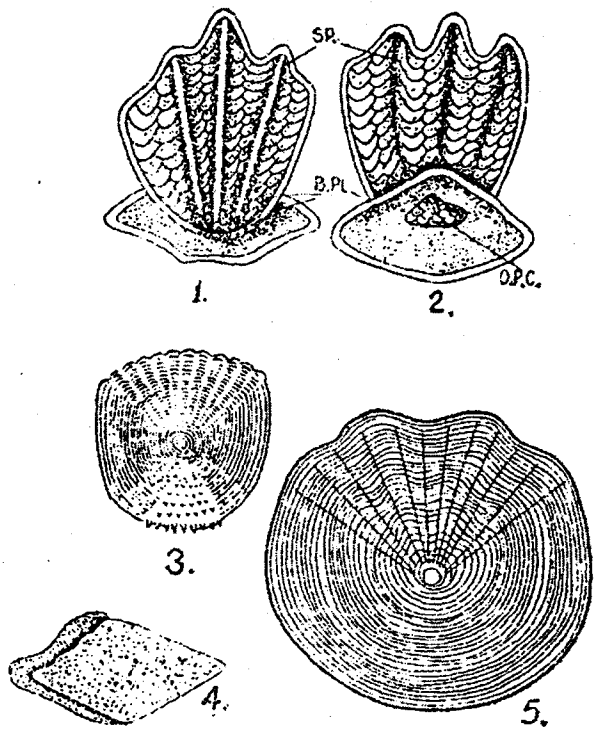

Fig. 2.7 Scales of fishes

1 and 2-Different views of a placoid scale; B. PL-basal plate; O.P.C-opening of the pulp cavity; SP-spine; 3-Cteniod scale; 4-Ganoid scale; and 5-Cycloid scale.

- They inhabit both fresh and seawaters. Mouth is antero terminal.
- Operculum covers the four pairs of gills with degenerated inter bronchial septae located on either side of the pharynx. Gill filaments are free and no spiracles.
- Gills conduct aquatic respiration while some fishes also possess air/swim bladder for hydrostatic or accessory respiratory function.
- Two chambered heart is lacking the conus. Ventricle is partially divided in lung fishes
- Lungfishes also possess pulmonary artery and pulmonary vein carrying impure and pure blood respectively.
- Olfactory lobes and cerebellum are small.

- Tail fin is of homocercal type.
- Kidneys are mesonephric. Blood contains less percentage of urea. Anus and urino-genital ducts open out separately.
- They possess neither cloaca nor copulatory bars.
- Gonads and gonoducts are continuous.
- Mostly oviparous but viviparous also are rarely seen.
- Eggs are small and laid in large number. Fertilization is external. Cleavage is holoblastic and life cycle may include a larval form.
- Skull has hyostylic or amphistylic jaw suspensorium. Pectoral girdle is reduced or absent.

This class is divided into two sub classes viz.,

Sub class 1. **Actinopterygii** : Internal nostrils absent. Fins supported by finrays. Small intestine is well formed with increased absorptive area. Gills are filamentous. Conus arteriosus extends into bulbus arteriosus. Brain is simple. Homocercal tail fin. Swim or air bladder for hydrostatic function.

This sub class is divided into three super orders viz.,

Super order a. Chondrostei *Acipenser, Polypterus*

Super order b. Holostei *Amia, Lepidosteus*

Super order c. Teleostei *Tilapia, Salmo, Leptolepis*

Sub class 2. **Crossopterygii** (choanichthyes): Fins are paired and lobed with radials. Internal nostrils are present.

This sub class is having two orders.

Ordera. Rhipidistia - Body is covered with cycloid scales. Tail fin is of diphycercal type. Notochord is undivided. Vertebral column is unossified. Air bladder is hydrostatic in function. Brain is small. Ex. *Latimaria chalumnae and Melania anjounia.*

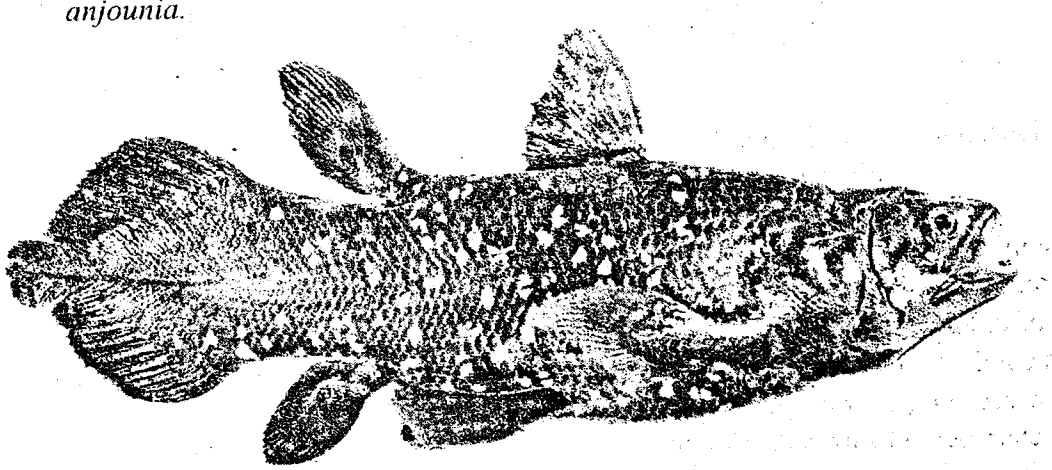

Fig. 2.8 Latimeria

Order b. Dipnoi – Fresh water fishes showing discontinuous distribution. Possess lungs also for aerial respiration. Ex. *Protopterus* (West Africa), *Neoceratodus* (Queens land of Australia), *Lepidosiren* (Amazon of South America)

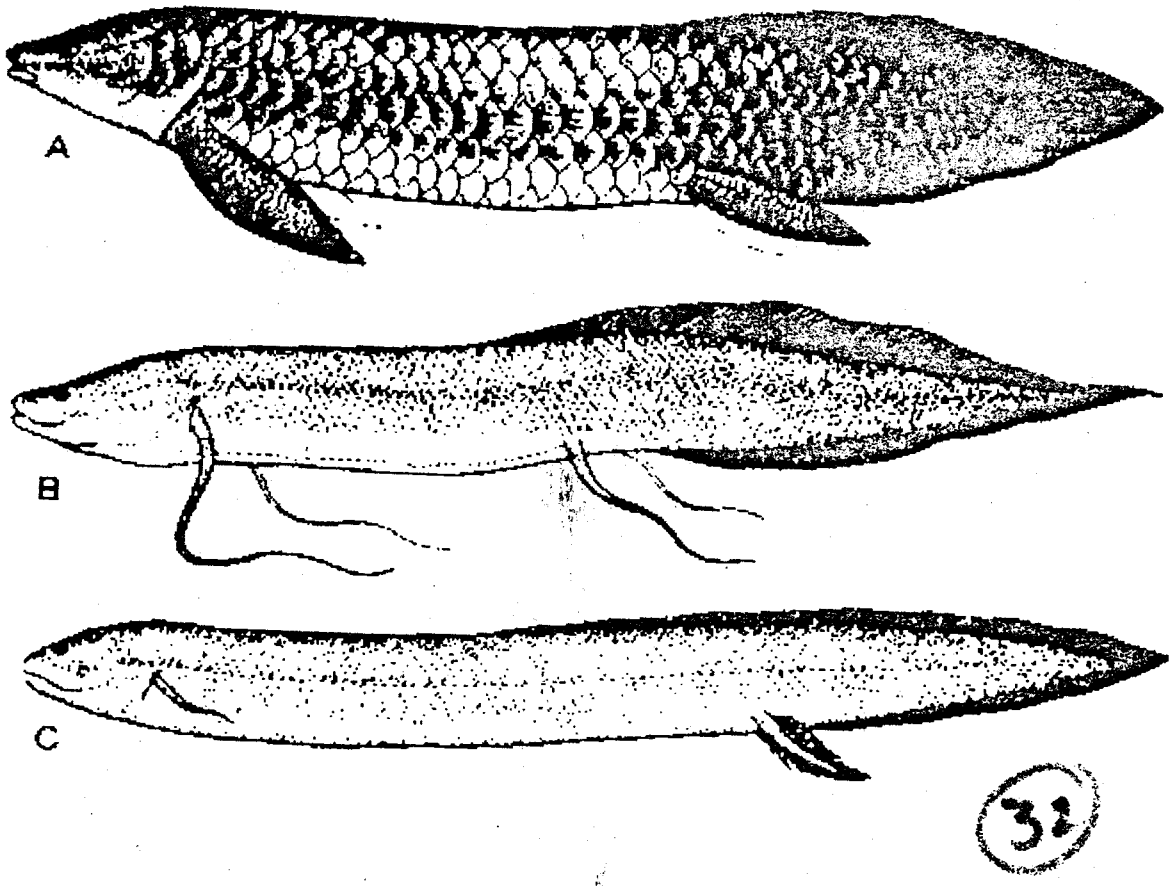

Fig. 2.9 Lungfishes. The Australian *Neoceratodus* (A) uses its sturdy lobed fins to walk across the bottom of the stagnant waterways it inhabits. The South American *Lepidosiren* (B) and African *Protopterus* (C) have reduced fins that cannot bear their weight but are still moved on the diagonal, like legs, during swimming.

2.1.4ORIGIN OF FISHES:

- First jawed aquatic vertebrates evolved from ostracoderms of agnatha during devonian period.
- Fossil history reveals that chondrichthys have evolved during late devonian and osteichthyes during early silurian periods.
- Fishes belonging to chondrostei, holostei and teleostei have grown to their maximum size and almost superceded other organisms of palaeozoic, mesozoic and coenozoic eras respectively.

Though several species became extinct, about 20000 species are thought to be living at present.

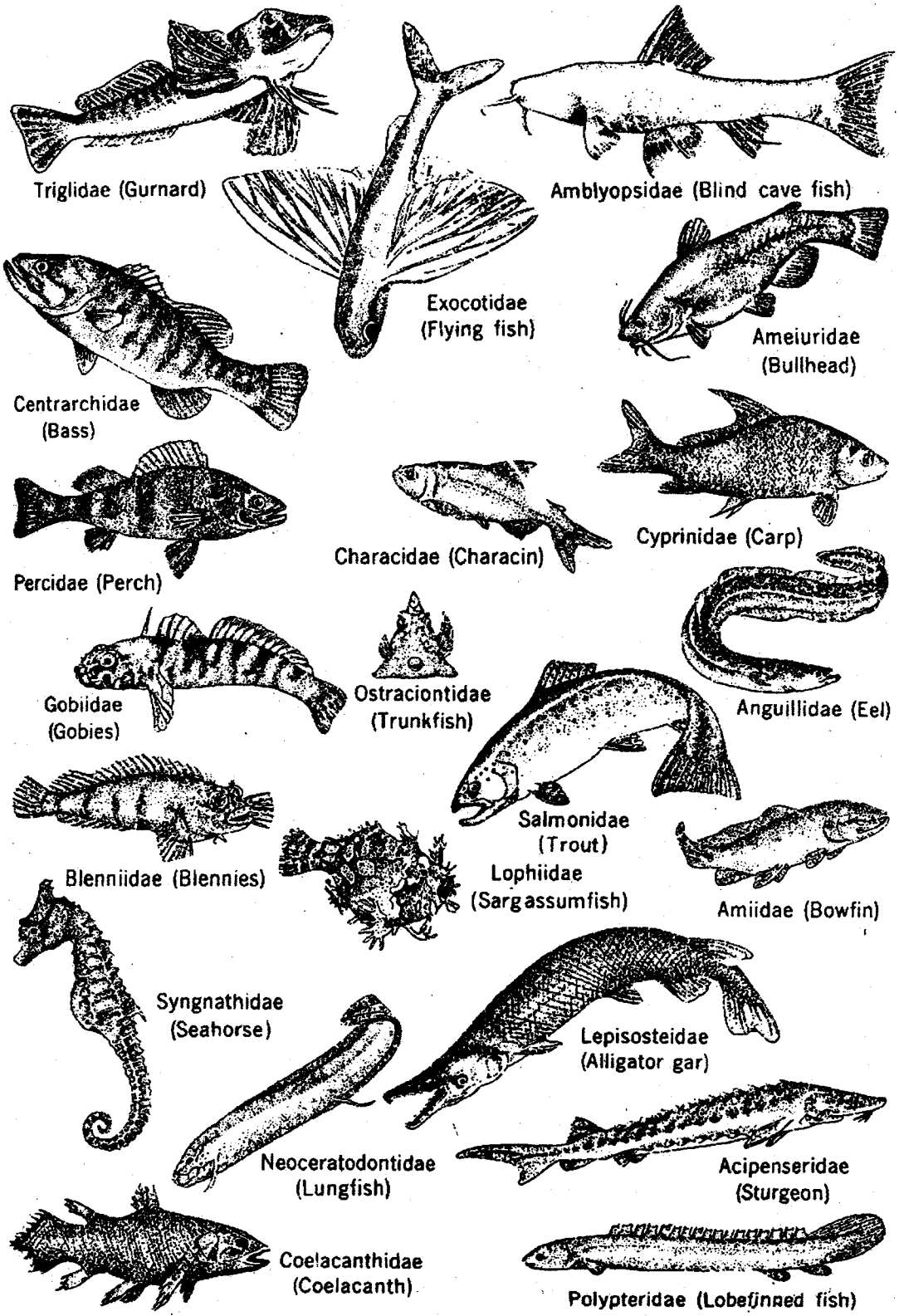

Fig. 2.10 Representatives of the bony fishes

2.1.5 COMMON FISHES:

General Name	Scientific Name
1. Electric ray	*Narcine, Torpedo*
2. Tiger shark	*Stegostoma tigrinum*
3. Whale shark	*Rhyncodon typicus*
4. Saw fish	*Zygaena, Sphyrna*
5. Shark	*Scoliodon sorrocova*
6. Skate fish	*Rhinodon*
7. Sting Ray	*Trigon*
8. Dog fish	*Cheiloscyllium*
9. Herring fish	*Chimera*
10. Gold fish	*Carasius auratus*
11. Carp fish	*Cyprinus carpio*
12. Mullet	*Mugil oir*
13. Rohu	*Labeo rohita*
14. Catla	*Catla catla*
15. Mrigal	*Cirrhinus mrigala*
16. Bombay duck	*Harpodon*
17. Sea horse	*Hippocampus*
18. Pipe fish	*Syngnathus*
19. Flying fish	*Exocoetus*
20. Oil sardine	*Clupea longiceps*
21. Indian herring	*Pellona*
22. Climbing perch	*Anabas*
23. Angler fish	*Lophius, Amtennarius*
24. Mud skipper	*Periophthalmus*
25. Sucker fish	*Echinis*
26. Snake head	*Ophiocephalus*
27. Ribbon fish	*Tricgurus*
28. Bow fin	*Amia calva*
29. Eel fish	*Anguilla anguilla*
30. Mackeral fish	*Scomber scombrus*

2.1.6 SUMMARY:

Fishes are the poiklothermus aquatic vertebrates evoloved from protochordates. Their body is well suited for swimming. Body is spindle shaped and covered by scales. Fins help in swimming. Gills are the chief respiratory organs. Some fishes also possess accessory respiratory organs. Blood vascular system possess venous heart and portal systems. Brain gives off 10 pairs of cranial nerves. Kidney is a mesonephros. The Super class fishes is classified into three classes basing on the skeleton, fins, scales and other important characters viz., Placodermi, Chondrichthyes and Osteichthyes.

Placodermi includes all the extinct fishes.

Chondrichthyes is included with cartilagenous fishes having placoid scales, claspers in males, antero ventral mouth and external nostrils, gill slits on either side of the pharynx etc.,
All bony fishes are included in the class Osteichthyes. They have operculum covering the gill slits, antero terminal mouth and varied fins.
The detailed classification is given.

2.1.7. Self Assessment Questions:

1. Write short notes on Actinopterygii, Dipnoi and Crossopterygii
2. Enumerate the general characters of Fishes and Classify the same up to classes giving suitable examples
3. Write Scientific names for Electric ray, Bombay duck and Mackeral fishes
4. Write general names for Sucker fish, Saw fish, Indian shad.
5. Give an out line classification of fishes.

2.1.8. Reference Books:

1. A Textbook of Zoology by Parker & Haswell. Vol. II
2. Student's text book of Zoology by Sedgwick
3. Vertebrate Biology by Robert T Orr
4. Vertebrate Zoology by Nigam
5. Theory and problems of Zoology by Nancy M. Jessop

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UNIT-II

LESSON 2.2

MIGRATION AND PARENTAL CARE IN FISHES

Introduction

Fishes are the anamniote gnathostomes evolved as true aquatic free living vertebrates. They bear paired and unpaired fins for locomotion and equilibrium; gills for aquatic respiration and scales for protection. Fishes, in general, live in clusters and move to shorter distances from their natural habitat for obtaining food. It is not uncommon to see fishes moving to far off areas for food, reproduction and to tide over the unfavourable conditions. This type of mass movement of fishes in specified periods is called migration. Fish migration is of great importance as it involves the behavioural aspect of the organism in relation to the environment, they prefer to live.

Another important concept observed in fishes is the care taken by some fishes to protect their eggs and progeny. This concept is studied under parental care. This is also of great importance as it relates with the size of their population. Both these phenomena are the natural instincts exhibited by the fishes in response to the environmental changes.

This lesson is discussed in the following Plan.

CONTENTS

2.2.1 Objectives

After studying this lesson, you would be able to understand and appreciate

(a) types of migration and reasons for migration in fishes.

(b) Parental care varieties of parental care exhibited by fishes.

2.2.2.3 Migration in Fishes

2.2.2.1 Definition: Migration in biology refers to the periodic movements of animals away from their abode of living and their subsequent return to the same region. It means that a round trip accomplished annually as seen in birds and mammals or a life time as in fishes. Distance travelled varies with species.

2.2.2.2 Types of Migration: It may be of three types.

(a) Temporary migration: It is the movement from a place of natural habitat to a little distance or from deep water zones to surface areas or from surface to middle or deep water zones in search of mainly food. The fishes return immediately or after a lapse of time but before dusk.

Ex: Mackerals, Tunny fishes, Herring, Cod and trout.

(b) Annual migrations: Many fishes show annual movements to feeding and breeding areas which are located some distance apart.

(c) Permanent migration: Fishes are restless creatures performing migratory movements by travelling thousands of miles. Here the organisms travel to far off places in the same water zone or from fresh water to marine water zones or vice-versa for their breeding activity. Such movements are completed once in the life time as seen in diadromous fishes. The migrants may return to their original places or may not. Here breeding occurs in one environment and growth to maturity in the other. This is again of two types.

i) Anadromous migration: This is an upstream migration where marine fishes migrate to fresh water for reproduction. Good example is the Pacific Salmon of the genus Oncorhynchus. This fish lives in atlantic sea waters. During reproductive seasons, Salmon migrates to freshwater areas. They bread and release eggs in between the crevices of the stones of waterfall zones. The distance may involve thousands of kilometers. Salmons along the pacific coast of North America travel several thousand kilometers from their hatching areas in the head waters of river systems to the Gulf of Alaska after breeding. During migration, skin becomes thick and sponge like. After hatching, the young ones spend two years in freshwater and then migrate back to the sea water for further growth and to attain maturity. Another example is *Hilsa ilisha,* the Indian shad fish living in sea moves to Yamuna and Godavari waters to breed. After hatching, they migrate back to seawater but spend much of their time in estuaries.

ii) Catadromous migration: This is a down stream migration where fresh water fishes migrate to far off distances in sea waters for breeding purposes. Paterson observed this type of migration in eel fishes (Anguilla). The fishes living in freshwaters of Europe and North Africa, migrate down stream, enter Atlantic sea and move thousands of kilometers where the breeding areas are located. After reproduction, females die. Zygotes hatch out into transparent larval forms called leptocephalus. They spend some years in estuarine waters and finally enter the rivers, return back to their original places

where they grow and attain maturity. Before they leave sea water, they undergo metamorphosis and transform into glass eels, develop pigmentation, possess enlarged eyes and degenerated digestive system.

iii) Amphidromous migration occuring inbetween two successive lifecycles as seen in gobies.

iv) Potamodromous migration exhibited by trouts living in fresh water and moving to fresh water areas.

2.2.2.3 Reasons for Migration

Migration is an adaptive type of behaviour providing distribution, constant food supply and a suitable reproductive environment. Hence the main causative reasons for migration can be attributed to alimental (food), gametic (reproduction) and climatic (environmental) requirements. Alimental or food requirements of many organisms are such that they induce seasonal migration. This is decidedly advantageous and results in favourable food supply thorough out the year. Certain fishes regularly migrate between breeding area and feeding grounds. The pacific salmon of the genus *Oncorhynchus* never feeds once they enter the freshwater zones. Hence they feed only in marine zones and thus the Salmon travel thousands of kilometers from their hatching areas in the river systems to the Gulf of Alaska to feed before they attain sexual maturity.

Gametic reason for migration can be observed in eel fishes of the genus *Anguilla* from the fresh water streams of eastern North America and Europe to the region of the Sargasso sea in the Western Atlantic ocean. Climatic reason has profound effect on the food production and gonadial maturity besides influencing the migratory activity. Factors such as salinity, p^H, smell and taste are some such factors. Similarly biological factors like sexual maturity, blood pressure and endocrine secretions also influence migration.

2.2.2.4. Environmental factors influencing migration

As the migration is a seasonal phenomenon, it is obvious to note that the environmental factors like length of the day, climate, food availability and lunar periodicity exert great influence on migration. Temperature plays an important role in the migration of fishes. Rainbow trout *Salmo gairdnerii* and cut throat trout *Salmo clarki* are the freshwater living species moving to spawning areas in the spring or early summer when the temperature rises. *Salvelinus malma* (Dolly Varden trout) of the pacific coast and *Salvelinus fontanalis* (brook trout) of eastern North America spawn in autumn when water temperature declines. During winters, the shallow waters of the coast become cold when the fishes move away from the coast and return to shore during summer. Lunar periodicity influence migration in the fish *Leuresthes*. This is a small smelt like fish of silver sides family moving to shore in large numbers to spawn on the first three or four nights after full moon or the new moon day during February to September. Actual spawning is limited to one to three hours after high tide. *Leuresthes sardinia*, a fish belonging to Gulf of California also exhibit similar migration except that it breeds during day time. The onset of migration in fishes is identified by the enlargement of eyes and well developed fins.

2.2.2.5 Patterns of Migration

- Fishes may migrate thousands of kilometers for breeding purposes and to few meters to several kilometers for feeding purposes.

- Tunas, pelagic fishes breeding in tropical seas perform great migrations.
- The young may migrate back to the original living abodes in search of food before attaining maturity.
- Fishes tapped off the Pacific coast of North America have been caught two years later near Japan.
- Specific migrations have also been observed from pelagic to shallow coastal waters for spawning in smelts and herrings.
- Sockeye salmon (Oncorhynchus nerka) remain in fresh water lakes or streams all through their life.
- *Salmo gairdneri*, a sea water rainbow trout living in the Pacific coast of North America and *Salmo salar* of eastern North America spawn in freshwater and mature in sea. *Salmo salar* returns to sea and spawn again in a subsequent year.
- *Anguilla vulgaris* inhabiting coastal streams of British isles and continental Europe move to Sargasso sea.
- Other species of fishes also migrate regularly to spawning areas but their movements are not spectacular.
- Variation in migratory behaviour is also observed in between the organisms of some sp. and even the same population.
- *Lampetra japonica* (arctic lamprey) of freshwater migrate to the sea while others of similar type live in fresh water only.
- Similarly sockage also grows and matures in only fresh water.

2.2.2.6 Physiological changes

- Accumulation of fat is seen in herrings, salmons and eels which conduct long migrations.
- Olfaction plays an important role in the orientation of fishes during migration. It is observed that the imprint of the odor of the home stream in the fish fry help in their return to reach the original abode. The memory of the odor is retained for several years and it serves as a guide against the water currents of sea to reach the fresh water zones.
- Wisby and Hasler (1954) demonstrated the remarkable guiding system in silver salmon (*Oncorhynchus kisutch*). Even bokanee salmon (*Oncorhynchus nerka*), a fish exhibiting catadromous migration leave lakes and move into their home streams to spawn making use of olfaction.
- Other factors having role in migration are light and swift current. Young ones of the sock eye salmon use polarized light and twilight.
- Arthur and Habler proved that sun compass orientation is used as guidance by white bass (*Roccus chrysops*) during migration.
- Water current seem to play an important role in the migration of European eel (*Anguilla vulgaris*) and American eel (*Anguilla rostrata*).

- Fishes attain a maximum speed of 10 times and a minimum speed of 3 times of its body length during migration.

2.2.2.7 Hazards of migration

- Hazards during migration are of both natural and man made.
- Natural enemies are the predators like gulls, cormorants, eagles, bears and man. Dams, pumping stations and pollution are posing great man made threat to the migrant fishes.

2.2.2.8 Methods of Study

Migration routes are accurately worked out using bands, removal of adipose fin, injection of a microtag having information into the nasal cartilage by an electronically operated hypodermic needle and sonar system.

2.2.3. Parental Care in Fishes

2.2.3.1 Introduction

- Care taken by the adult organisms in protecting their eggs and young ones forms the concept of parental care. The process of growth starts with the fertilization of the ovum and continues from birth to maturity.
- The parent offspring relationship varies greatly in vertebrate organisms.
- Parental care is lacking in many of the fish sp. There are certain fish sp. exhibiting care to their eggs and young ones basing on the dependence of these stages on their parent individuals.
- Fishes are mostly oviparous except sharks and the related sp. which are viviparous in their nature.
- Fishes showing parental care adapt diversified methods to protect their progeny till they become independent and lead free swimming life.

Fishes lay eggs either in water or in places which are kept wet by wave action. Some fishes lay eggs of low specific gravity and hence they float (pelagic). Certain others lay eggs of higher specific gravity and hence they sink. Such eggs are called the demersal eggs. These eggs are laid at the bottom. They possess a sticky outer coat that helps in adhesion to objects or to each other.

2.2.3.2 Types of parental care: It is mainly of two types

(a) by constructing nests, (b) without constructing nests

(a) **By constructing nests:** Here eggs are released in lesser number.

Eg: Stickle back (100 eggs) and Seahorse – 100-400 eggs

- Salmon ensheaths eggs in a tough permeable membrane called chorion. These ensheathed eggs are laid in grooves or sand made by females. Then the grooves are covered by pebbles.
- Some starks lay eggs surrounded by both albumen and shells.

- Amia lays eggs in the circular nests constructed between water plants.
- *Labeo* constructs nests using corals and shells.
- *Gambia* constructs nests with the help of grass in shallow water zones.
- *Gasterosteus* constructs an elaborate nests with grass needles. Males guard the nests.
- Floating nests are constructed with the help of buccal secretions by males of gowrami (*Trichogaster trichopterus*) *macropodus, polyacanthus* etc. These secretions are released in the form of gas bubbles where eggs are laid by the female. Males protect the eggs caught in air bubbles.
- Lingcod (*Ophiodon elongatus*) deposits eggs in adhesive masses located in between rocks below the low tide level. Males take utmost care of the eggs and protect them.
- *Pimephalas notatus*, a blunt nosed minnow lays eggs under stones or other objects to be protected by males.
- Males of small mouth bass (*Micropterus dolomi*) and large size bass (*M. salmoides*) construct a circular nest by digging the soil with their tails in which female lay egs. Males takes up the responsibility of guarding the eggs.
- Male sand goby (*Gobus minutris*) not only guard the eggs but also aerates with the help of its movements.
- Lampreys bury their eggs in gravel.
- Killi fishes of South America and Africa lay tough coated eggs during the periods of drought. They can survive in the mud till rainy season returns.

b) Parental care without constructing nests

- Several families of fishes are known to be mouth-breeders. Here one or both the parents incubate the eggs in their mouths as seen in *Arius* where males keep the eggs in their mouth till they hatch. Similarly male jaw fish (*Opisthognathus*) protect the eggs laid in mouth.
- Bitterling (*Rodeus amarus*) lays eggs in the siphon of a mussel. For this, females develop an elongated tubular ovipositor during breeding season under the influence of hormones.
- Some fishes carry the eggs either on the underside of their body or tail. These eggs are enclosed in brood pouches located abdominally or subcaudally. The folds forming the pouch come together and join or stay apart. If they join, they may or may not fuse.
- Lateral abdominal folds fuse through out their length to form a brood pouch with a narrow hole in front in male sea horse (*Hippocampus* sp.).
- *Pholis* wound around the eggs and protect them till they hatch.
- Male butterfishes protect their eggs laid in rock burrows made by molluscans.
- Male *Cyclopterus* protects the eggs by driving water on to the eggs with the help of pectoral fins.

Offspring attach the males with the help of suckers and thus protected.

- Male *Mystus* develops a spongy pad on their ventral side. Eggs laid by female gets attached to the pad where they are taken care of.

2.2.4. Summary

Fishes are the oviparous aquatic vertebrates living in both fresh and marine water zones.

- Several fishes live in their natural habitat through out their life.
- Some fishes exhibit temporary migration for want of food such fishes return to their abodes.
- Some fishes migrate to far off places for feeding and breeding. They are categorised as anadromous and catadromous types as seen in anguilla and salmon fishes.
- Many fishes are oviparous. They lay eggs and leave them to their fate. But some fishes take care of their eggs and offspring to certain time. This depends upon the number of eggs laid, dependence of the youngones over one of their parents. In such cases, fishes take care of the eggs either by constructing nests in sandy or rocky bottoms or protect them by guarding and without constructing the nests as seen in *Arius, Mystus, Hippocampus* etc.

These two interesting concepts are also seen in other higher vertebrates.

2.2.5. Self assessment Questions

a) Define migration and parental care.
b) What do you understand by Anadromous and catadromous migrations? Support your answers with suitable examples.
c) How parental care can be discussed in relation to fishes?

2.2.6. Reference Books

1. **A Text Book of Zoology**, Vol. II by Parker & Haswell.
2. **A Student Text Book of Zoology**, Vol. II, Adam Sedgwick.
3. **Vertebrate Biology** by R.T. Orr.

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UNIT II

LESSON 2.3

GENERAL CHARACTERS AND CLASSIFICATION OF CLASS AMPHIBIA

INTRODUCTION: Amphibians are the first terrestrial vertebrates. They led successful life both on land and in water. **Carboniferous** age is considered as **the Golden age of Amphibians** when they raised to the peak level. Most of them became extinct because of the evolution of reptiles during mesozoic era. Their branch of study is called **Batracology**. Amphibians possess a number of common characters in general. This lesson is dealt on the following plan:

Contents:

2.3.1 OBJECTIVES:

After studying this lesson, you wold be able to

- enumerate the distinguishing characters of Amphibians
- classify the Amphibians up to sub classes giving reasons and examples
- list out the common amphibians with their scientific names

2.3.2 ORIGIN OF AMPHIBIANS:

Amphibians were considered to have evolved from devonian Osteolepids or Crossopterygian fishes. Nobel divides class Amphibia into six orders. Subsequently Parker and Haswell divided it into two sub classes viz., Aspido spondyli having order Anura and Lepospondyli having orders Urodela and Apoda. These three orders had diphyletic origin. Recent investigations proved that these three orders had only monophyletic origin (Romer in his book The Vertebrate body). Hence the class Amphibia is divided into three sub classes viz., Aspidospondyli and Lepospondyli with extinct organisms and Lissamphibia with extant organisms.

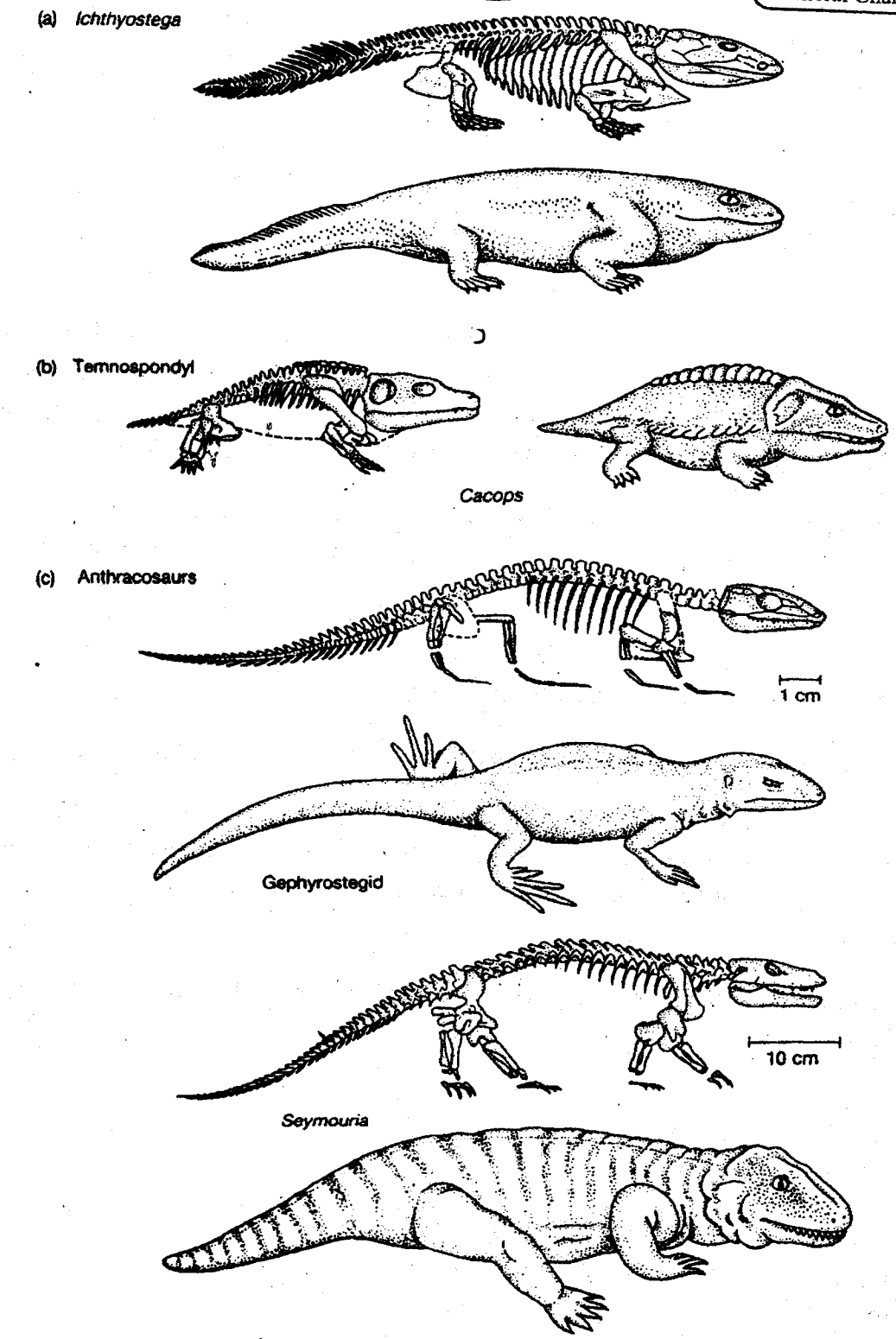


Fig. 2.11 Early amphibians : skeletons and restorations. (a) Devonian *Ichthyostega.* the earliest known labyrinthodont. with fish like scales and a caudal fin supported by fin rays. (b) *cacops,* a Permian temnospondylid labyrinthodont. (c) Reptile like anthracosaurs: a Carboniferous gephyrostegid and the Permian *Seymouria.*

2.3.3 GENERAL CHARACTERS:

1. Amphibians are the first tetrapod vertebrates which moved into the terrestrial conditions and led successful life both on land and in water

2. They enter water at least once in their life time for reproduction

3. Poikilothermous anamniote organisms changing their body temperature in relation to the environment

4. Skin is moist and slimy due to mucous glands. In toads poison glands are present in the skin for protection. There are no exoskeletal structures except in gymnophiana where tiny scales are embedded in the skin. This helps in cutaneous respiration during aquatic life. Generally adults respire by lungs while larvae by gills. Gills may also be seen in some adults.

5. The paired pectoral and pelvic fins of fishes have modified to fore and hind limbs for locomotion both on land and in water. These are pentadactyle and flexible due to joints causing easy movements

6. External nostrils open into the buccal cavity through the internal nostrils. Hence for pulmonary respiration enters the lungs through these openings.

7. Fins are absent and if present as seen in larvae, they are not supported by fin rays.

8. Eyes are accommodative and can function in both the environments to see the objects. A transparent third eyelid namely the nictitating membrane covers the eyeball and gives protection while in water. Harderian gland is formed in place of reduced lachrymal glands to secrete tears and oily fluids.

9. External ears are absent and their place is occupied by stretched tympanic membranes. Middle ear is present only in anurans with columellauris to transfer the sound vibrations to the internal ear. Eustachian tubes connect the pharyngeal cavity with the auditory cavity.

10. Anteriorly attached, movable, sticky tongues helps in food collection. Maxillary and vomerine teeth prevent the prey from escape.

11. Alimentary canal is short and is well suited for their carnivorous habit. Oesophagus is lacking because of the absence of neck. Neither the system has salivary glands nor the oesophageal glands.

12. Blood vascular system consists of a tri-chambered heart having two auricles and one ventricle. Only one pacemaker called sinuauricular node regulates heartbeat. RBC is nucleated, oval and

biconvex. Three pairs of aortic arches from the heart distribute blood to different parts of the body. Circulation is of incomplete double circulation. Portal system is well developed.

13. Brain is well developed with slightly large cerebrum, small cerebellum. A pineal body is present in all amphibians except in anurans where pineal organ or parietal body is seen. Bony cranial box protects it. Ten pairs of cranial nerves arising from brain and spinal nerves from spinal cord innervate various organs of the body.

14. Jacobson's organ or vomeronasal body is formed for the first time from the nasal canal. It is lined by olfactory epithelium to smell the taste.

15. Kidneys are mesonephric and excrete mostly urea and hence are ureotelic. Urinary bladder develops from the ventral side of the cloacal wall. Digestive and urinogenital systems open into cloaca.

16. Unisexual and sexually dimorphic. Males possess copulatory structures in apoda. Archinephric ducts help in transporting the sperm cells to cloaca. Oviparous organisms with external fertilization and development. Life history is indirect involving a fish like larva.

17. Internal skeleton is made of bones. Skull is dicondylic with autostylic jaw suspensorium. Hyomandibular arch of teleost fishes breaks up to form mandibular of lower jaw and columella auris of internal ear. Cranium is flat with reduced number of bones as seen mainly in salientia. Palate is absent and hence internal nostrils are anteriorly located in buccal cavity.

18. Vertebrae are procoelous or of amphicoelous types. Tail vertebrae are seen in caudates and cicilians. Number of vertebrae varies from 10 to 200.

19. Pectoral pelvic girdles support fore and hind limbs.

20. Sternum is flat. It appears for the first time in these organisms.

21. Hyomandibular arch of fishes is modified into columella auris in the middle ear to transfer sound vibrations.

22. Muscular system is specially organized. Thoracic muscles exhibit metamerism. Limb muscles are well developed to help in locomotion.

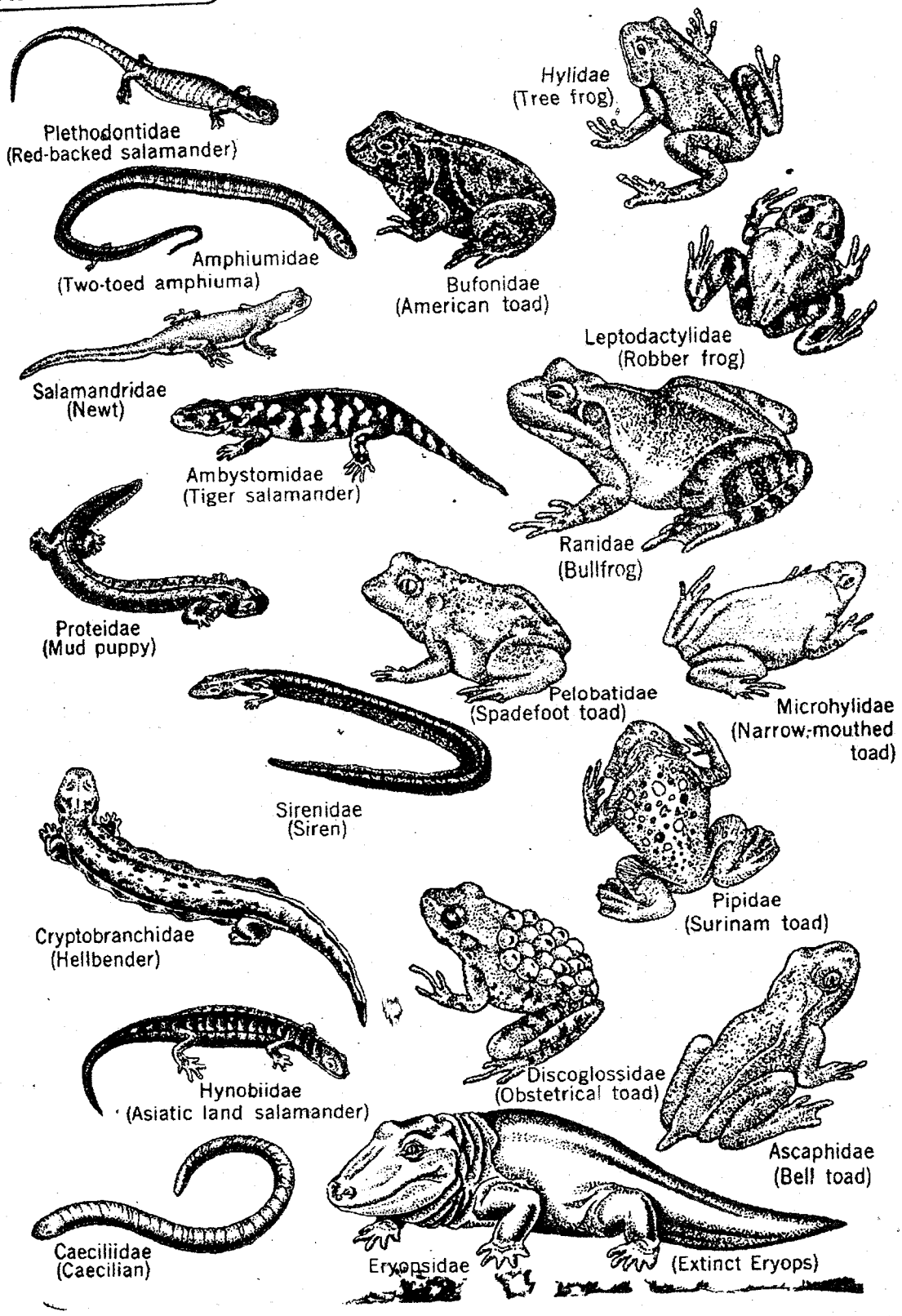


Fig. 2.12 Some orders and families of amphibians

2.3.4 Classification of Class Amphibia having extant organisms is given hereunder.

Class AMPHIBIA (Divided into three sub classes by Parker and Haswell)

Sub. class 1. Aspidspondyli: Extinct organisms originated from crossopterygian fishes. It includes one Super order 1. Labrynthodontia or Stegocephalia having five orders viz.,

Order i. Ichthyostegalia with first organisms having labrynthodont dentition

Ex: *Ichthyostega, Ichthyostegapsis*

Order ii. Rachitomi with rachitomous vertebrae

Ex: *Eryops* and *Cacops*

Order iii. Stereospondyli having organisms evolved from Rachitomes

Ex: *Capitosaurus, Cyclotosaurus,* and *Paracyclotosaurus*

Order iv. Embolomeri having resembling osteolepid fishes

Ex: *Palaeogyrinus*

Order v. Seymouriomorpha with organisms evolved later into reptiles.

Super order Salientia with three orders viz., Proanura, eoanura (Extinct) and Anura (Extant)

Sub class II. Lepospondyli: Organisms having centrum of the vertebrae directly formed from embryonic notochord. They appeared during carboniferous period and disappeared in Permian period. This includes three orders.

Order i. Aistopoda: Carboniferous small snake like creatures. Ex: Ophiderpaton

Order ii. Phyllospondyli. Organisms resemble the larval forms of Labrynthodonts

EX: *Bronchiosaurus*

Order iii. Nectridia: Lived during later part of carboniferous period having lepospondylian vertebrae and showing similarities with Labrynthodonts.

Ex: *Sauroplura, Ciplocaulus.*

Order iv. Microsauria or Adelospondyli:Permian urodeles with incomplete roof in the skull and subsequently evolved into modern urodeles. Ex. *Lysorophus.*

Order v. Urodela (Caudata) and order Apoda(Gymnophiana or caecilia) having living organisms.

According to Romer, the living amphibians are included in one sub class viz., Lissamphibia.

Sub Class III. LISSAMPHIBIA: All living modern amphibians of carboniferous age to the present are included in three Orders namely Apoda, Anura and Urodela or Caudata.

The characters and classification are dealt in detail .

Extant Groups:

Order i. Apoda or Gymnophiana popularly representing the apodus amphibians called caecililans or blind worms or naked snakes with or without tail.

a. Distributed in tropical and sub tropical parts of the world.
b. Limb and tail less fossorial amphibians mostly living near burrows and canals.
c. Minute and granular cycloid scales are embedded in the skin
d. Eyes are non functional and reduced
e. Tympanum and middle ears are absent.
f. Jaws are toothed and ribs are flexible. Skull has a bony roof.
g. Vertebrae are amphicoelous. Absence of girdles, limbs and sternum.
h. Kidneys and lungs are assymmetrical
i. Ductus botalli connecting systemic and pulmonary arches.
j. Males have eversible cloaca serving as copulatory structure.
k. Fertilization is internal and parental care is seen where females take care of eggs. Larval forms are the eel elvers.

Ex: *Ichthyophis glutinosa*(Karnattaka and Malabar)
Gegenophis carnosis (Travancore and Malabar)
Ureotyphlus minomi (Cochin and Malabar)

Order ii. Urodela or Caudata:

a. Tailed amphibians with head, neck, trunk and tail and living in marshy places. Laterally compressed tail may help in swimming also.
b. Jaws are toothed . Vertebrae are amphicoelous in newts and opisthocoelous in salamanders. They lack both external and middle ears.
c. Limbs are equal in size and in some they are weak or degenerated
d. Presence of ductus botalli or ductus arteriosus
e. Respiration is by skin since lungs are absent.
f. Widely distributed in North America, Europe and South Africa
g. Axolotl larva of salamanders shows neoteny or paedogenesis where the larval forms reproduce by sexual method.

Ex: *Ambystoma, Amphiuma, Salamander, Tilototriton, Siren,* and ***Proteus***

Order iii. Anura or Salientia or Batrachia:

a. Tail less amphibians commonly called as frogs and toads
b. Skull is wide and flat while mouth is a wide gape.

c. Hind limbs are longer than fore limbs and locomotion is by leaping movements. Body is divided into head and trunk. Neck and tail are absent
d. Vertebrae are procoelous with posterior ones fused to form urostyle
e. Possess smallest number of vertebrae among all the vertebrates
f. Presence of annulus tympanicus, a ring cartilage supporting tympanic membrane is the characteristic feature of anurans. Middle and internal ears are well represented.
g. Lungs, Buccal cavity and Skin help in respiration except in toads.
h. Ductus botalli is absent.
i. Unisexual, sexually dimorphic and indirect dc pment involving a free swimming tadpole larva in the life history.
j. Oviparous and carnivorous organisms with external fertilization and development.

2.3.5 COMMON AMPHIBIANS

General name	*Scientific name*	Order
Oldest Fossil frog	*Triadobatrachus*	Anura
Bull dog	*Rana esculenta*	..do..
Toad	*Bufo melanosticus*	..do..
Mid wife toad	*Alytes*	..do..
Arboreal frog	*Hyla arborea*	..do..
Flying /chunam frog	*Racophorus malabaricus*	..do..
Burrowing frog	*Cacopus callula*	..do..
Water/tiger frog	*Rana tigrina*	..do..
Fire bellied frog	*Bombinator*	..do..
American frog	*Pipa americana*	..do..
Marsupial toad	*Nototrema marsupium*	..do.
Aftrican toad	*Xenodus*	..do..
Tingling frog	*Ixalus*	..do..
Viviparous frog	*Dermophilis*	..do..
Mudpuppy	*Necturus*	Urodela or caudata
Newt	*Triturus*	..do..
Indian urodele	*Tilototriton himalyances*	..do..
Fire salamander	*Salamander atra*	..do..
Uropean ohm	*Proteus*	..do..
Congo eel	*Amphiuma*	..do..
Mud eel	*Siren eel*	..do..

Tiger salamander	*Ambystoma tigrinum*	..do..
Giant salamander	*Cryptobranchus*	..do..
Longest salamander	*Dicamptodus*	..do..
Lungless urodele	*Desmognathus fuscus*	..do..
Viviparous urodela	*Salamander atra*	..do..
Cicilians or blind worms	*Ichtyophis glutinosa*	Apoda
	Gegenophis cornosus	..do..
	Ureotyphlus minami	..do..
Viviparous cicilian	*Typhlonectus*	..do..
Fossil salamander	*Branchiosaurus*	Phyllospondyli
Fossil frog	*Eryops, Cocops*	Labrynthodontia

2.3.6 Summary:

The discussed topics of this lesson are the origin, general characters and classification of Amphibians. These are the first tetrapod vertebrates moved to land during devonian period. They took their origin from poikilothermous Osteolepids, which had neither scales nor lungs. First organisms having the sternum and trichambered heart with incomplete double circulation.

Common and scientific names of common amphibians are listed.

2.3.7 Self Assessment Questions:

a. Discuss the origin and outline classification of Class Amphibia.
b. Enumerate the general characters of Amphibia.
c. Give a detailed account on the classification of Amphibia with suitable diagrams.
d. List out any three scientific names of important organisms from each of the orders of lissamphibia.

2.3.8 Reference Books:

1. A Textbook of Zoology by Parker & Haswell. Vol. II
2. Student's text book of Zoology by Sedgwick
3. Vertebrate Biology by Robert T Orr
4. Vertebrate Zoology by Nigam
5. Theory and problems of Zoology by Nancy M. Jessop

T II

LESSON 2.4

GENERAL CHARACTERS AND CLASSIFICATION OF REPTILES

RODUCTION: Reptiles are the first true landed, pentadactyle tetrapods leading their life to- in terrestrial environment. Some of them have migrated in to aquatic environment and developed al of the secondary adaptations. Sturdy limbs to bear huge body; dry and scaly skin to conserve r; lungs for pulmonary respiration; extra embryonic membranes for protection of the embryo g development are the important features of reptilean evolution.

Since these are creeping organisms, their branch of study is called Herpetology. Reptiles pos- a number of common characters in general. This lesson is dealt on the following plan:

tents:

1 **Objectives**
2 **Origin of Reptiles**
3 **General characters of Reptiles.**
4 **Classification of Reptiles**
5 **Common Reptiles**
6 **Summary**
7 **Self assessment questions**
8 **Reference Book**

OBJECTIVES:

studying this lesson, you should be able to

- Appreciate the evolution of reptiles as successful terrestrial organisms
- Understand the origin, supremacy and extinction of gigantic reptiles viz., the dinosaurs during mesozoic era
- Enumerate the general characters of reptiles
- Classify the living reptiles upto order level
- List out the scientific names of commonly seen reptiles.

2.4.2 ORIGIN OF REPTILES:

- Reptiles have evolved from amphibians during permian period.
- Mesozoic reptiles in heavy number grown to greatest size.
- The giant reptiles of this era viz., dinosaurs weighed hundreds of tons and measured more than 100 ft.

- They occupied all the three environs and showed supremacy over other land living organisms during mesozoic era.
- Geological and biological factors at the close of mesozoic era and their enormous size are the the two main reasons for their extinction.
- Subsequently the changed environmental conditions forced reptiles to evolve into birds on one side and mammals on the others side.
- Mesozoic era is described as the Golden age of reptiles.

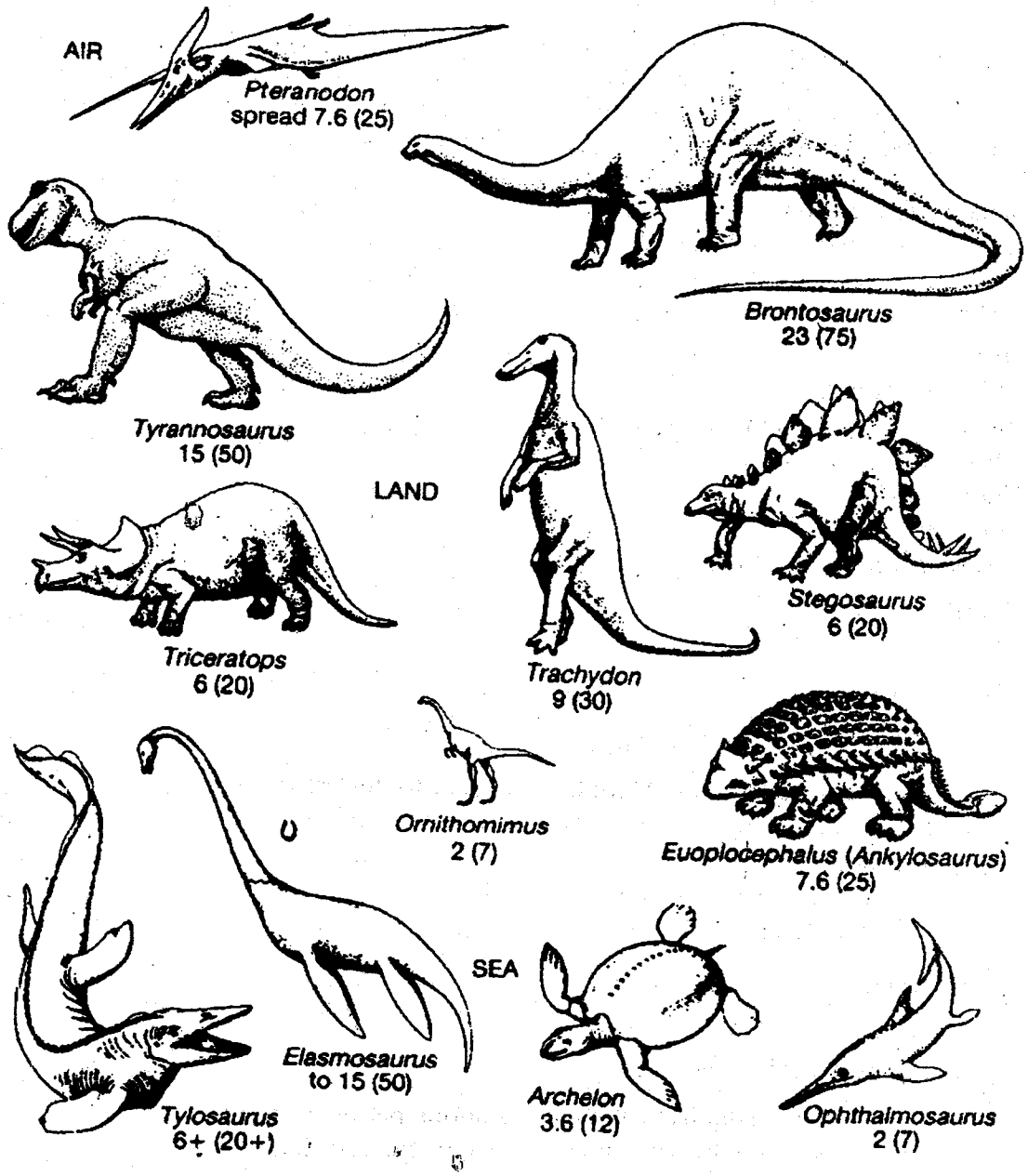


Fig. 2.13 Mesozoic Extinct Reptiles

2.4.3 GENERAL CHARACTERS OF REPTILES:

1. Reptiles are the creeping tetrapods with powerful claws a the tips of fingers
2. Body is divided into a head, a neck, a trunk and a tail.
3. Skin is dry and has no glands. It is covered with epidermal scales, scutes and plates constituting the exoskeleton. These structures protect their body from environmental pressures besides conserving water from transpiration.
4. Limbs are pentadactyle ending in claws to help in creeping. Limb less reptiles is the snakes and some lizards.
5. Mouth is anteroventral. It is a wide gape with toothed jaws. Teeth are homodont and thecodont. Tongue is movable and bifid in snakes. It is entire and shows slight movements in other reptiles
6. Eyes are lateral with upper and lower eyelids. Eyelids are fused and transparent in snakes. Nictitating membrane is also seen
7. Tympanic membrane is present. External ear pinnae are absent. It is represented by external auditory meatus. Middle ear has a long bone viz., extra columella. Inner ear has a lagena with more number of acoustic cells.
8. Monocondylic skull with temporal fossae.
9. Heart with partially divided ventricle is present. Ventricle is completely divided in crocodiles.
10. Truncus arteriosus is absent. The three arterial branches viz., one pulmonary and two systernics arise directly from ventricle.
11. Blood with nucleated, biconvex and oval red blood corpuscles flows in blood vascular system.
12. Respiration is by lungs since these animals are terrestrial. Cloacal respiration is found in chelonians.
13. Brain has a pair of pedunculate olfactory lobes, enlarged cerebral hemispheres and gives off 12 pairs of cranial nerves except in snakes where only 10 pairs are present.
14. Poikilothermous organisms since they are capable of changing their body temperature in relation to the environment.
15. Metanephric kidneys excrete uric acid and hence are uricotelic.
16. Unisexual but sexual dimorphism is not clear
17. Males have a pair of male genital organs called hemipenes and are the expanded skin of cloaca.
18. Fertilization is internal but development is external and direct as they are oviparous and lay shelled eggs. Eggs are laid in crevices, corners, under the stones and in sand. Eggs are macrotelolecithal. Sufficient amount of yolk is stored in the eggs as the entire development occurs inside the egg.
19. Amnion, serosa, yolksac and allontois are the four extra embryonic membranes formed during the development of the embryo. Of these, Amnion is meant for protection as the amniotic fluid prevents the embryo from mechanical shocks.

20. Clavicles and inter clavicles unite to form a 'T' shaped bone in front of the sternum which is rhomboidal. It is absent in snakes.
21. In turtles, a bony box formed of a dorsal carapase and a ventral plastron covers body.
22. Limb bones are sturdy. Digits end in powerful claws helping in creeping.
23. Neck possesses several vertebrae of which first one is the atlas and second one is the axis. Sacrum with 2-5 vertebrae.
24. Skull has cavities viz., temporal fossae.

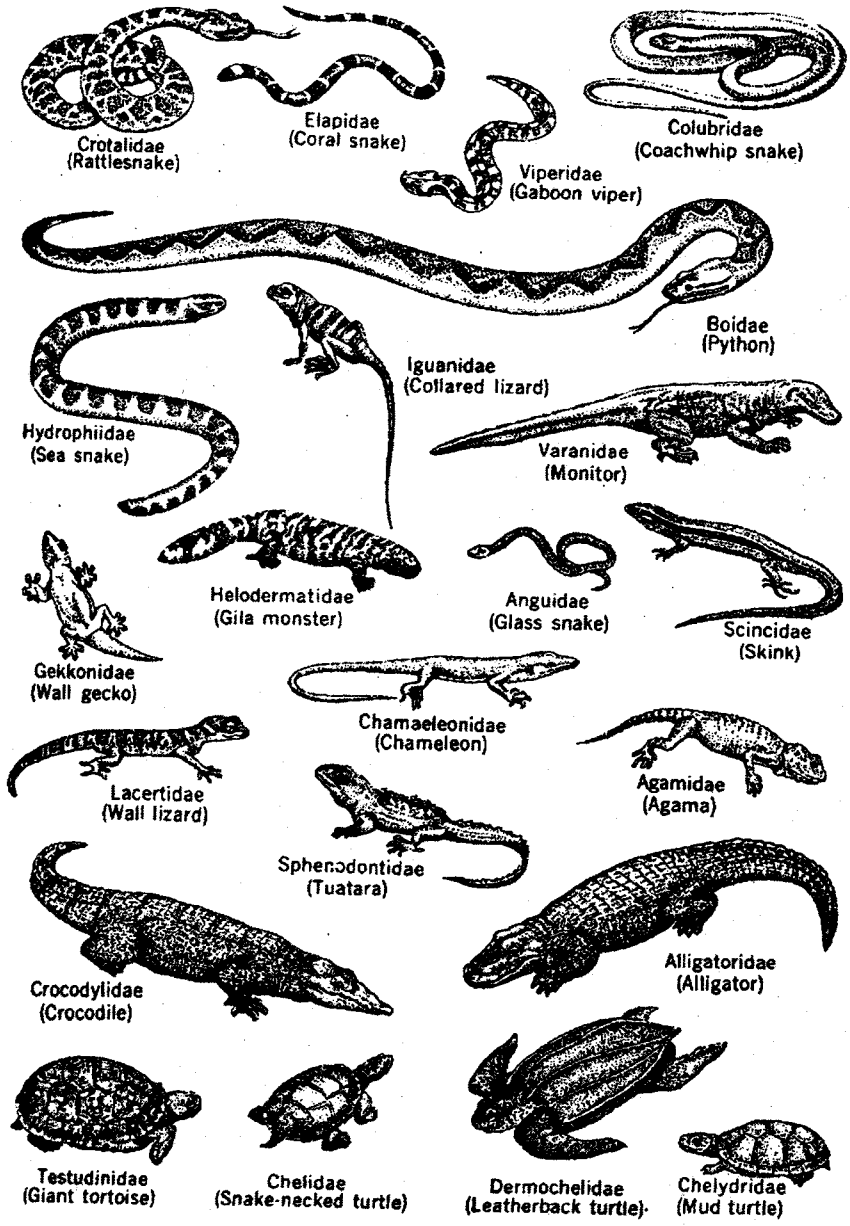


Fig. 2.14 Representatives of Extant Reptiles

2.4.4CLASSIFICATION:

The outline classification of the Reptiles is given here under.

Class reptilia is divided into six sub classes each of which is further divided in to orders.

Sub class i. **Anapsida** having two orders viz., Cotylosauria- having extinct organisms.
And Order **Chelonia** - Ex: Turtles, Tortoises and Terrapins (living)

Sub class ii **Ichthyopterygia** having two orders viz., Mesosauria and Ichthyosauria (all extinct organisms).

Sub class iii **Synaptosauria** having two orders viz., Protosauria and Sauropterygia (all extinct organisms).

Sub class iv **Lepidosauria** having two orders viz., Eosauchia (all extinct organisms) and Rhynchocephalia and Squamata (Living organisms)

Sub class v Archosauria having five orders viz., Thecodontia, Plerosauria, Saurischia, Ornithischia (all extinct organisms) and Crocodilia or Loricata (Living organisms)

Sub class vi. **Synapsida** having three orders viz., Pelycosauria, Therapsida and Ictidosauria (all extinct organisms).

Classification of extant or living reptiles:

All living reptiles are divided into four orders.

Order **Chelonia**:

i. Fresh water living turtles, terrestrial tortoises and marine terrapins belong to this order. They didn't under go any changes since their origin in triassic.

ii. The organisms are enclosed in an armor case composed of inner bone and outer keratinous sheath. It consists of a dorsal carapace and ventral plastron.
   i. Skull has no temporal fossae but a temporal notch for the attachment of jaw muscles exists. Hence it is of anapsid type.
   ii. Trunk has only 10 vertebrae. Ribs are tightly fused to the carapace.
   iii. Teeth less jaws are covered by keratinous sheath called rhampothca.
   iv. Males have a true cloacal penis. Females construct nests for laying eggs.
   v. In aquatic chelonians, limbs are modified into paddles for swimming

   Ex: *Dermochelys, Chelone mydas,* and *Testudo elegans.*

Order **Squamata**:

i. Terrestrial creeping reptiles of common occurrence

ii. Skull has two pairs of temporal fossae and hence is of diapsid type.

iii. Body is covered with scutes and plates.

iv. Teeth are homodont , thecodont and pointed

v. Males possess a pair of copulatory structures called hemipenes.

This order is divided into two sub orders viz.,

a. Lacertelia having lizards with pentadactyle limbs, clawed digits, movable eyelids, tympanic membranes. Ex: *Calotes, Chamelion, Heloderma, Varanus, Mabuya, Hemidactylus.*

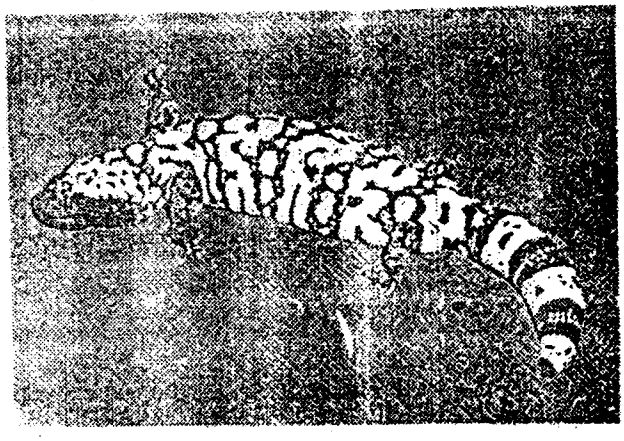


Fig. 2.15 Poisonous Lizard - *Heloderma*

b. **Ophidia** having Snakes with long rope like body without limbs, sternum, eyelids, tympanums; body covered with scales and plates; salivary glands modified into poison glands, maxillary teeth into fangs in poisonous snakes; bifid tongue etc., Ex: Cobra, Krait, Viper, Seasnake, Phoorsa, Crotalus, Callophis etc.,

Order **Rhychocephalia** (Beak head):

i. The only living fossil sp. of this order is the Sphenodon punctatum or tautara lizard.

ii. It took its origin 200 million years ago along with dinosaurs and is still seen along the shores of freshwater aqua bodies in Newzealand.

iii. Nocturnal organisms feeding on insects and possess a penial eye.

iv. Vertebrae are amphicoelous while quadrate is fixed in the upper jaw.

v. Males have no copulatory structures.

vi. Skull is of diapsid type.

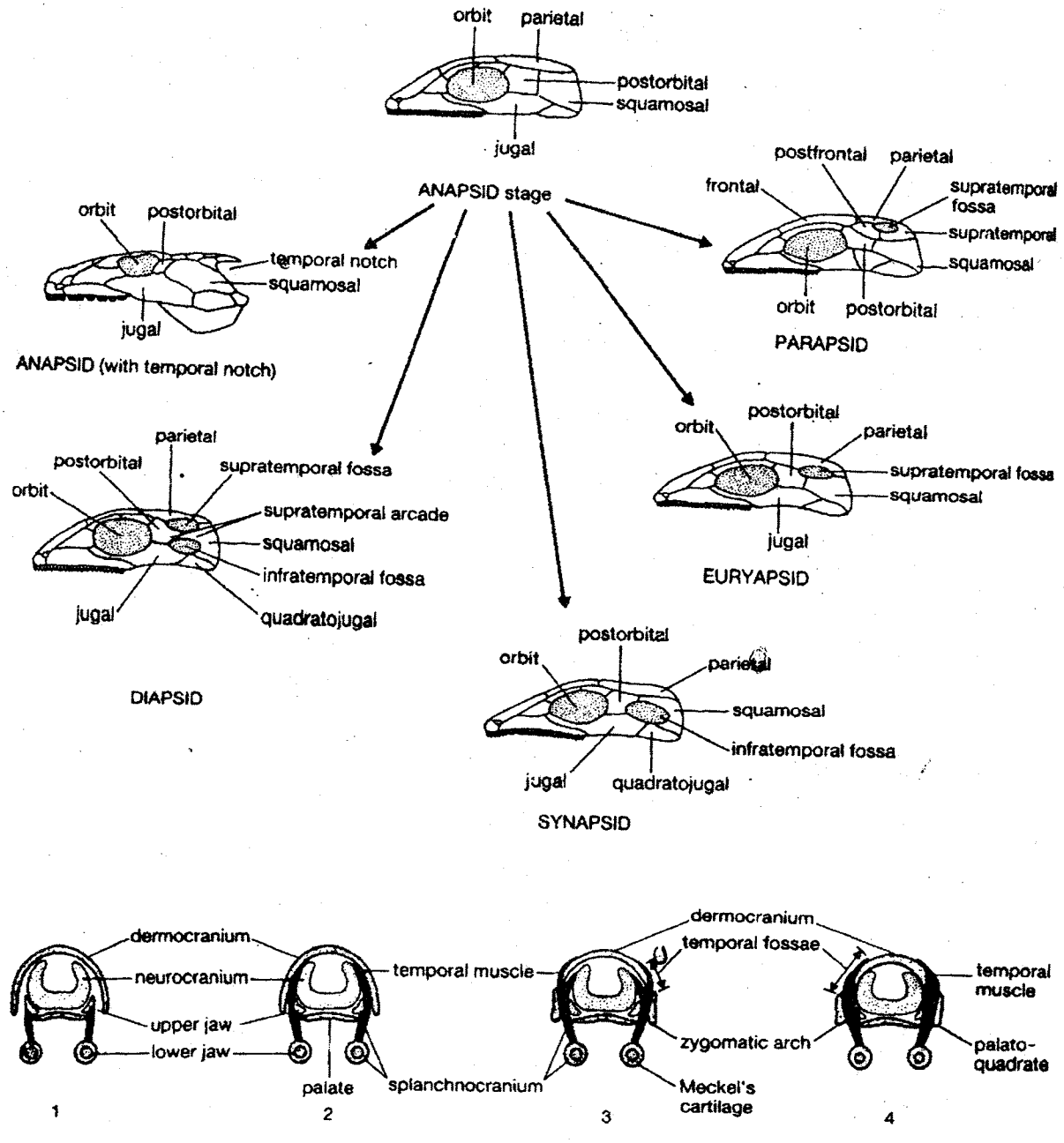


Fig. 2.16 Evolution of temporal fossae in reptiles. One or two pairs of large openings in the temporal region of the skull appeared independently in several reptilian lineages, allowing the temporal muscles that clench the jaws to pass out onto the exterior of the dermocranium and become anchored there. This permitted these muscles to expand resulting in a more powerful crushing action during mastication.

Order Crocodilia:

i. Largest organisms of the class reptilia.
ii. Head is long and jaws are toothed
iii. Teeth are of homodont and thecodont.
iv. Tail is long and laterally compressed helping particularly in swimming
v. Limbs are strong, pentadactyle and fingers end in claws.
vi. Bony plates and warts cover dorsal side of the body.
vii. Thoracic and abdominal cavities are divided by means of a muscular diaphragm.
viii. Heart is a four chambered one with arterial and venous circulation's
ix. Nostrils located at the tip of the snout are valvular and open into the pharyngeal cavity.
x. Secondary palate formed by the fusion of premaxillae, maxillae and ptrygoids separate the nasal and buccal cavities.

Ex: Crocodiles: Snout is narrow and concave, nostrils are closely placed, 15 teeth on each side of the jaw, enlarged fourth tooth of the lower jaw fitting in the notch of the upper jaw.

Gharials: Extremely narrow and slender tubular snout armed with long recurved, interlocking teeth.

Alligators: Broad and blunt snout, widely separated nostrils and enlarged fourth tooth of the lower jaw fits into the pit of the upper jaw.

Caimans : Commercially important ones as their belly skin is tanned for leather. When irritated, they inflate their belly and jump making hissing sounds.

2.4.5 Common Reptiles:

Common name	*Scientific name*	Order
Garden lizard	*Calotes versicolor*	Squamata
Flying lizard	*Draco*	..do..
Wall lizard	*Hemidactylus brooki*	..do..
Skink	*Mabuya carinata*	..do..
Limbless lizard	*Barkudia*	..do..
Monitor or comodo lizard	*Varanus monitor*	..do..
Mimicking or arboreal lizard	*Chamelion*	..do..
Gila monster	*Haloderma*	..do..
Glass snake	*Ophiosaurus*	..do..
Horned lizard	*Phrynosoma*	..do..
Cobra	*Naja naja*	..do..
King cobra or Hamadrayad	*Naja hannah*	..do..

Krait	*Bungarus coerulens*	..do..
Viper	*Russels viper*	..do..
Pit viper	*Trimerisaurus himalyancis*	..do..
Phoorsa	*Echis carinata*	..do..
Sea snake	*Enhydrina valaikadia..*	Squamata
Coral snake	*Callophis trimacularis*	..do..
Rattle snake	*Crotalus*	..do..
Green whip snake	*Dryophis*	..do..
Blind snake	*Typhlops*	..do..
Rat snake	*Ptyas*	..do..
Wolf snake	*Lycodon*	..do..
Water snake	*Tropidonotus*	..do..
Python	*Python molurus*	..do..
Pseudocobra	*Macropisthodon*	..do..
Burrowing snake	*Uropeltis*	..do..
Double headed snake	*Eryx johnii*	..do..
Mimicking snake	*Eryx conicus*	..do..
Fresh water terrapin	*Trionyx*	Chelonia
Marine green turtle	*Chelone mydas*	..do..
Terrestrial tortoise	*Testudo elegans*	..do..
Tatara lizard	*Sphenodon punctatum*	Rhychocephalia
Crocodile	*Crocodilus*	Crocodilia
Gharial	*Gavialis gangeticus*	..do..
American Crocodile	*Alligator*	..do..

2.4.6 SUMMARY: Reptiles are the creeping organisms with dry and scaly skin. These have taken their origin from amphibians. They possess skull with temporal fossae. Basing on the presence and number of temporal fossae, the class is divided into sub classes. All the living organisms are included in four orders viz., Chelonia, Squamata, Rhynchocephalia and Crocodilia. The gigantic mesozoic reptiles are the dinosaurs, which lived for 100 million years and became extinct by the end of mesozoic era because of huge body, lack of food and changed environmental conditions. Hence the era is called the golden age of reptiles.

2.4.7 SELF ASSESSMENT QUESTIONS:

i. Write a brief account on the origin and decline of gigantic reptiles

ii. Enumerate the general characters of reptiles

iii. Classify the extant reptiles to the order level giving suitable examples

iv. List out any three scientific names of important organisms from each of the orders of living reptiles.

2.4.8 REFERENCE BOOKS:

A Text Book of Zoology by Parker & Haswell. Vol. II

Vertebrate Biology by Robert T Orr

Vertebrate Zoology by Nigam

Theory and problems of Zoology by Nancy M. Jessop.

Dr. K. Kon

UNIT -II

LESSON – 2.5

POISONOUS AND NONPOISONOUS SNAKES

INTRODUCTION: Snakes are the apodus, terrestrial creeping reptiles belonging to class Reptilia, subclass Lepidosauria, order Squamata and suborder Ophidia which has 13 families and about 3000 species. About 216 species occur in India. They appeared in early cretaceous period. These are world wide in distribution except in Antarctica and Newzealand and Ireland while only non poisonous snakes are represented in Australia. Snakes are abundant in Tropical and Temperate Zones. These snakes are of both poisonous and nonpoisonous type and move mostly during nights. This lesson is dealt on the following plan:

Contents:

2.5.1 OBJECTIVES:

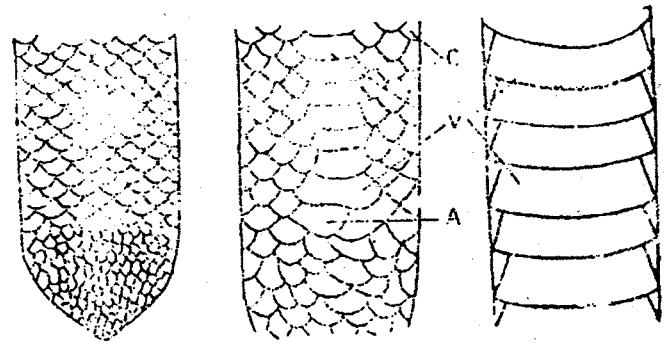
After reading this unit, you should be able to

- understand the general characters of snakes
- know the poison apparatus and the biting mechanism in snakes
- differentiate poisonous and non-poisonous snakes
- enumerate the poisonous and non poisonous snakes of India

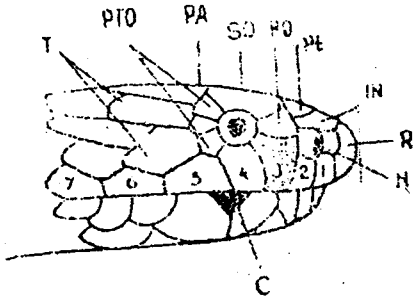
2.5.2 OPHIDIA IN GENERAL:

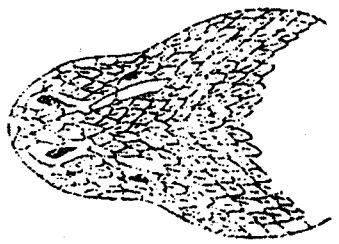
- Ophidians include the limb less reptiles famously known as serpents or snakes. However pythons have vestigial hind limbs.
- They are the terrestrial vertebrates with elongate whip like body
- They are nocturnal and creeping organisms

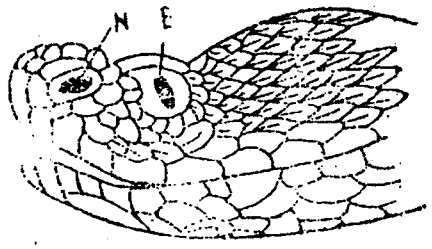
- People are scared of the snakes with the assumption that they are poisonous
- Their body is dry as there are no cutaneous glands
- Plates cover Head while ectodermal scales forming the exoskeleton cover the body. Ventral scales may be wide or small. Post anals are generally divided in poisonous snakes.
- Shed their skin periodically by moulting
- Salivary glands have modified into poison glands and the maxillary teeth into fangs in poisonous snakes.
- Eyelids are immovable. A transparent eyelid covers eyes. Pupil may be circular or vertical. Yellowish lens is seen in the vitreous chamber
- There is neither external auditory opening nor auditory meatus and tympanum. Internal ear is present which can grasp only the earth borne vibrations. Thus they cannot hear air borne sound.
- Tongue is distensible and bifid
- Olfactory function is taken over by Jacobson's organ located in the palate.
- Lungs, kidneys and gonads are asymmetrical. Left ones is reduced.
- Ribs are not complete and they help in locomotion.
- Poikilotherms with ten pairs of cranial nerves
- Optic lobes are represented as Corpora bigemina.
- Cloaca is a transverse slit.
- Unisexual but sexual dimorphism is absent.
- Males have a pair of hemipenes.
- Mostly oviparous. Viviparity is rarely seen
- Pineal body in the brain, left pulmonary artery, urinary bladder, sternum, limbs and girdles, supratemporal fossae and lachrymal bone are absent which are generally seen in lizards.
- Vertebral column has precaudal and caudal regions. Vertebrae possess paired additional articulating processes viz., zygosphenes, and zygantra besides zygapophysis.
- Monocondylic diapsid skull with great modifications.
- The two halves of the lower jaw are not united and are connected by a ligament.
- Quadrates, pterygoids, ectopterygoids and maxillae are movable in poisonous snakes. Hence they can open their mouth to any extent and swallow the food larger than their size.

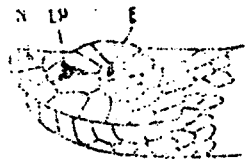


Ventral scales of snakes.
A—anal; C—costals; V—ventrals



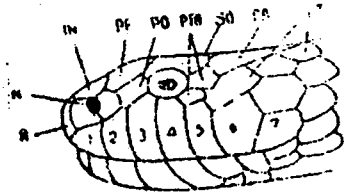


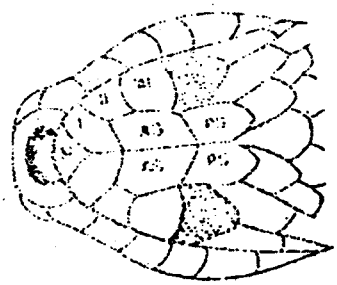


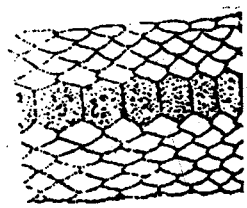


(Above)Head of the Cobra, Lateral view. (Below) Head of Russell's Viper, Lateral view.

(Above)Head of the Russyell's Viper, Dorsal view.
(Below) Head of the Pit-Viper.







Head of the Krait Lateral and Ventral view.

Trunk of the Krait showing the enlarged vertebral

Fig. 2.17 Head and tail in poisonous snakes

2.5.3 CHARACTERS OF POISONOUS and NONPOISONOUS SNAKES:

Poisonous and non poisonous snakes can be identified by examining the tail, scales, head and its shields, ventrals, subcaudals and sublabials.

a. **Round and tapering tail** ... Poisonous or non poisonous snake

Laterally compressed oar shaped tail ...Deadly poisonous sea snakes *Hydrophis* or *Enhydrina*

b. **Ventral Scales:**

Ventral scales are broad and fully extended across the body...Poisonous or non poisonous.

Ventrals are small or broad but not extended fully across the body.. Non Poisonous.

c. **Head:**

Head is covered with scales. Pupil is vertical ...Poisonous Ex: Vipers

i. Dorsal side with three rows of coloured rings; head is triangular; subcaudals are divided; poison is a haemolysin...*Russel's viper*

ii. Scales are keeled and has saw edge; arrow mark on the head and subcaudals are undivided...*Echis carinata* or Phoorsa

iii. Heat sensitive loreal pit in between nostril and eye...Pitviper.

Shields cover Head; pupil is circular..poisonous or nonpoisonous

d. **Examination of supralabials, infralabials and vertebrals:**

i. Hexagonal vertebrals on the mid dorsal side of the body; Fourth infralabial along the margin of the lower jaw is large; divided subcaudals...poisonous.

Ex. Krait -*Bungarus*

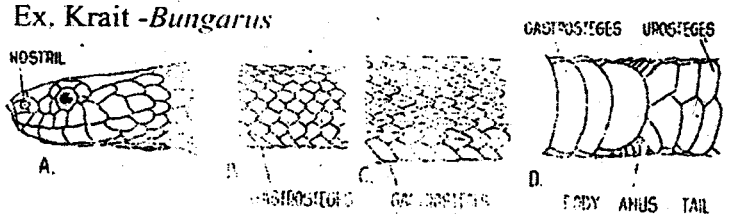


Fig. 2.18 Shields and scales of snakes.
A— shields of head ; B— unkeeled scales of trunk ; C— keeled scales of trunk; D—ventral view of the anal region showing ventrals and subcaudials (urosteges).

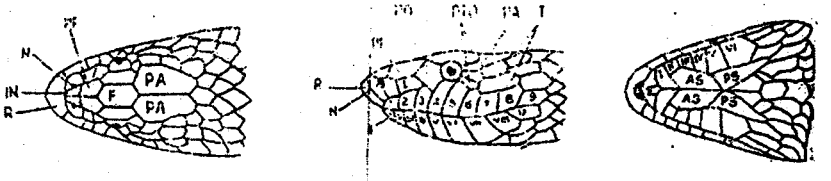


Fig. 2.19 Arrangement of the shields on the head of the Chequered Keelback. Dorsal view; Lateral view; Ventral view; AS-anterior chin shield; F-frontal; IF-Internasal; M-mental; N-nasal; PA-pariental; PF-prefrontal; PO-preocular; PS-posterior chin shields; PTO-postocular; R-rostral; T-temporal; 1-9 upper labials; 1-IX-lower labials, left shields at the sides of the frontal are the supraocculars, in-the shield above the eye is the supra-ocular.

ii. Belly is pink or red. Neck without hood. Anal shield is with cleft. Third and fourth supralabials touch eye...Coral snakes-*Callophis* and *Hemibungarus*

iii. Third supra labial is large and touches the nasal shield on one side and eye on the other side....Poisonous-Cobra

Naja naja(Cobra): Subcaudals are divided; Hood with biocellate spectacle mark on the hood: small triangular cuneate shield in between the fourth and fifth infralabials; anal shield with out cleft.

Naja hannah (King cobra): Cuneate scale is absent. Anal shield without cleft; subcaudals are in single row just behind the cloaca and divided posteriorly.

2.5.4 Poison apparatus and biting mechanism:

- Poison apparatus is well developed in poisonous snakes. It has poison glands, fangs, modified bones and muscles.
- Poison glands are the modified salivary or supralabial glands. They secrete a light yellowish fluid with concentrated proteins in the form of albumins. Cobradines are the neurotoxins acting on respiratory and nervous systems causing respiratory paralysis while the cardiotoxins or viperines act on the blood vascular system causing hemorrhage and haemolysis.
- Fangs are the modified maxillary teeth. They are pointed, grooved or perforated and erectile. They bent inwards when the mouth is closed. When mouth is opened, fangs project out at 90 and become straight.
- The movement of fangs is controlled by a number of articulating bones in the skull modified for this purpose. Each fang is attached to the maxilla. It's movement is regulated by a prefrontal. Pterygoid , quadrate and trans palatine are movable in coordinated fashion. Proximal end of the lower jaw articulates with quadrate of the upper jaw.
- Muscles helping in the opening of mouth and working of poison apparatus are

  Capitomandibularis superficialis or mandibularis constrictor or temporal muscle or masseter muscle for the movement of fangs and

  Digastric muscles for opening the mouth.

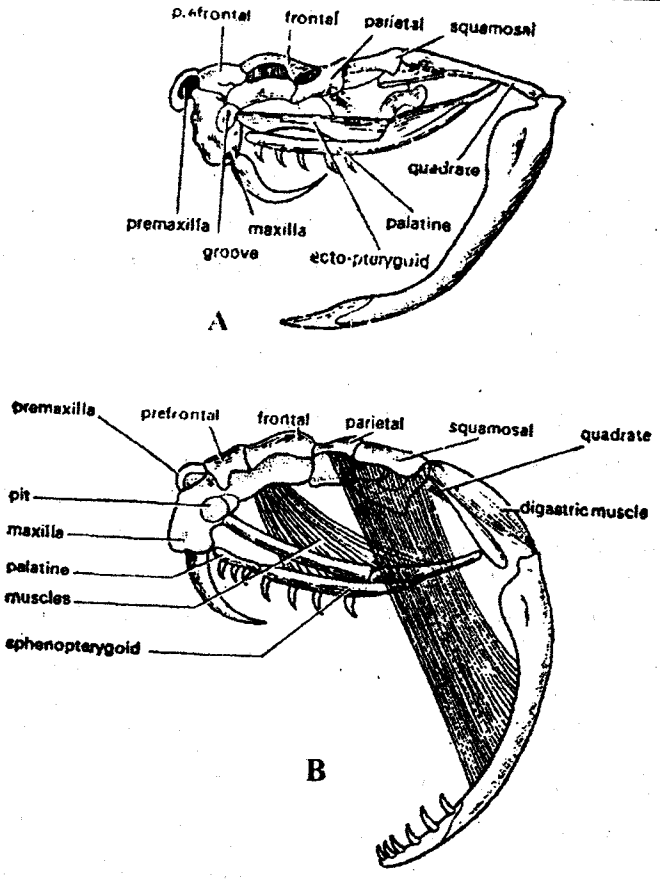


Fig. 2.20 Skull of rattle snake A) with jaws partly opened B) with its jaws fully extended

- Biting mechanism: When the mouth is opened to bite the prey, the pressure moves quadrate forward from lower jaw. As this happens, pterygoid and trans palatine and maxilla are pushed forward causing the fangs to project at an angle of 90. Sphenopterygoid or digastric muscles help in this process.
- Making a tourniquet knot above the place of bite after cleaning it; keeping the patient calm, undisturbed and unexcited; counseling the patient assuring him relief, quick recovery and bringing him out from fear and shock; carrying the patient to the nearest hospital for proper treatment with the injections of antivenin serum are the important steps involved in the first aid.
- All snake bites are not fatal. Patients die of psycological fear as the snake is not seen in most of the bites or identified as poisonous or nonpoisonous one. Hence the patient must be given first aid soon after the bite and should be taken to the nearest hospital in minimum time possible.

2.5.5 POISONOUS SNAKES OF INDIA: All snakes are not poisonous. It is a bad contention that all snakes are poisonous. Now-a-days snakes are tamed. One can identify the poisonous snake by observing the place of bite, tail and head, ventrals, subcaudals etc., when it is dead. Following are the poisonous snakes commonly seen in our country.

i. ***Naja naja:***

- It is the most common cobra living in bushy areas of open land
- Grows to a length of 6' .
- Body is gray or brown coloured one with white spots
- Active snake moving briskly on land and in bushes
- Neck expands into a hood bearing a biocellate spectacle mark on the dorsal side and two dark black spots on the ventral side
- Sub caudals are divided.
- Third supra labial touches nasal shield and eye.
- A triangular cuneate scale in between fourth and fifth sublabials
- Poison is a cobradine with a pH of 6.8 causing respiratory paralysis

ii) ***Naja or Ophiophagus hannah*** (King cobra):

- Commonly called as hamadrayad
- Longest poisonous snake growing to a length of 16' and appears in deep colours
- Cannibalistic snake eating rats
- Highly dangerous one appearing in colours.
- Builds nests for laying eggs.

iii) ***Naja naja kaouthia*** : Cobra with a round spot on the hood (monocled)

iv) ***Bangarus coerulens*** (Krait) :

- Gray snake growing to a length of 4'.
- Body with light cross bands toward anterior half and deep white bands on the posterior half of the body on the dorsal side
- Hexagonal vertebral scales on the mid dorsal side of the body
- Ventrals are wide and extend fully across the body.
- Fourth infralabial is large
- Poison is a neurotoxin and is more dangerous than cobradine

v) ***Bungarus fasciatus*** is another banded krait with dark yellow and black bands.

vi) ***Russel's viper*** :

- A sluggish snake with triangular head covered by small oblong scales
- Pupil is a vertical slit like one. Lens is yellowish.
- Head has a small white scar
- Three rows of coloured diamond marks on the dorsal side of the body
- Wide ventrals extending across the undersurface of the body

- Viviparous one laying young ones
- Poison is a viperine with a pH of 5.8 and acting on blood vascular system causing hemorrhage and haemolysis

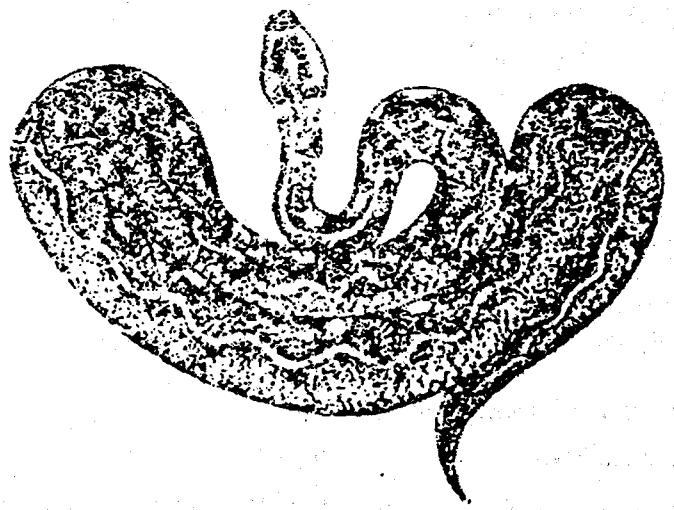


Fig. 2.21 *Echis carinata*

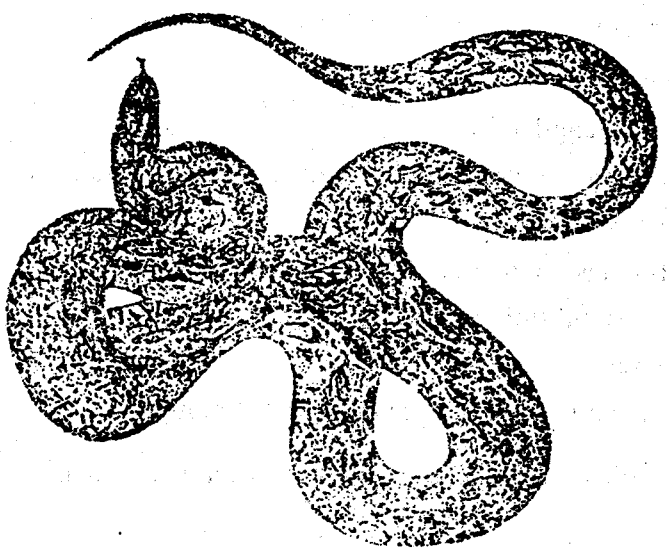


Fig. 2.22 *Vipera russelli*

vii) ***Echis carinata*** (Phoorsa):

- Reticulate viper growing to a length of 2'.
- Scales are keeled and possess saw edges
- Head bears arrow mark
- During movement, the scales produce a characteristic sound 'phoos'.

viii. ***Trimerisurus gramineus*** (pit viper): Viper with a heat sensitive loreal pit in between the nostril and eye.

ix. ***Enhydrina or Hydrophis*** (seasnakes)

- Short snakes having dark coloured body with white wavy lateral and ventral sides
- Tail is flat and leaf or oar like one to swim in water
- Body is covered with small scales while the head with shields
- Nostrils are valvular
- Highly poisonous one with viviparity.

x) ***Callophis trimaculatus***(Coral snake):

- Brightly coloured slender short (25-35cm) snakes with a blunt and black head and living in between corals. Ventral side colours pink.
- Resembles Cobra in all features except for length and absence of hood.
- Snakes are nocturnal and Poison is not fatal

2.5.6 . NONPOISONOUS SNAKES: These are identified by the presence of ventrals not extending totally across the ventral side and the absence of poison apparatus. Their bite is not fatal and one need not fear as the first aid itself relieves him from pain and fear. Following are the non poisonous snakes found in our Country.

i) ***Python molurus*** (Indian rock python) : Longest heavy bodied snake of the world with powerful constrictor muscles. It lives on the tree branches and feeds on small and big organisms. Python reticulatus is called the regal python, which is seen in Nicobar islands and is the longest snake measuring about 10 meters. It kills the warm blooded prey with its muscles. It possesses heat sensors near the nostrils. Vestiges of the hind limbs can be seen under the skin.

ii) ***Typhlops braminus***: Smallest active snake with degenerated eyes is seen under rocks and logs. It is commonly called as blind or worm snake. Tail is blunt. Scales are small and are arranged in rows on the body. It is a fossorial burrowing snake. Males are rare and the snakes reproduce by parthenogenesis

iii) ***Ptyas musosus*** : It is a long active one commonly called as rat snake. It attacks the enemies with its powerful whip like tail.

iv) ***Lycodon***: Snake resembling the krait in having cross bands. It can be differentiated from the poisonous snake by the presence of deep white bands in the anterior half and light white bands in the posterior half of the body.

v) ***Tropidonotus or Natrix***: Common water or garden snakes like striped keelback, green keelback, checkered keelback,olive keelback etc., belong to this group having dark brown body with yellowish stripes on the lateral sides of the body . It mainly feeds on frogs and fishes.

vi) ***Macroopisthodon:*** It is a non poisonous snake but produces hissing sound rising its anterior end as that of the cobra.

vii) ***Uropeltis:*** A burrowing snake with columnar body. Tail is sheathed. Eyes are large. It lays young ones and hence is a viviparous one.

viii) ***Dryophis:*** Common name is the green whip snake or tree snakes or wine snakes found on the tree branches with parrot green coloured body. It's snout is long and pointed. Nocturnal animal moving actively over branches and feeding on lizards, rats and other nocturnal animals. It is a viviparous one.

ix) ***Eryx johnii***: It is the double headed snake as it has a blunt head like tail. It can move on either direction. This burrowing snake is highly sluggish and feeds on rats and lizards.

x) ***Eryx conicus*** (Sand boa): It is a short, stout bodied, brightly coloured nocturnal snake with blotches on the dorsal side resembling that of viper. Small and similar scales cover body. Feeds on rats but the young ones feed on insects and small lizards. It is capable of changing its body colours to suit its surroundings.

2.5.7 **Summary**: Snakes are the limbless terrestrial reptiles covered with scales and shields on their body. Their skin is dry and is devoid of cutaneous glands. Their whip like body is well suited for their mode of life. All snakes are not poisonous and snake deaths are mainly due to psychological fear. Poisonous snakes possess poison apparatus. Poisonous and non poisonous snakes can be easily identified by observing the place of bite, tail and shields, scales, ventrals, head. Various poisonous and non poisonous snakes of our country are discussed at the end of the book.

2.5.8 Self Assessment Questions:

i. Enumerate important characteristics of poisonous snakes. Add a note on two important poisonous snakes?
ii. Describe the structure and mechanism of Poison apparatus in snakes
iii. What are the various poisonous snakes found in India?

2.5.9 **Reference Books**:

1. A Text Book of Zoology by Parker & Haswell. Vol. II
2. Student's text book of Zoology by Sedgwick
3. Vertebrate Biology by Robert T Orr
4. Vertebrate Zoology by Nigam
5. Theory and problems of Zoology by Nancy M. Jessop

Dr. K. Kondaiah

UNIT III

LESSON 3.1

GENERAL CHARACTERS & CLASSIFICATION OF AVES

INTRODUCTION: Aves are the first aerial vertebrates evolved from reptiles during mesozoic era of geological time scale. Modern birds have taken their birth during cretaceous period (45 million years back). These are described by Huxley as glorified reptiles. There are about 8590 species of birds living in the universe. Though the birds are mainly aerial, few exceptions can still be noted leading aquatic and terrestrial life. Their study is called ornithology. Since they fly in air and rest on trees, they have efficient flying mechanism . Birds possess a number of common characters in general. This lesson is dealt on the following plan:

Contents:

3.1.1 OBJECTIVES:

After studying this lesson, you wold be able to

- enumerate the distinguishing characters of Birds
- classify the birds up to sub classes giving reasons and examples
- list out the common birds

3.1.2 GENERAL CHARACTERS:

1. Feathered bipeds adapted for aerial life
2. Spindle shaped body with head, neck, trunk and tail
3. Skin has no cutaneous glands except uropygeal or preen gland located at cloaca
4. Jaws are elongated to form beak made of horny material called rampotheca. Jaws are teeth less, pointed and variously modified to suit their food habit and help in tearing the prey.
5. Hind limbs help in perching, running and swimming.
6. Body is covered by plumage formed of ectodermal feathers of four types viz., contour feathers and filoplumes. Down feathers are seen over the body of freshly hatched ones. Barbs, barbules and barbicels of feathers form an interlocking mechanism facilitating easy flight in air.

7. Wings are the modified forelimbs having three digits. Quills attached with wings are the quills called remiges facilitating flight. Tail quills are arranged as a fan and are called retrices. They help in deciding the direction of movement. Quills possess after shaft. Feathers possess inter locking mechanism for swift flight. Different types of feathers are associated with birds.

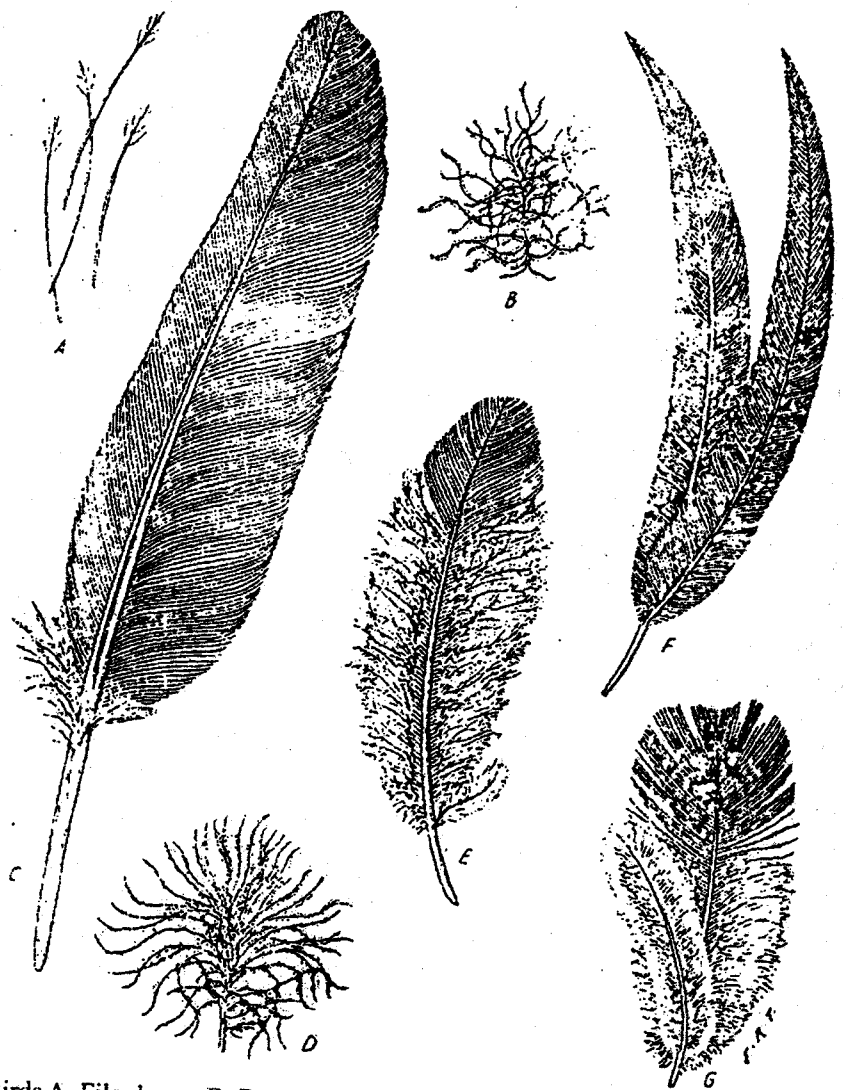


Fig. 3.1 Feathers in Birds A. Filoplumes B. Down Feathers (nestle) C. Quill D. Down feathers (adults) E. Contours F. Feaher of *Emu* G. Contour of Pheasant.

8. Hind limbs are strong, powerful and naked possessing only four clawed digits. These limbs are covered by scales and help in perching over the trees. Hind limbs are variously modified to conduct different functions in different birds.

9. Digestive system has a long oesophagus with a crop to store the food material.

10. Stomach proximally represented as a muscular proventriculus or gizzrd or a grinding mill at the end of oesophagus to grind the food material.

11. Homiothermic or warm blooded organisms with nucleated bi-convex red blood corpuscles in blood.
12. Heart is a four chambered muscular one with sinuauricular node and auriculo ventricular node as pace makers regulating its beat. Only right aortic arch arises from heart to supply blood to different parts of the body. Renal portal system is reduced. Circulation is of complete double circulation
13. Lungs are spongy and non elastic having nine air sacs reducing the density of the body. Double respiration helps in rich supply of oxygen required for the release of more energy required during flight. Alveoli are lacking.
14. Syrinx is the main sound producing organ. No vocal cords in larynx.
15. Brian is a well developed one with enlarged cerebral hemispheres and cerebellum. Reduced olfactory lobes
16. 12 pairs of cranial nerves innervating different parts of the body.
17. Eyes with acute sight are conspicuous and laterally arranged except in owls. They are protected by sclerotic oscicles arranged in the form of a ring. Eyes have an internal fan shaped structure called pecten to supply nourishment.
18. External ear pinna is absent. Internal ear has utriculus, sacculus and a slightly coiled cochlea.
19. Metanephric tri lobed kidneys excreting uric acid. Urinary bladder is absent.
20. Bones are strong and pneumatic. Skull is monocondylic and bones are totally fused leaving no suitures in the skull.
21. Vertebrae are heterocoelous or saddle shaped ones giving free movement to the neck. Presence synsacrum and pygostyle by the fusion of vertebrae, keeled sternum, 'V' shaped furcula formed by the fusion of clavicles and inter clavicles, double headed ribs with uncinate processes are some more important characters observed in fowls.
22. Pectoralis major, pectoralis minor and coraco brachialis are the three important well developed muscles attached to the sternum and wing bones facilitating flight.
23. Unisexual, sexually dimorphic and males without copulatory organs.
24. Internally, left ovary is well developed but right ovary and oviducts are either reduced or wanting. Fertilization is internal but birds are oviparous and hence development is external. Generally males incubate the macro telolecithal or megalecithal eggs. Zygotes undergo meroblastic cleavage.
25. Extra embryonic membranes like amnion, serosa, yolksac and allontois are formed during the development as protective membranes. Hence birds are called the amniotes . Birds are nidicolous or altrecious as the young ones depend upon their parents for food and other needs.

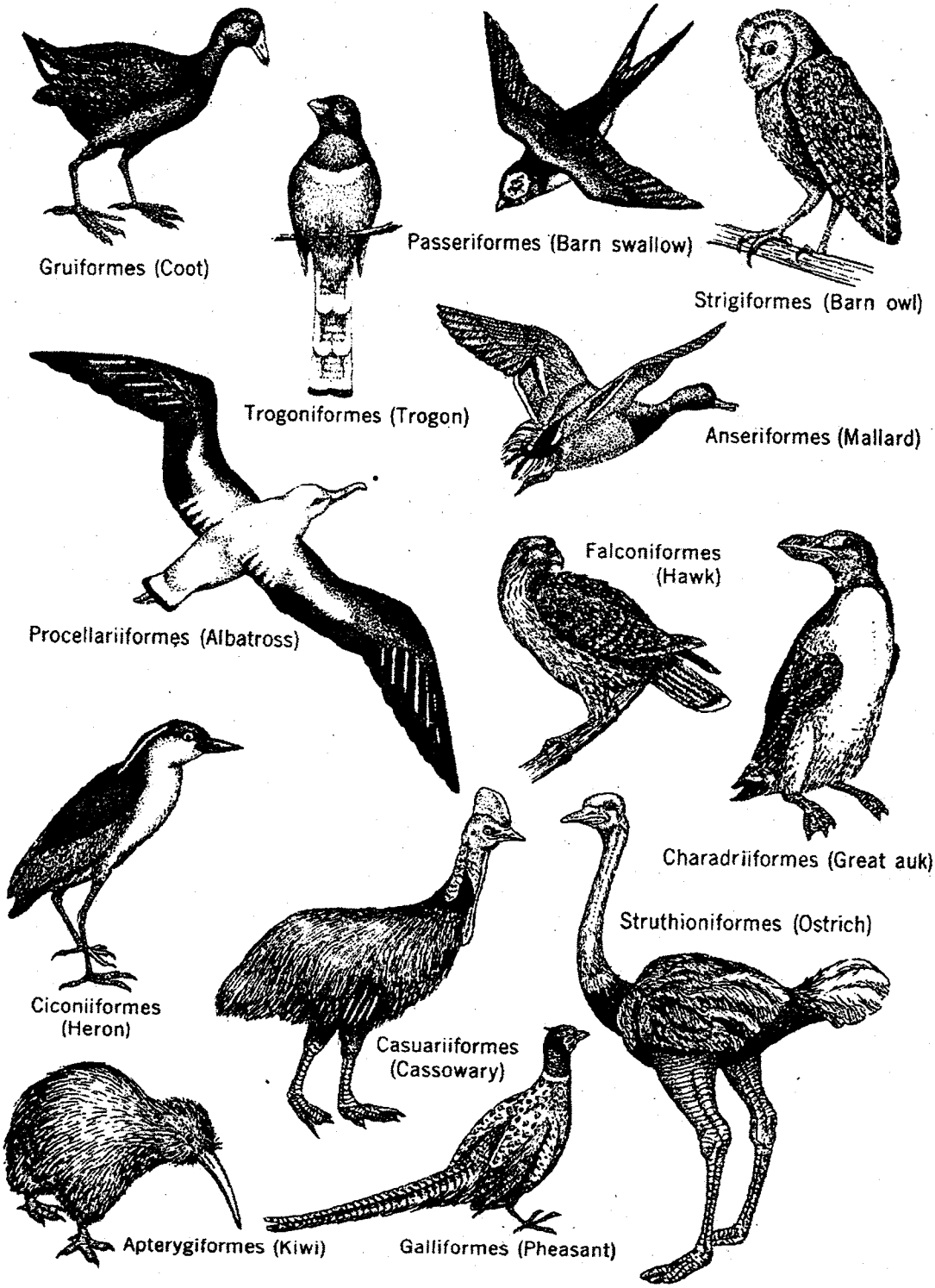


Fig. 3.2 Representatives of Class Aves.

3.1.3 Classification of Birds :

Aves is a class under **sub phylum Vertebrata** and **Phylum Chordata**. This class is divided into Two sub classes, which in turn are further classified into various super orders. The classification of **class Aves** in general can be summarized as hereunder.

Class **AVES**

Sub Class **ARCHAEORNITHES**

Order: **Archaeopterygiformes** — Ex: *Archaeopteryx lithographica*, *Archaeornis siemensi*

Sub Class **NEORNITHES**

Super Order — 1.**Odontognathae**

Orders a. **Hesperornithiformes** — Ex: *Hesperornis, Hargeria* and *Enaliornis*

b. **Ichthyornithiformes** — Ex: *Ichthyornis, Apatornis*

Super Order — 2. **Palaeognathae**:

Orders a. Struthioniformes — Ex: *Struthio camelus*(African ostrich)

b. Rheiformes — Ex: *Rhea americana*(American ostrich)

c. Casuariiformes — Ex: *Casuarius*(Cassowary), *Dromoeus*(Emu)

d. Apterygiformes — Ex: *Apteryx* (Kiwis)

e. Tinamiformes — Ex: *Eudromea elegans*, *Tinamus rhyncodon*

f. Aepyornithiformes — Ex: *Aepyornis titan*(Elephant bird)

g. Dinornithiformes — Ex: *Dinornis maximus* (Moa)

Super order — 3. **Impennae**

Order Sphenisciformes — Ex: *Aptenodytes forsteri* (Emperor penguin), *Pygoscelis adelie* (Adelie penguin)

Super order 4. Neognathae:

Orders:

i. Gaviformes — Ex: *Gavia* (Loons)

ii Columbiformes — *Columba livia* (Pigeons)

iii. Podicipitiformes — *Podiceps* (Grebs)

iv. Procellariiformes — *Puffinus tenuirostris* (Shear waters) Albatrosses, Petrels etc.,

v. Pelecaniformes — *Pelecanus*(Pelicon), *Elopteryx* (Darter bird)

vi. Ciconiiformes — Herons, egrets, storks, open bills

vii. Anseriformes — Screamers

xi. Falconiformes — Eagles, vultures, kites and falcons

x. Galliformes — Fowls, turkeys, grouses, patridges

xi. Gruiformes — Cranes, bustards, quails, trumpeters

xii. Diatrymiformes	Diatryma
xiii. Charadriiformes	Sandpipers, gulls, terns,skimmers
xiv. Psittaciformes	Parrots,
xv. Cuculiformes	Cuckoo birds,
xvi. Strigiformes	Barn owls
xvii. Caprimulgiformes	Hawks, goat suckers
xviii.Micropodiformes	Humming birds, swift birds
xix. Coraciiformes	kingfishers, todies, rollers, hoopoes
xx. Piciformes	Woodpeckers, barbets, honeyguides
xxi. Passeriformes	Flycatchers. crows, finches, sparows

Sub Class 1. **Archaeornithes**:

- Oldest known fossil birds lived during jurassic periods and having both avian and reptilian features. Hence they are the connecting links in evolution
- Feathered reptile with toothed jaws
- Long tail with free caudal vertebrae and feathers on either side of the tail
- Wings are the modified three digited forelimbs helping in flight for short distances
- Entire body is covered with contour feathers
- Vertebrae are of amphicoelous type

Sub Class 2. **Neornithes**:

- Modern birds with well developed wings for flight
- Jaws are sharp and toothless made of horny substance called rampotheca
- Wings are the modified thee digited forelimbs for efficient flight
- Hind limbs born the entire weight of the body. They are strong with toes and claws for perching over the branches of the trees.
- Exoskeleton is formed of feathers having good interlocking mechanism
- Pterylae are regular from which arise the feathers
- Retrices over the tail are arranged in the form of a fan to act as rudder
- Preen gland at the cloacal region as only cutaneous gland secreting a waxy substance to proon the feathers
- Skull with fused bones and sternum having a ventrally drawn keel for attachment of flight muscles
- No copulatory organs and females incubate the eggs except in ratitate.

3.1.4 COMMON BIRDS :

General name	*Scientific name*	Order
Myna	*Acridotheris tristis*	Passeriformes
Sparrow	*Passer domesticus*	..do..
Crow	*carvus splendins*	..do..
Black crow	*Carvus macrorhynchus*	..do..
Humming bird	*Acromyodi*	..do..
Indian pitta	*Pitta brachyura*	..do..
Lark	*Galerida cristata*	..do..
Black drango	*Dicrurus adsimilis*	..do..
Jungle crow	*Carvus macrorhynchus*	..do..
Bulbul	*Picnonotus leucogenis*	..do..
Tailor bird	*Orthotomus notorius*	..do..
Whistling thrush	*Myophonius horsefieldi*	..do..
Honey bird	*Nictarenia asiatica*	..do..
Weaver bird	*Plocius philiphiana*	..do..
Indian roller	*Coracius bengalensis*	Coraciformes
King fisher	*Alcidoathis orientalis*	..do..
Wood pecker	*Brachypternus bengalensis*	Piciformes
Green wood pecker	Camarhynchus pallidus	..do..
Honey badger	Mellivora capensis	..do..
Swift bird	*Micropodus*	Micropodiformes
Edible nest swiftlet	*Collocalia*	..do..
Barn owl	*Tito alba*	Strigiformes
Spotted owl	*Athena brahma*	..do..
Horned owl	*Bubo bubo*	..do..

Hunter bird	*Podargus*	Caprimulgiformes
Frog mouth	*Podargus strigoides*	..do..
Night hawk	*Caprimulgis*	..do..
Parrot	*Psittacula krameri*	Psittaciformes
Koel	*Eudenamus scolopacia*	Cuculifoermes
Nest building kukoo	*Centropus*	..do..
Pigeon	*Columba livia*	Columbiformes
Crested pigeon	*Goura cristata*	..do..
Sand piper	*Tringa hypoleucas*	Chadriformes
Gull bird	*Larus bravicephalus*	..do..
River tern	*Sterna arantia*	..do..
Crane	*Antegon*	Gruiformes
Patridge	*Phamcolinus*	Galliformes
Gray jungle fowl	*Gallus sonnareti*	..do..
Red jungle fowl	*Gallus gallus*	..do..
Peacock	*Pavo cristatus*	..do..
Turkey	*Meliagris*	..do..
Peria kite	*Milvus milvus*	Falconiformes
Brahminy kite	*Milvus govinda*	..do..
Egyptian vulture	*Triginiceps occipetalis*	..do..
Vulture	*Gips indicus*	..do..
Falcon	*Falco perigrinator*	..do..
Wedge-tailed eagle	*Uroaetus audax*	..do..
Monkey eating eagle	*Pithecophaga*	..do..
Sea eagle	*Halioetus pelagicus*	..do
Condor(Biggest flying bird)	*Teratornis incredibilis*	..do

Gray pelicon	*Pelecanus philippensis*	Pelicaniformes
Darter	*Anhinga ruba*	Pelicaniformes
White pelican	*Pelecanus erythrorhynchus*	..do..
Gray heron	*Ardia cinaria*	Ciconiformes
Large egret	*Agratta alba*	..do..
Pond heron	*Ardiolagal*	..do..
Flamingo	*Phoenicopterus roseus*	..do..
Greater flamingo	*Phoenicopterus antiquorum*	..do..
Spoon bill	*Platelia*	...do..
Goose	*Anser indicus*	Anseriformes
Graylag	*Anser anser*	Anseriformes
Spot bill	*Anaspocitorhyncha*	..do..
Long necked loon	*Gavia*	Gaviiformes
Storm petrel	*Oceanites*	Procellariformes
Wandering Albatross	*Diomedea exulans*	Procellariformes
Shear water(mutton-bird)	*Puffinus tennurostris*	..do..
Penguin	*Aptenodytes*	Sphenisciformes
Kiwi	*Apteryx*	Apterygiformes
Moa	*Dinornis maximus*	Dinornithiformes
Elephant bird	*Aepyornis*	Aepiornithiformes
Emu	*Dromoeus*	Casuariformes
New Guinean orstrich	*Casuaris tricoroculatus*	..do..
South Americanostrich	*Rhea americana*	Rheiformes
African ostrich	*Struthio camelus*	Struthiformes
First fossil bird	*Archaeopteryxlithographica*	Archaeopterygiformes
	Archaeornis siemensi	..do..

3.1.5 Summary:

Birds are the glorified reptiles evolved from reptiles during jurassic period of mesozoic era. All the modern birds can fly as they have feathers and powerful flight mechanism for which their body is well adapted. Body of a bird is covered with different types of feathers such as contours over the body, remiges on the wings, retrices on the tail and downs over the nestling bird. These feathers have interlocking mechanism between the barbules and barbicels facilitating the wing to hold air. Several of the modifications in the skeleton formed of pneumatic bones also facilitate easy flight.

Birds belong to class Aves of subphylum Vertebrata and Phylum chordata. This class is further divided into two subclasses namely Archaeornithes and Neornithes, the later having several orders in which all the extant flight less birds are included in super order Palaeognathae or Ratitae, penguins in Odontognathae and modern flying bird in Neognathae basing on their specified characters.

List of General and Scientific names of common birds is given for the information of the students.

3.1.6 Self Assessment Questions:

a. Enumerate the General characters of the Class Aves and classify the same up to super orders giving suitable examples.
b. Discuss the characters of Odontognathae
c. How Archaeopteryx is considered as a special bird with evolutionary significance?
d. Write general and scientific names of at least 15 birds of your area.

3.1.7 Reference books:

1. A Text Book of Zoology by Parker & Haswell. Vol. II
2. Student's text book of Zoology by Sedgwick
3. Vertebrate Biology by Robert T Orr
4. Vertebrate Zoology by Nigam
5. Theory and problems of Zoology by Nancy M. Jessop

Dr. K. Kondaiah

UNIT III

LESSON – 3.2

BIRDS-ADAPTATIONS TO FLIGHT

INTRODUCTION: Birds are the arboreal, feathery, bipedal vertebrates evolved from the reptiles of ornithischian dinosaurs during jurassic period of mesozoic era. Modern birds have taken their birth during cretaceous period (45 million years back). These are described by Huxley as glorified reptiles. There are about 8590 species of birds living in the universe. Though the birds are mainly aerial, few exceptions can still be noted leading aquatic and terrestrial life. Their study is called ornithology. Since they fly in air and rest on trees, they have efficient flying mechanism besides several modifications to suit their mode of life. These modifications collectively constitute flight adaptations. This lesson is dealt on the following plan:

Contents:

3.2.1 OBJECTIVES:

After reading this unit, you should be able to

- enumerate flight adaptations seen in birds
- classify the characters basing on the structural and functional activities of birds.

3.2.2 FLIGHT ADAPTATIONS:

- **Shape**: Boat or spindle shaped body helps easy movement in air
- **Position of the organs**: In the viscera, organs with light weight are located towards upper side of the body and heavy ones towards ventral side of the body cavity facilitating easy take off in to air.
- **Head**: It rotates in 180 and hence it can see all sides even during flight.
- **Tail**: It is in the form of a plough and is supported internally by fused vertebrae. It acts as a rudder to decide the direction of the movement.
- **Feathers**: Body is covered by contour feathers to keep the body protected against environmental variations. They are heat resistant. Quills present over the wing are the remiges

and they help in holding air during flight movements in air. Tail feathers constitute the retrices whose arrangement gives it the shape of a fan and act as rudder. Feathers are the ectodermal structures homologous to the scales in reptiles and constitute the exoskelet- .

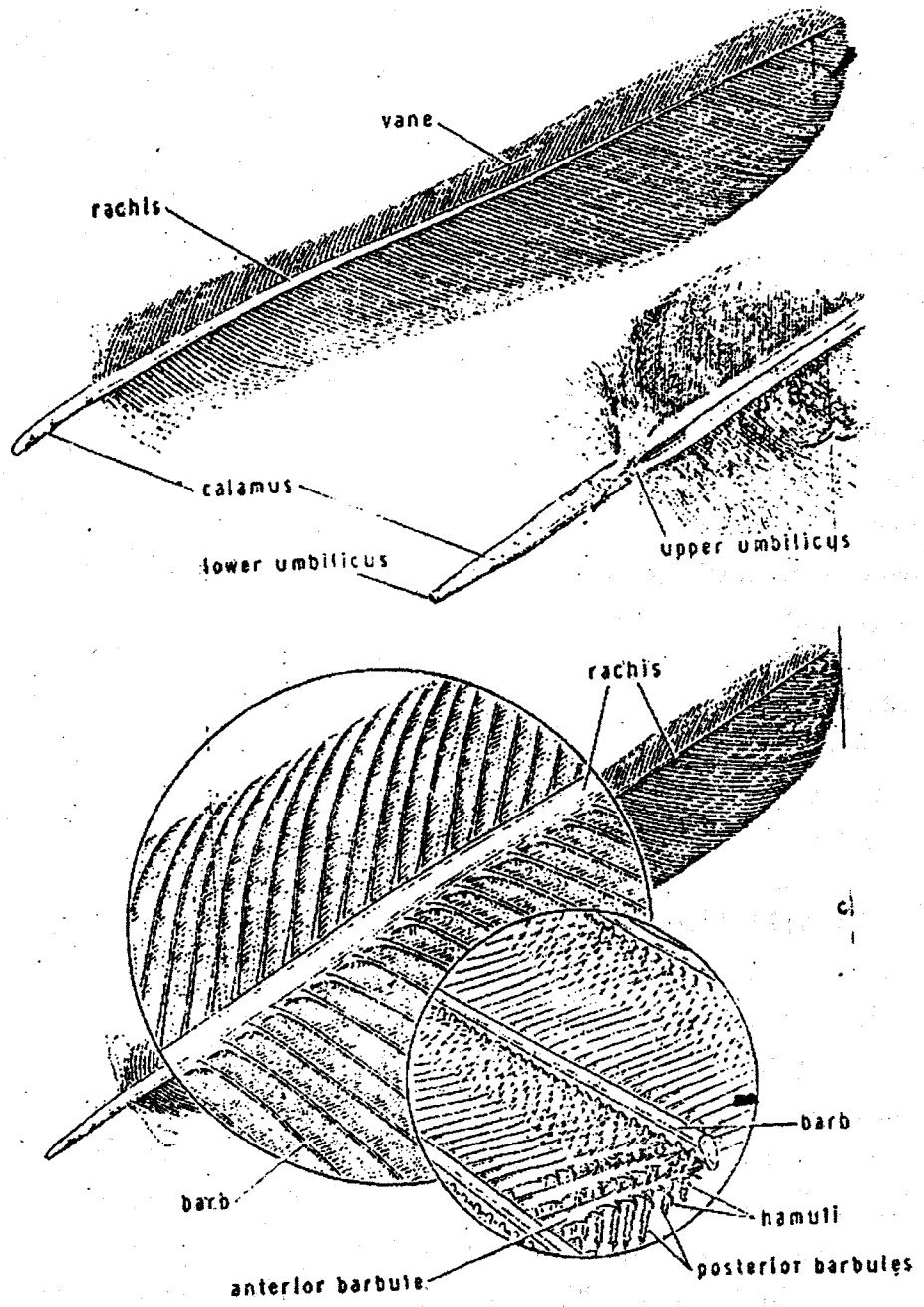


Fig. 3.3. Interlocking mechanism in Feathers.

- These feathers develop from feather follicles located in definite tracks over the body called pterylae. Thus feathers bring out flight, streamlining, insulation, waterproofing, visual and acoustic communication besides cryptic colouration to the body.
- **Wings**: These are the modified forelimbs having only three digits. Wrist bones and metacarpals fuse to form a common carpometacarpus with which remiges attach. At rest, they fold in the form of Z. They expand during flight. Effective and recovery movements of the wings bring easy and speedy movement in air.
- **Homeothermic animals** maintaining a body temperature of 40-42 C. By erecting their plumage and panting, they can cool their body whenever needed
- **Skin** is kerotinized to prevent water loss. Scales are present over the hind limbs. Uropygeal or preen gland located at the tail base near cloaca helps in secreting oil for preening the plumage.
- **Flight Muscles**: There are three pairs of strong muscles attached to the bones of the sternum, pectoral girdle and fore limbs. They can bring about powerful movements in air. These muscles are

  a. **Pectoralis major** is the heavy muscle extending between sternum and humerus. Its contraction bring powerful and effective down and backward movement of the wing.

  b. **Pectoralis minor or supra coracoides** is a muscle with a long tendon. It attaches sternum on one side. Its long tendon passes through the foramen triosseum and attaches with the upper side of the humerus. It brings up and forward movement of the wing facilitating its total recovery and prepares the wing for next effective stroke

  c. **Coracobrachialis** supporting major in its functioning.

  Besides these three major muscles, tensor longus, tensor brevis, tensor accessorius and tensor posterius are also present facilitating the expansion and flexion of the wing during flight.

- **Hind limbs** are short and strong and medially arranged on the ventral side of the body. Each limb has four toes of which one or two are directed backward and the rest directed forward. Toes are clawed to hold the food material with grip during feeding. They can grasp the substratum firmly during rest and sleep. They borne the entire weight of the body during landing of the bird either on land or on the branches of the tree. They are also supported by powerful muscles to borne the weight.

- **Metabolism**: For active movement in air, metabolic activities should be at a greater pace. Double respiration provides sufficient quantities of oxygen necessary for the release of more energy from the burning of food materials.
- **Head** is round without any external projections. Jaws are elongated to form the beak. Tympanum is deeply located. There is no external ear. External auditory meatus opens out through a small opening. Hearing is cute because of the presence of a long lagina with dense phono receptors. Saddle shaped cervical vertebrae provide simple harmonic motion of the head besides its complete rotation at an angle of 180.
- **Digestive system** is well adapted as birds feed on the food whenever it is available. It has a crop to store the food and a muscular gizzard or proventriculus to grind the food material for easy digestion. Gall bladder is not seen in general.
- **Respiration** is brought by spongy lungs. About 9 air sacs are present in association with lungs facilitating double respiration to occur at every inspiration. Exchange of gases occur twice for every intake of air during inspiration and is by simple diffusion. Airflow into the lungs is unidirectional and continuous through the air capillaries. Reserve fats are burnt during prolonged flight facilitating the release of more energy required for flight. No residual air remains after exhalation. Fresh air passes into the body during inhalation. Cross current exchange helps in thorough transfer of gases between air and blood capillaries.

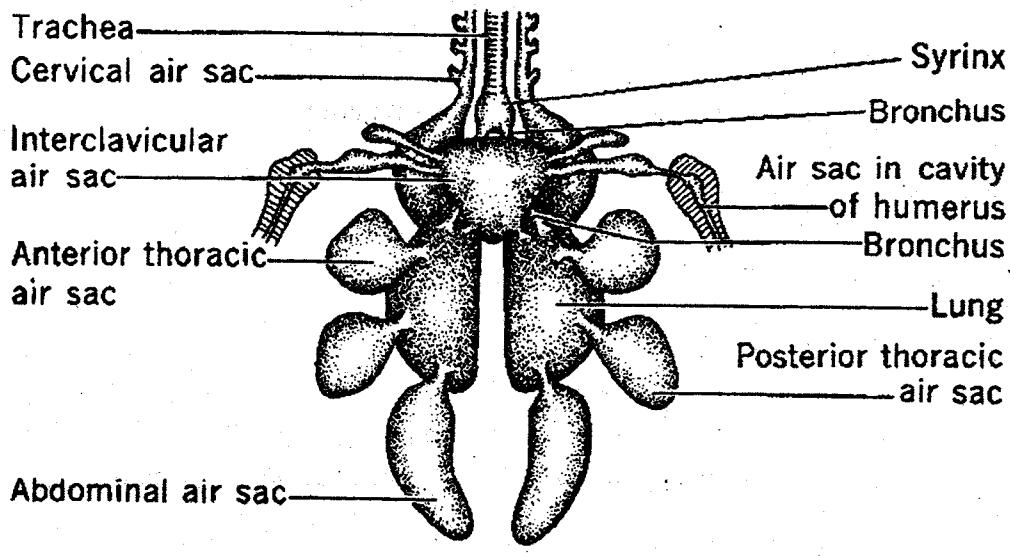


Fig. 3.4. Lungs and air sacs in Birds

- **Blood vascular system** consists of a four chambered highly pulsatile heart, right systemic arch and nucleated RBC. Wings are supplied pure blood through pectoral vessels. Complete double circulation supplies oxygenated blood required for the release of more energy. Much weight of the body is reduced due to the absence of left systemic and renal portal system.
- **Nervous system** consists of a solid brain with enlarged cerebral hemispheres for imprinting and well developed cerebellum to establish equilibrium besides muscular coordination.
- **Eyes** are larger and conspicuous with densely arranged photoreceptors. They are protected by eyelids. Diurnal colour vision is cute due to oil droplets in the cones. Internally, a fan shaped highly vascular pecten is present to facilitate quick exchange of materials and more food supply. Eyes are surrounded by sclerotic ring of bones to protect them from the pressure of air and to prevent distortion during flight. Eyes are originally set for distance vision. Accommodation of the eye is further enhanced by the presence of a Crampton's muscle. Cornea is protected by the third eyelid namely the nictitating membrane.
- **Urino genital system** consists of a pair of powerful metanephric kidneys for the conservation of water by secreting uric acid as excretory material; lack of urinary bladder as an adaptation for weight reduction; presence of only left ovary in females to compensate the absence of left systemic arch.
- **Endoskeleton** consists of thin hollow and strong but light pneumatic bones due to the extension of air tubules from air sacs. They not only give strength to the body but also lessens the weight of the body facilitating easy flight.
- **Skull** is monocondylic and easily rotates like a pivot. Cranial bones are totally fused and hence sutures are absent. This fusion gives protection to the brain from the pressure of air. Foramen magnum is towards the ventral side of the skull. Hence head lies at right angles to the neck. Teeth less jaws are made of a hard material called rampotheca to tear and eat the food even during flight.
- **Vertebral column** is formed of several fused and free vertebrae to minimize distortion by the pull of flight muscles. Cervical vertebrae are saddle shaped and heterocoelous bringing easy mobility of the neck in all directions. Last thoracic, six lumbar, 2 sacral and first five caudal vertebrae fuse to form a complex bone synsacrum. It gives support to the body and protection to the internal organs from external air pressure besides providing increased surface area for the attachment of the muscles and internal organs. Last four caudal verte-

brae unite to form a plough shaped bone called pygostyle to which retrices and muscles attach to control the movement of the tail fan .

- **Sternum** is drawn ventrally into an expanded and huge keel for the attachment of flight muscles.
- **Ribs** are double headed ones with a hook like uncinate process directed backward to keep the thoracic basket intact during flight. Thoracic and abdominal ribs attach with the boat shaped sternum to form a thoracic basket for the position of visceral organs.
- **Pectoral girdle** has a V shaped anterior furcula or merry thought bone formed from the fusion of clavicles and inter clavicles. It is located in between the two wings and acts as a spring for the wings during flight. Scapula is plate like and penetrates strongly into the shoulder muscles to provide strength to the wings. Coracoids are strong to borne the weight of the viscera. Opening at the junction of clavicle, coracoid and scapula is the foramen triosseum acting as pulley for the contractions of pectoralis minor.
- **Pelvic girdle** is strong and is fused with the synsacrum. Iliac bones are long and backwardly extended giving support to the hind limbs during landing.

Thus the body of the bird with all modifications in the morphology, anatomy and physiolcgy is well suited for flight.

3.2.3 Summary:

- Birds are the first aerial vertebrates evolved from reptiles during jurassic period.
- Spindle shaped body with hind limbs bearing the weight of the organism.
- Forelimbs modified as wings with quill feathers(remiges) for flight and tail with retrices for deciding the direction of movement during flight.
- Flight muscles; lungs with airsacs air tubules extending into the hollow bones facilitating pneumatic nature and double respiration; monocondylic skull without sutures; heterocoelous saddle shaped vertebrae; synsacrum and pygostyle formed by the fusion of vertebrae; kidneys for excreting uric acid and lack of urinary bladder to eliminate excretory products produced immediately are some of the flight adaptations seen in birds

3.2.4 Self Assessment questions:

i. What do you understand by the following terms
   a. furcula b. synsacrum c. rampotheca d.pygostyle
ii. Enumerate important flight adaptations encountered in modern birds.

3.2.5 Reference Books:

1. A Text Book of Zoology by Parker & Haswell. Vol. II
2. Student's text book of Zoology by Sedgwick
3. Vertebrate Biology by Robert T Orr
4. Vertebrate Zoology by Nigam
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UNIT-III

LESSON 3.3

ARCHAEOPTERYX & FLIGHTLESS BIRDS

INTRODUCTION

The first air living vertebrates are the birds. They have evolved from reptiles during the jurassic period of mesozoic era. Evolution of birds from reptiles can be traced out from the features of archaeopteryx, a fossil bird belonging to the subclass archaeornithes.

Modern birds have highly developed flight mechanism while the birds belong to the subclass Palaeognathea or ratitae cannot fly. They are famously known as flightless birds exhibiting discontinuous distribution. Thus the two subclasses viz., archaeornithes and ratitae are of interesting nature as they have evolutionary importance. This lesson is organised in the following plan.

CONTENTS

3.3.1 OBJECTIVES

After going through this lesson you should be able to:

- enumerate the characters of archaeopteryx.
- trace out the evolution of modern birds.
- explain the significance of archaeopteryx.
- list out the characters of ratitae.
- describe the flight less birds distributed in different parts of the world.
- discuss the significance of ratitae.

3.3.2 *ARCHAEOPTERYX* AND ITS CHARACTERS

- *Archaeopteryx lithographica* is a fossil bird obtained from the lithographic lime stones of Solenhofen in Baveria of West Germany in 1861. The recovered bird is kept in the museums of Britain & Berlin. This oldest fossil was discovered by Andreas Wagner from the excavations conducted. Second fossil bird was discovered in 1877 and was named as *Archaeornis siemensi.*

- Basing on the primitive characters, these birds were considered as the first formed birds and lived during late jurassic period (140 mill. years ago).
- The bird measured about the size of a crow. Feathers and skeletal parts were obtained as fossils. Feathers as fossils could only helped the scientists to decide the skeletal parts to be of avian one.
- The bird possessed the characters of both birds and their ancestral organisms viz., reptiles. Hence it is considered as a connecting link between reptiles and birds.
- Body is long and lizard like but resembled the birds as it is covered by exoskeletal feathers.
- Skull is round without any projections and sutures as seen in modern birds. Bones of the skull are firmly fused.
- Foramen magnum is located posteroventral, thus making the head at right angles to the body.
- Jaws are elongated and made of hard material rampotheca.
- They possessed teeth arranged in sockets showing thecodont dentition. Beak is short and strong with a blunt tip.
- Fore limb bones are separate and digits end in claws. Phalanges are arranged in the formula of 2, 3, 4 in fore limb and 2, 3, 4, 5 in hind limb.
- Tibio and fibula of hind limb are separate while metatarsal bone is a fused one.
- Eyes are surrounded by mesodermal skeletal parts called sclerotic plates.
- Vertebrae are of amphicoelous type having concavities on both the sides of centrum. They re free and hence there is no synsacrum.
- Pelvic girdle had separate or free iliacs.
- Ribs possessed backwardly directed hook like uncinate processes. Sternum is long and almost flat without any keel.
- Clavicles and inter clavicles fuse to form a 'V' shaped furcula in front of the pectoral girdle. It acts as a fulcrum during flight.
- Bones are heavy and strong as they are not pneumatic and filled with air.
- These birds could fly for a short distance as they possessed degenerated or vestigeal flight muscles.
- Tail is long with 21 or 23 free caudal vertebrae with retrices arranged on either side of the vertebrae.
- Cold blooded vertebrate without urinary bladder for storing urine.

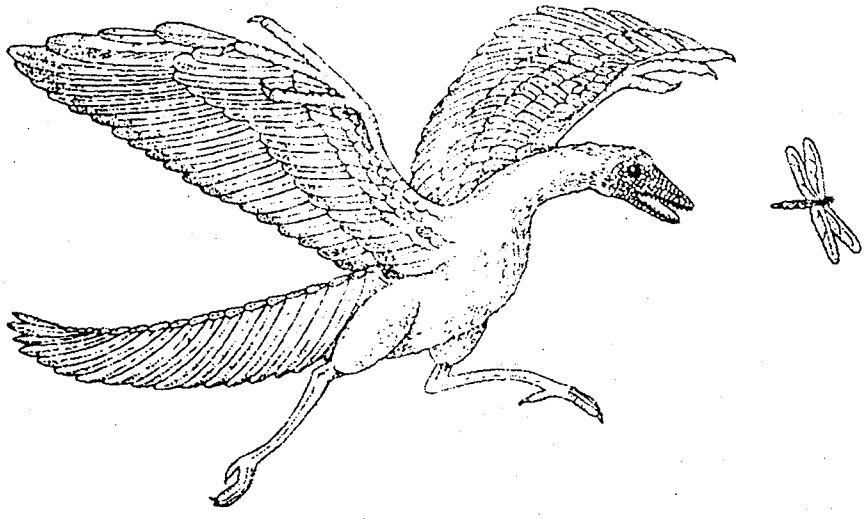

Fig. 3.5. *Archaeopteryx*

3.3.3 *ARCHAEOPTERYX* AS A CONNECTING LINK

This fossil bird shared the characters of both reptiles and lizards as stated earlier.

Reptilian features in *Archaeopteryx:*

- Short, strong and blunt snout like beak with teeth on thecodont fashion.
- Long tail with about 21 to 23 free caudal vertebrae.
- Amphicoelous nature of the centrum of vertebra as seen in sphenodon.
- Bones are strong and solid without pneumaticity.
- Presence of abdominal ribs as in crocodiles.
- The sternum is flats and unkeeled.
- Hind limbs having free tibio and fibula and bear epidermal scales.
- Metacarpals are free in the palm and end in strong curved claws.
- A hip structure lacking pubic symphysis.
- Pubic bones lying parallel to ischia.

Avian features

- External appearance as that of a bird like crow.
- Forelimbs are modified into wings with three digits each.
- Body is covered by contour feathers while wings possess quills as remiges having barbules.

- Bones of the cranium are totally fused and bear no projections. The bones are thin and strong.
- Jaws are elongated to form a beak. Hind limbs with four toes and a hallux, are well suited for perching as seen in modern birds.
- They possess a fused metatarsal bone and are rotated under the trunk with a vertical orientation.
- The elevated position of the backwardly directed toe is a modification for cursorial habit. The curved talons (claws) of its free digits helped in seizing the prey.
- Vestigeal flight muscles and reduced sternum.
- Neck supported by free cervical vertebrae.
- 'V' shaped furcula formed from the fusion of clavicles and interclavicles.
- Firmly fused scapula and corocoids in the pectoral girdle to aid in flight for short distances.
- Pelvic girdle fused to six sacral vertebrae.
- Absence of urinary bladder as in modern birds.

3.3.4 SIGNIFICANCE OF *ARCHAEOPTERYX*

- Archaeopteryx is only a fossil bird reconstructed from the fossil remains from Baveria. Hence most of the features are from skeletal remains of the body.
- Basing on the skeletal features, they were first kept under subclass Thecodontia which also included primitive dinosaurs.
- As this bird possessed feathers, jaws, uncinate processes, reduced flight muscles, furcula, suture less skull, it was considered as the first formed primitive bird and as the anchestor of the modern birds.
- The sub-class archaeornithes included two fossil birds namely *Archaeornis* and *Archaeopteryx*. They were thought to have evolved during jurassic period of mesozoic era. Still they could not live beyond mesozoic era.
- Another interesting and unsolved question is the origin of the homeothermic nature of the modern birds from the poikilothermous primitive fossil birds.
- Basing on the structural features, scientists concluded that the modern birds have evolved from arboreal reptiles to escape from the gigantic dinosaurs, by developing the powerful flight mechanism.
- However, the avian and reptilian features of archaeopteryx reveal the fact that modern birds have took their origin from reptiles. Thus this bird forms a connecting link between reptiles and birds. The main significance lies in the fact that this bird helped in tracing out the origin of aves in the process of evolution.

3.3.5 FLIGHTLESS BIRDS AND THEIR SALIENT FEATURES

Salient features

⇒ Flightless birds belong to the super order Palaeognathae or ratitae. Romer thought that these birds have evolved from modern flying birds.

⇒ These are mostly distributed in places where predators and natural enemies are lacking and are evolved during the end of meosozoic era.

⇒ Most of these birds possess heavy body and long legs suited for running. Wings are reduced in size. They may be vestigeal or absent.

⇒ Feathers lack barbules and barbicels and hence there is no interlocking mechanism. Hence the contours, remiges are in the form of hair arising from irregularly arranged feather tracks viz., Pterylae. They resemble down feathers in appearance.

⇒ Plumage covers the entire body except on head, the neck, the extremities and the abdomen.

⇒ Caudal vertebrae are free and hence retrices are absent or if present are irregular.

⇒ Absence of preen gland, keel, furcula, uncinate processes on the ribs, clavicles, syrinx and reduced or degenerated flight muscles are some of the important characters of these birds which make them special.

⇒ Males possess a penis and females possess a clitoris.

⇒ Males incubate the eggs and young are precocious as they can run along with parent birds soon they are hatched.

⇒ Bones are strong and are not filled with air (non-pneumatic).

⇒ Skull has a large and broad vomer separating the palatines. Sutures are present in between skull bones. Brain has a well devleoped cerebellum.

⇒ The long axis of the adjuscent parts of coracoid and scapula are parallel or similar. These two bones are small and acrocoracoid processes are vestigial.

⇒ The anterior ends of pterygoids and posterior ends of palatines are not articulated with basisphenoidal rostrum. Such a skull is called dromeognathus one which was considered as neotenous by De-Bear.

⇒ Strong basipterygoids arising from basisphenoid articulate with the anterior facets of pterygoid bones.

3.3.6 FLIGHTLESS BIRDS OF THE WORLD

The super order includes seven orders.

(a) Struthioniformes: Ex: *Sruthio camelus* (camel bird-ostrich)

- Native bird in the plains of Africa and Southern Asia (Arabia). They existed during phiocene to recent.
- Larger living bird with a height of 8 feet and a weight of 300 pounds.

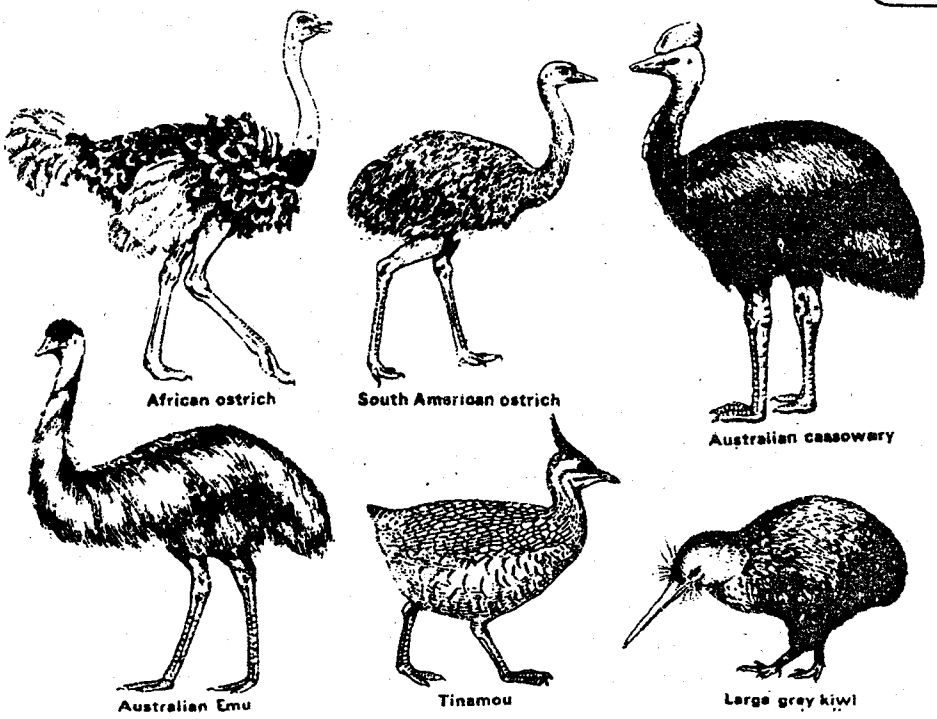

Fig. 3.6. Commonflightless birds (Ratitae)

- Since there is neither interlocking mechanism in the feathers nor after shaft, plumage is filamentous.
- Head, neck, pubic symphysis and the shanks of leg are nacked.
- Wings are extended while running at a speed.
- Squatting birds lower their head so as to lie at out of sight.
- Head is small with large mouth. Cornivorous.
- Pes has two toes (3 & 4).
- Maxillopalatines articulate with the vomerine facets
- Vomer is short and never articulates either with palatine or pterygoid.
- The female birds live in groups with a single male and are polygamous. Male incubates eggs.
- Eggs are large and equivalent to about 20 hen's eggs in quantity. They are megatelolecithal and are laid in troughs made in sand. They are covered with sand during day time and are incubated by males in nights.

(b) Rheiformes: Ex: *Rhea americana* (American ostrich)

- ✓ Large running birds of pliocene to recent with head and neck partially covered by feathers.
- ✓ Herbivorous birds having three toes in hind limb. Pelvic girdle has ischiatic symphysis.
- ✓ Feathers without after shaft.

(c) Casuariformes: Ex: *Dromoeus* (Ernu) and *Casuarius* (Cassowaries). Birds of Pleistocene to recent.

- They are the natives of Australia, East Indies, North Queensland and New Guinece and live in plains and savannahs.
- Grow to a height of 6' and runs swiftly with their long legs having three toes of which inner toe has a powerful claw. With this, they can rip the belly of a dog or kill the human being.
- Largest birds next to ostriches are the emus.
- Feathers have after shafts measuring the length of the quill.
- Vegetarian (Emu) and fruit eating habit (cassowary).
- Wings are vestigial and are supported by a single digit. The bear a number of spine like feather shafts.
- In emu, Beak is compressed and has a helmet shaped bony comb on the head.
- Large vomer articulates with palatines and perygoids.

(d) Aepyornithiformes: Aepyornis (Elephant bird) of Madagaskar

- Recently extinguished birds with tiny wings and powerful legs with four ties.
- A titan was about 10 feet in height laying eggs measuring about two gallons. Perhaps the largest eggs ever known.
- Sternum is small.
- Fossils were obtained from both pliocene and pleistocene periods.

(e) Tinamiformes: Ex: *Tinamus rhyncodon*

- Birds of South America and North Mexico resembling patridge.
- They possess characters of both flightless and flying birds.
- Tailed birds with cursorial habit and can fly for short distances.
- Sternum is keeled. They can run swiftly and conceal by squatting.
- Eggs are covered by coloured glossy shell.
- Fossils were obtained from pliocene and pleistocene periods.

(f) Apterygiformes: Ex: *Apteryx australis* (Kiwis)

- Natives of New Zealand and adjacent islands.
- Small wingless birds with a size of a fowl.
- Swift runners defending their enemies with claws.
- Nocturnal birds feeding upon worms and insects

Fig. 3.7. *Apteryx australis*, with egg.

- Eyes are small and nostrils located at the tip of the long weak beak.
- After shaft is not present in feathers.
- Legs with four toes and covered by scales.
- Body is totally covered by long hair like feathers.
- They live in pairs. Mostly males incubate the eggs which are considered as the largest eggs of living birds.

(g) Dinornithiformes: Ex: *Dinornis giganteus* (Moas) *D. maximus*

- Birds of New Zealand which became extinct in recent times.
- They measure about the size of a Turkey bird with a height of 10'.
- Wings and pectoral girdles disappeared and Sternum has no keel.
- Beak is short and adopted for vegetarian diet.
- Hind limbs are massive and large while fore limbs are absent.
- Fossils were obtained from pliocene rocks.

3.3.7 SIGNIFICANCE OF FLIGHTLESS BIRDS

The flightless birds are thought to have been evolved from modern birds during pleistocene and pliocene periods.

Because of the prevalence of dinosaurs during mesozoic era, some reptiles escaped into aerial environment and evolved into the modern birds by undergoing several structural and functional modifications to flight. Following the extinction of gigantic dinosaurs towards the end of mesozoic era,

some modern birds returned to terrestrial environment. They lost several of the flight adaptations and evolved into the flightless birds.

These are distributed not all over the world. They are restricted to certain areas where the natural enemies could not be seen. Thus they show discontinuous distribution which has impact on evolution.

3.3.8 SUMMARY

This lesson mainly deals with two important groups of birds namely Archaeornithes and ratitae represented by the fossil bird *Archaeopteryx* and flightless birds respectively. These groups possessed many of the avian characters. *Archaeopteryx,* though is a fossil representation showed both avian and reptilian features in its organization. Hence, it is considered as a connecting link between reptiles and aves. This has made the scientists to distinct the correct path of evolution. The other group of birds under ratitae also possessed major avian features but lost several of the flight adaptations. Hence they became flightless. They are very much significant in the sense that these organisms show discontinuous distribution which has profound importance on the process of evolution.

3.3.9 SELF ASSESSMENT QUESTIONS

1. Enumerate the salient reptilian features in *Archaeopteryx.*
2. Discuss the affinities of Archaornithes.
3. How *Archaeopteryx* can be considered as a connecting link – Discuss.
4. What are different orders of sub-class Ratitae. Exemplify the same with important characters.
5. Write the notes on the significance of both *Archaeopteryx* and flight less birds.

3.3.10 REFERENCE BOOKS

1. **A Text Book of Zoology, Vol. II** by Parker & Haswell.
2. **A Student Text Book of Zoology, Vol. II,** Adam Sedgwick.
3. **Vertebrate Biology** by R.T. Orr.

Dr. K. Kondaiah

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UNIT IV LESSON 4.1

GENERAL CHARACTERS OF MAMMALS

Contents

4.1.1 INTRODUCTION

All mammals possess dermal milk-glands, and only mammals possess them. All mammals are at least partially hairy. A single dentary, articulating with the squamosal, occurs on each side in the lower jaw. The skull has a double occipital condyle. The brain, and particularly the forebrain, is relatively large. The vertebrae are gastrocentrous. Each vertebra consists of a Centrum and a neural arch and in addition, thin plate-like disks of bone-the epiphyses-at each end. On the cessation of growth these fuse with the body of the body of the vertebra. The tympanic membrane or eardrum is supported by a tympanic bone and there are three minute auditory ossicles (malleus, incus, and stapes) in the middle ear. A muscular diaphragm completely separates the thorax from the abdominal cavity. Excluding the monotremata all viviparous, i.e. they produce their young alive. Most of them develop a filtering placenta between the maternal and embryonic tissues in the uterus and employ special means, both anatomical and behavioral, for the protection and nourishment of the newly born young. Like the birds, they are homoeothermous with a four-chambered heart separating completely the oxygenated and deoxygenated blood. Birds and mammals are characterized also by the retention of a single aortic arch, in Mammalia the left one, in Aves the right.

The manifold physiological and behavioral advantages conferred by thermo-regulation and by the hyper-development of the cerebrum (as well as by the female's capacity to produce and carry in her body perfectly suitable food for the unborn young) have enabled eutherian mammals successfully to colonize most of the earth including some of its least hospitable parts. More than 8,500 extant mammalian species have been described.

Although prodigious gaps occur in our present understanding of mammalian evolution it is at least clear that they are derived from the Synapsida mammal-like reptiles of an ancient stem which appeared late in the Carbonic-ferrous. The synapsida prospered exceedingly in the Permian, yet were, surprisingly, seemingly on the wane before the great reptilian radiations came to fruition in the Mesozoic. The transition from primitive reptile to early mammal occurred between the upper Carboniferous and the end of the Triassic. By the lower triassic there had appeared advanced theriodonts (e.g. *Cynognathus)* that were probably distinctly mammalian in appearance *Cynognathus* possessed a well-developed secondary palate, a feature that is characteristic of (though not peculiar to) sucking mammals. (A false palate occurs also in phytosaurs, crocodiles and one dinosaurian group.) In some advanced theraspsids large infra-orbital foramina (which in mammals) carry a rich nerve and blood

supply to sensory whiskers and moist nasal mucosa) also occur. It must be emphasized, however, that these structures are no more than suggestive. There is, of course, no absolute evidence that any of these animals were homoeothermous, had a four-chambered heart, were hairy or milk-producing. It seems possible, in fact, that many extinct animals not possessing the conventional squamosal-dentary articulation, and at present retained in the class Reptilia, might be called mammalian if their soft parts were available for study. In almost every fossil uncovered the bones alone are preserved or petrified, and although evidence can be got from endocrinal casts, and further suggestive information obtained from other studies, it is inevitable that conventional definitions should be based wholly on osteological considerations.

After its successful radiation in the Permian the proto-mammalian stock suffered a set-back, and from the Triassic until the late Cretaceous it survived only as relatively inconspicuous, small animals that are very rarely fund as fossils. Five groups-Multituberculata, Triconodonta, Symmetrodonta, Dryolestoidea and Docodonta have been recognized. Pre-Pleistocene monotreme fossils are unknown, but certain of the reptile-like skeletal components, the egg-laying habits, and the imperfect thermoregulation and other primitive characters of the Monotremata suggest that they are survivors of some such early group. Specific cranial features argue that they are descended from triconodonts.

No agreement has been reached as to the classification that most adequately expresses the relationships of these early mammals. Those particularly interested in mammalian paleontology should refer to works included in References. It must be pointed out again that any phylogenetic arrangement adopted for animals of whose origins so little is known can only be provisional. For example, it was believed for many years that the Multituberculata were marsupials, but work done during the first half of this century has tended to disprove this and multi-tuberculates are now placed in a sub-class of their own. This arrangement indicates that they are mammals, but that they do not appear to be closely related to any other mammalian group.

4.1.2 General Characters and organization

1. Mammals are warm blooded animals.
2. The skin is more or less covered with hairs (except Cetacea).
3. Sudoriporous (sweat) glands and sebaceous (oil) glands are present in the skin.
4. Mammary glands in females, whose function is that of nourishing the young, are also present.
5. External ears (pinnae) are present.
6. Teeth are heterodont (differentiation into incisors, canines and molars), thecondont (embedded in the alveolar pockets of jaw) and diphyodont (only two sets of teeth, a milk set replaced by permanent set).
7. Skull with two occipital condyles which are formed entirely by the exoccpitals.
8. Skull is without prefrontals, postfrontals, quadrato-jugal, supraorbitals and basipterygoids.
9. The lower jaw is composed of a single bone, on each side, the dentary which articulates with squamosal of its side.

10. Vertebrae are gastrocentrous composed of three pieces, the centrum, and two epiphyses.
11. With few exceptions mammals possess seven cervical vertebrae.
12. The ribs articulate with the vertebrae by two heads, capitulum and tuberculum.
13. The digits in the fore and hind limbs are never more than five, but often reduced.
14. Limbs are either plantigrade or digitigrade or unguligrade.
15. Presence of a muscular diaphragm between thoracic and abdominal cavities.
16. Heart is four chambered with only a left aortic arch.
17. R.B.C. are non-nucleated.
18. Brain with four optic lobes.
19. The kidney is metanephros.
20. Penis is always present.
21. Viviparous. The young, except in monotremes, develops in the uterus for some time and born alive.

4.1.3 Conclusion

The mammals (Gr., mammae=mammary glands) are at the top of the animal kingdom and are undoubtedly derived from the reptilian subolass symapsida, most probably from ammal-like reptiles, the therapsids. The transition from primitive reptiles to early mammal-like forms occurred in between upper carboniferous and the end of the Triassic but they suffered a set back in Permian. In Jurassic only a few small mammals existed but in Cretaceous these small forms became abundant and later on, form them in early of Tertiary a number of different types of mammals arose which became perfect, therefore, the Tertiary period in known as the age of mammals. Thereafter, mammals have radiated, adapted and colonized almost all parts of the globe in different ecological conditions. However, the mammals are characterized by the following features. The body is usually covered with hairs which are epidermal in origin. Warm-blooded or ectother. Mal or homoiothermal animals. The skin is provided with sebaceous, sweat, scent, and milk-glands. The milk-glands produce milk for the nourish. Meant of the young for some time after birth. Only due to the posseasion of milk-glands and mammae the name mammalia have been derived for this group of animals. Skull is provided with two occipital condyles, i.e., dicondylic skull. Cervical vertebrae usually seven, tail is generally long and mobile. Two pairs of pentadactyle limbs present which are adapted variously for walking, running, climbing, burrowing, swimming or flying. The toes are usually provided with horny claws, nails, hoofs or fleshy pads in aquatic forms. The nasal passage is usually long and mobile. The lower jaw is reduced to a single bone, the dentary which articulates with the squamosal. Usually external ear or pinna with external auditory meatus present. The pinna may be reduced or absent in burrowing and aquatic forms. T eh middle ear is provided with three ear-ossicles. The malleus, incus, and stapes. Both the jaws are provided with teeth embedded in sockets, i.e., thecondont. Only two sets of teeth are recognized during the life time, the deciduous or milk teeth which re replaced by the other set called permanent teeth. This condition is known as diphyodont. The teeth are usually differentiated into four types depending upon their feeding habits, i.e., heterodont. However, tooth are rarely ab-

sent. The tongue is usually mobile. The eyes are provided with mobile lids. Heart four chambered, aortic arch asymmetrical, i.e., only left aortic arch present. Respiration occurs by lungs and usually a larynx with vocal cords present. A muscular transverse plartition, the diaphragm, separates the body cavity into an anterior thoracic cavity and a posterior abdominal cavity. The erythrocytes are more, spherical and non-nucleated (except in camel). Brian well developed and specialized with different centres like memory, learning, etc. Males are with a ccopulatory organ, the penis, and the testis situated outside the abdominal cavity in a scrotal sac (except in aquatic mammals and elephant). Fertilization internal usually viviparous. The development of the embryo occurs in the uterus of the mother where a placenta is formed by the association of uterine and foetal tissues. The placenta helps the embryo in the physiological exchange of materials from the maternal blood and thus it brings about nutrition, excretion and respiration, etc. of the embryo in the womb.

4.1.4 Expected questions

1. Give an account on the general organization on mammals
2. Write in detail the characters of mammals
3. Describe the phylogenetic characteristics of mammals

4.1.5 References

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UNIT IV LESSON 4.2

MAMMALS OF SOUTH INDIA

CUVIER Divides the mammals into nine orders, as follows.

4.2.1 BIMANA
4.2.2 QUADRUMANA
4.2.3 CARNARIA
4.2.4 MARSUPIATA
4.2.5 RODENTIA
4.2.6 EDENTATA
4.2.7 PACHYDERMATA
4.2.8 RUMINANTIA
4.2.9 CETACEA

4.2.1 Order BIMANA include Man

4.22 Order QUADRUMANA: include two families

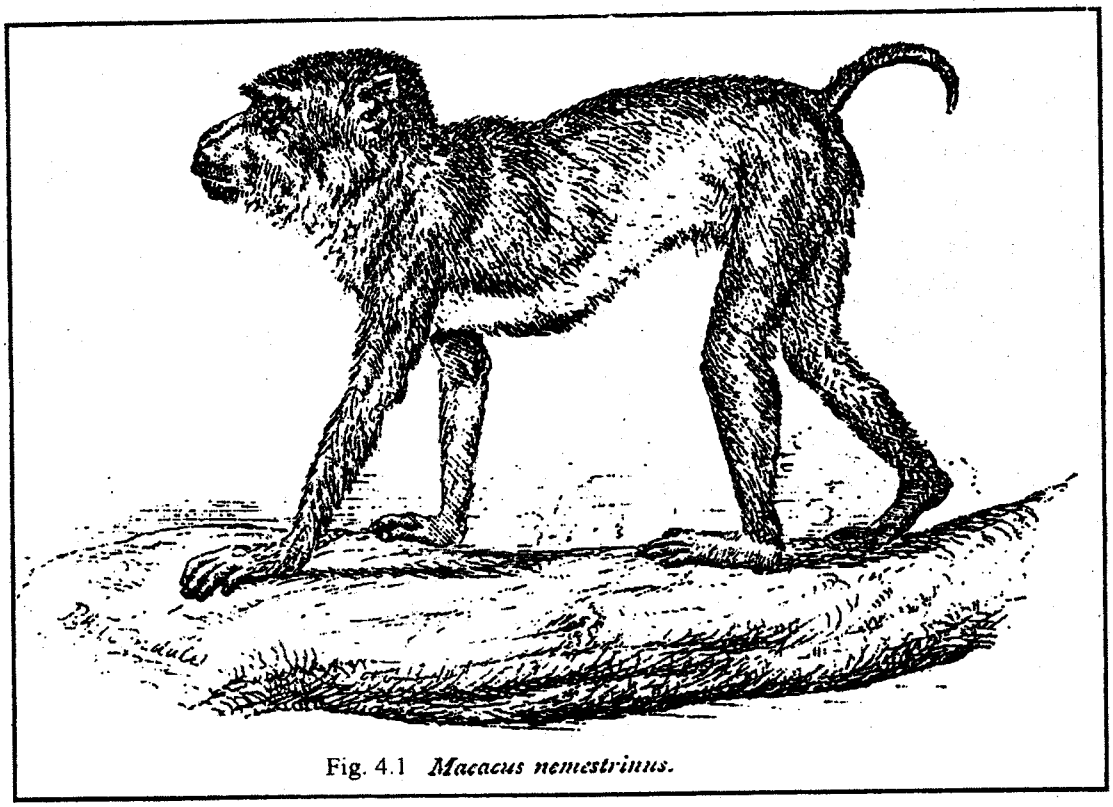

Fig. 4.1 *Macacus nemestrinus.*

1. **Ist, Apes and Monkeys and**
2. **2nd Lemurs**

4.2.3 Order CARNARIA: include three families

1st Chiroptera – Bats

Fig 4.2 The Flying Fox at Home.

2nd Lemurs

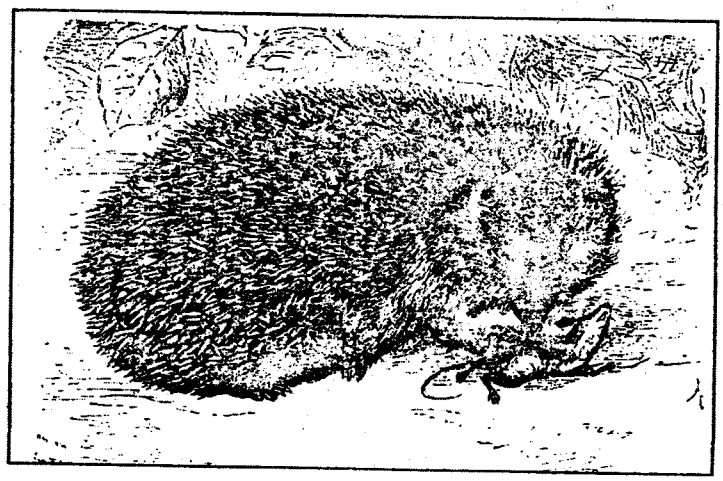

Fig 4.3

3rd Carnivora – Bears, Ailurus, Badger etc.

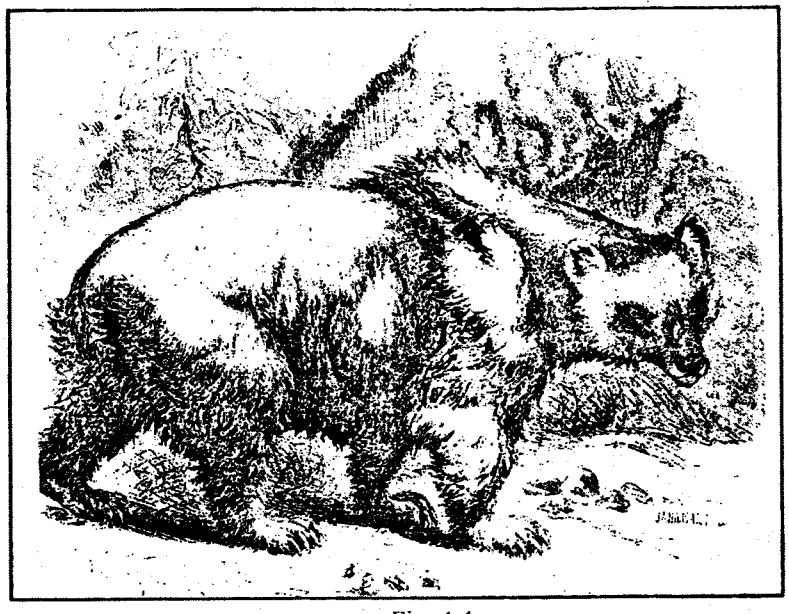

Fig. 4.4

4.2.4 Order MARSUPIATA: Implacental mammals peculiar to America and Australia such as opossums, Wombats and Kangaroos. We have none in India.

4.2.5 Order RODENTIA: includes squirrels, Marmots, Jerboas, mole – rats etc rats, mice, voles and hares

Fig. 4.5 *Sciurus maximus.*

4.2.6 Order EDENTATA: or toothless mammals, either partially or totally without teeth. It includes three families

1. Tardigrades 'the sloths' peculiar to America
2. Effodientia or burrowers 'of which the Indian type is the Mains
3. Monotremata, spiny anteaters or Echidnas & the ornithorynchus.

4.2.7 Order PACHYDERMATA, or thick – skinned mammals, it includes three families

1. Proboscidians - Elephants
2. Ordinary pachyderms – Rhinoceroses, Hogs

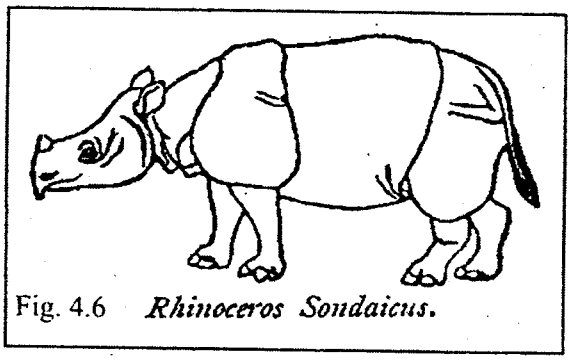

Fig. 4.6 *Rhinoceros Sondaicus.*

3. Solidungula – Horses.

4.2.8 Order RUMINANTIA, or cud – chewing mammals. It includes four families

1. Hornless Ruminants, camels, Musks
2. Cervida, true horns shed periodically, Deer

Fig. 4.7 Mouse Deer.*

3. Persistent horns, Giraffes
4. Hollow horned ruminants 'Antelopes' Goats. sheep and oxen.

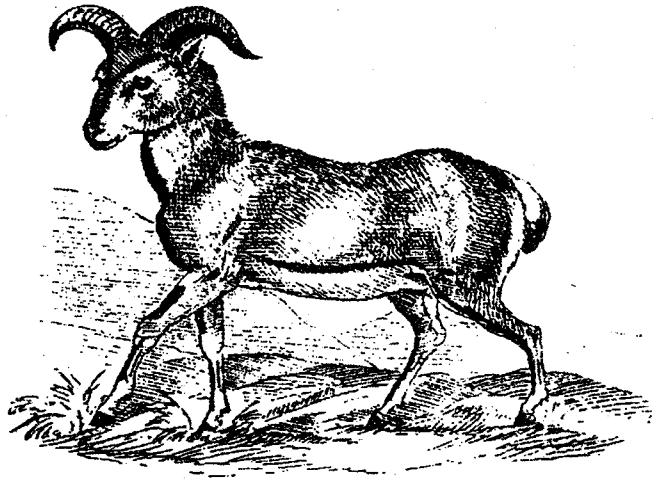

Fig. 4.8 Ovis nahura.

4.2.9. Order CETACEA: It includes three families

1. Herbivorous Cetacea, Manatees, Dugongs
2. Ordinary Cetacea, porpoises
3. Balanida, whales

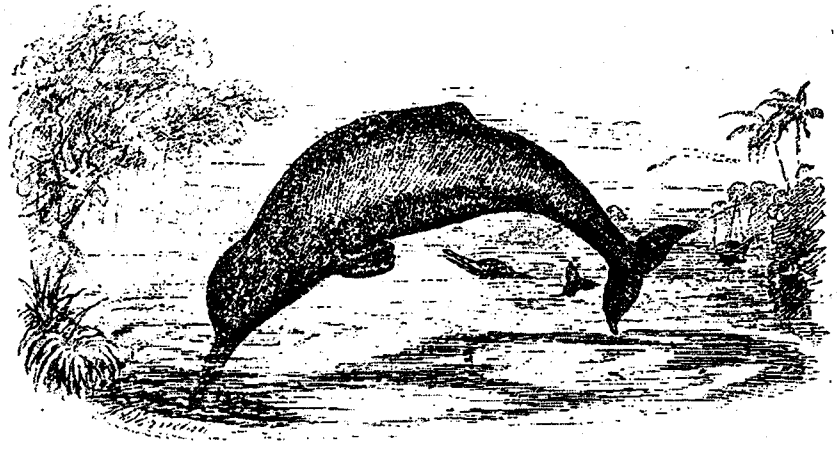

Fig. 4.9 Platanista Gangetica.

PTEROPUS LESCHENAULT
(The Fulvous Fox – Bat)

Dobson places this bat in this subgroup cynony cteris. It seems to differ form pteropus only, it is having small distinct tail, though the above – quoted author considers it closely allied to the next genus.

HABITAT : Madres and Pondicherry

Description: Fur short and downy; fulvous ashy, or dull light ashy brown color, denser and paler beneath; the hairs whitish at the basic; membranes dark brown.

SIZE ; Length, 5 to 5/12 inches; extent of wing, 18 to 20 inchs.

RHINOLOPHUS TRIFOLIATUS.

Habitat: East west of India

Description: very much like R. Permiger, but is distinguished by its smaller size and by the more pointed vertical process of the central nose – leaf, which in the other is truncated.

SIZE: Length of head and body 2 inches; tail about 1 inch.

HIPPOSIDEROS MURINUS

Habitat: Southern India

Description: Muzzle short; body short and thick; a transverse frontal leaf with a sac behind it no folds of skin on each side of the horse-shoe as in the last species; ears large, naked and rounded; color dusky brown or mouse, sometimes light fawn; using membrane blackish, interfemoral membrance large, and including the tail all but the tip.

SIZE; Head and body, 14/5 inch; tail 1 1/5 inch; wing expanse 10.

MACACUS RADIATUS

(The Madras Monkey)

Fig. 4.10 Macacus radiatus and Macacus pilcatus

Habitat: All over Southern parts of India.

Description: Of a dusky olive brown, paler and whitish underneath, ashy on outer sides of limbs; tail dusky brown above, whitish beneath; hairs on the crown of the head radiated.

SIZE: Twenty inches; tail 15 inches.

Elliott remarks of this monkey that it inhabits not only the wildest jungles, but the most populous towns, and it is noted for its audacity in stealing fruit and grain from shop. It may be taught to turn a wheel regularly; it smokes TOBACCO without inconvenience.

LORIUS GRACILIS
(The Slender Lemur)

Habitat: Southern India.

Description: About grayish rubescent; beneath a paler shades; a white triangular spot on forehead, extending down the nose; fur short, dense, and soft; ears thin rounded. A hooded claw or inner toes; nails of other toes flat; posterior third of palms and soles hairy.

SIZE: About 8 inches; arm 8; leg, 5 1/2.

This, like the last, is also nocturnal in its habitats, and from the extreme slowness of its movement it is called in ceylon the ceylon sloth. Its diet in varied, fruit, flavor and leaf buds, insects, eggs and young birds.

PHYLLORHINA BICOLOR

HABITAT ' NICOBAR ISLANDS

Description: Fur above reddish chestnut; the base of the hairs pale reddish – white, or base of hair pure white, the tip desk reddish brown. Ears as long as the head, broad; the longer half of the inner margin very convex; the summit of the ear conch rounded off broadly as for as a point on the outer side.

TAPHOZOUS MELANOPOGON
(The Black – beared bat)

Habitat: Common about East Coast of India and Cochin.

Description: No gular sac, the openings of small pores appearing along a line corresponding to the position of the mouth of the gular sac in other species; in some male specimens the hair behind these pores is very long, forming a dense black beard. Ears moderate, oval, with outer margin extending under the eyes, dilated into a large rounded lobe; the tragus leaf shaped; the head, muzzle and chin covered with short hairs.

SIZE: Length of body and head about 31/2 and tail 2/2; wing expanse, 14 inches.

VESPERUGO PACHYPUS
Habitat: Andaman Islands.

Description: Crown of head very flat; ears short, triangular with broadly rounded lips, tragus short; under surface of the base of the thumb and soles of the feat with broad fleshy pads; wings rather short; fur fine and dense; above reddish brown, paler beneath.

SIZE: Head and body 1.75 inch; tail 1 inch.

VESPERUGO DORMERI

Habitat: Southern India and Ballary hills

Description: Head flat; ears shorter, triangular with rounded tips; tragus with a small triangular lobe near base of outer margin; fur brown, with ashy tips above, darker brown below, with the terminal third of the hairs white. Dentition approaches the next genccs, there being only one pair of unicuspidate uppper incisors placed, one by each upper conine.

SOREX NEMORIVAGUS
(The Rufescent shrew)

Habitat: Southern India
Description: Color dusky grayish, with rufous brown to the hairs. Above dusky slate colour with rebescent tips to the fur; beneath paler, with a faint rubous tingle about the breast fur short ashy-brown, with a ferruginous smear on the upper surface; beneath a little paler colored. Teeth and limbs small; tail slender.

SOREX PERROTETI
Habitat: Neilgherry hills, probably also other parts of the southern India

Description: Back deep blackish brown; belly pale; limbs and feet brown; palms and planate clad with hairs; ears large, conspicuous.

Size: Head and body, 4/12 inch, tail 11/12 inch.

ERINACEUS MICROPUS
Habitat: South India.

Description: Ears moderately large; form some what elongated; tail very short, concealed; feet and limbs very small; head and ears nude, sooty colored; belly very thinly clad with yellowish hairs; spines ringed dark brown and whitish or whitish with a broad brown. Sub terminal ring, tipped white.

SIZE: Head and Body about 6 inches.

TUPIA ELLIOTI
(Elliot's Tree shrew)

Habitat: Southern India, Godavary district

Description: Fur pale rufous brown, darker on the back and paler on the sides; the chin, throat, breast and belly yellowish, also a streak of the same under the tail; the upper surface of the tail is of the same color as the centre of the back; there is a pale line from the muzzle ones the eye, and a similar patch beneath it; the fur of this species is shorter and more harsh, and the head is more blunt.

TUPAIA NICOBARICA
Habitat: Front and sides of the face, outside of fore limbs, throat and chest, golden yellow; inner side of hind lilmbs rich red from, which is also the color of the hind legs and feet; head dark brown, with

golden hairs intermixed; back dark maroon, almost black; upper surface of the tail the same; pale oval patch between shoulders.

SIZE: Head and body 7-10 and tail 8 inches.

FELIS RUBIGINOSA

Habitat: Size of small domestic cat, with a tail half the length of the body; color grayish with a refocus tings, or greenish grey tinged with subous; the under parts white, with large refocus spots; ears small; four well defined dark brown or black lines along the forehead and nape, and three along the back, and latter being interrupted into longish spots ; a series of rusty colored spots on the sides; fur is very short, tial uniform in color.

Size: Head and body 16 to 18 inches; tail 91/2 inch.

FELIS TORQUATA

Habitat: Southern India.

Description: Ground color pale grayish fulvous or cat grey with numerous round black spots, smaller on the head, nape and shoulders; longitudinal lines on the occiput, check striped; breast spotted but belly free from spots, on the limbs distinct cross bands are present.

Size: Head and body, from 16 to 24 inches; tail, about half the length.

FELIS JUBATA

Habitat: Southern India, especially in Hyderabad.
Description: A tall slim animal, with body much drawn in at the flanks like a greyhound; purely cat-like head with short round ears; long tail, much compressed at the end, in a colour a bright rubous fawn.

HERPESTES SMITHII

Habitat: Southern India.

Description: Reddish ferruginous brown, long hair, well grizzled more red on the head and oter part of limbs; hairs annulated dark and white, with reddish tips; muzzle long and flesh-colored; feet black; tip of tail black.

HERPESTES VITICOLLIS

Habitat: Southern India.

Description: Grizzled grey, more or less ferruginous, especially on the rump and tail; a dark stripe from the ear to shoulder; tail rufous black at the tip; skull characteristics; large with flattened and expanded frontal region, projected narrow muzzle and powerful teeth.

Size; Head and body 21 inches; tail 15 inches.

DELPHINUS LPERNIGER

Habitat: Bay of Bengal

Description: Twenty –six teeth on each side above and below, obtuse, slightly curved inwards; of a uniform shining black above, beneath blackish.

Size: Total length 5 feet 4 inches.

DELPHINUS MACULIVENTER

Habitat: Madras Coast

Description: Forehead more convex than even D. gadamee, and had proportionately larger and body deeper. A deep shining plumbeous black on the upper part, becoming paler near the belly, which from the under part of the jaw to the perineum is ashy-grey with irregular spot size = about 7 feat.

DELPHINUS GADAMU

Habitat: Madras Coast

Description: Body fusiform, gaining its greatest diameter at the bore-part of the dorsal bin, decreasing forward to the head by straight converging lines, and with a gentle convex curve to the eyes and blowhole.

The Dentition varies from

$\frac{24\text{-}24}{24\text{-}24} = 96$ $\frac{23\text{-}23}{27\text{-}28} = 101$ and $\frac{27\text{-}27}{27\text{-}27} = 108.$

Size: About seven feet from snout to fork of tail; girth about 3 feet 9 inches.

DELPHINUS LENTIGINOSUS

Habitat: Madras Coast

Description: Body bursiform, as in the last, but with smaller pectoral and dorsal but larger caudal bin; the back is straighter and not so much rounded on the shoulders, and the colour is bluish-cinereous or salty, freckled with small irregular spots of brown or plumbeous, and longitudinal streaks of the same flecked with white; the under parts a shade lighter than rest of the body. The snort is six inches inlength.

Dentition $\frac{32\text{-}32}{32\text{-}33} = 129$

Size: Seven to eight feet; girth 4 feet.

DELPHINUS POMEEEGRA

Habitat: Madras Coast

Description: More slender than any of the foregoing species; longish snout with 173 teeth,

Viz $\frac{41\text{-}41}{45\text{-}46} = 173$ it is well to note the

regularity here, not only an odd number, but the lower jaw has the greater number, whereas it as generally the other way. Color almost black, lighter beneath.

LOBICEPHALUS INDICUS

Habitat: Bay of Bengal

Description: Body cylindrical, tapering to the tail; dorsal bin high, falcate and placed about the middle of the body proper, excluding the tail portion; the forehead with a prominent boss ones the snout, which is short; pectoral fins long and narrow; color uniform leaden black; paler beneath.

Size: 14 feet, flippers 2 feet; dorsal bin, 21/4 feet long, 11 inches high, tail flukes 3 feet broad.

PHYSETER OF EUPHYSETES SIMUS

Habitat: Bay of Bengal

Dentition: $\frac{1\text{-}1}{9\text{-}9} = 20$

Size: six to seven feet.

SCIURUS MACROURUS

Habitat: Southern Inida

Size: Head and body, 131/2 inches; tail 11 inches.

Description: Fur of the upper parts coarse and slightly waved; above; the color varies from maroon-black to rufous brown; hairs sometimes grizzled and tipped white or pale yellow.

SCIURUS LAYARDI

Habitat: Southern India.

Description: Dark dingy olive, inclining more to ashy than fulvous, except on the head and blanks. Lomer parts ferruginous, paler on the breast; middle of back very dark, with a narrow bright fulvous streak in the middle.

SCIURUS SUB LINEATUS

Habitats: Southern India.

Size: Head and body 5 to 6 inches; tail 41/2 – 6 inches.

Description: Smaller than the palm squirrel; fur soft dense, girzzled olive brown; base of hairs dusky black; three pale and four dark lines on the back and croup, the lineation being obscure, and reaching only from the shoulder to the sacral region.

PETROMYS FUSCOCAPILLUS

Habitat: Southern India

Description: Upper parts rufous chesnut according to kellaart, who named it sciuropterus layardil; rufescent fulvous or dark brownish isabelline hue, as jerdon described it; the fur durky blackish colour for three-four the of its length; the tips coarser and colored rufous chestnut; hairs fuscous with a fulvous lip; two-thirds of the base dusky ashy, the remainder reddish brown with a black tip; the ears are moderate in size, cheek bristles well developed, tail is very bushy and not distichous in the adult.

Size: Head and body 73/4 inches; tail 63/4 inches with hair.

PLATACANTHOMYS LASIURUS.

Habitat: Southern India.

Size: Head and body, 6 inches; tail. 3/12 or five inches including the hair; planta 1 inch.

Description: Light subsequent brown; the under fur paler, more rufous on the borehead and crown; whiskers black; underparts dull white; the hairs on the tail, which one arranged distichously, are darker than those of the body, infascated except at the tip of the tail, where they are whitish; the muzzle is acute; ears moderate and naked; the fur above is mixed densly with sharp hat spines; the under coat is delicate and fine; the few spines on the lower parts are smaller and fines; the thumb is without a nail.

Nesokia providens

(The Southern India field rat)

Habitat: Southern India

Description: Head short and truncated, with a deep muzzle; ears nearly round, semi nude, sparsely covered with minute hairs; eyses moderately large, halp-way between snout and ear; feet largish; claws short and stout; tail nearly equalling lingth of head and body, seminude; ringed, and with short brown bristly hairs round the margin of the annuli; whiskers bull and long; the ears nose and feet are dark flesh colored or brownish and the feet are covered with short brown hair the incisors are orange yellow; the claws yellowish.

MUS ANDAMANENSIS

Habitat: The Andaman and Nicobar Islands.

Description: A little darker on the back than mus decumonus, plaer on the sides, and dull white below. The long piles are at once distinguished by their flattned spinous character, which also slightly in case in M. rattes, through much less conspicuously than in the parent species. It would appear to be a burrower in the ground. Ears round as in the brown rat.

Size: Head and body, about 8 inches, tail the same.

MUS INFRALINEATUS

Habitat: Madras

Description: "Above, the fur fulvous, with the shorter hairs lead colored; throat, breast and belly pure white with a central pale fulvous brown streak; tail slightly hairy.

Size: Head and body 51/2 inches, tail NOT quite 5 inches; another about 5 inches; tail 41/4 inches.

MUS CERVICOLOR

Habitat : Southern India

Description: Distinguished by its short tail. Above dull fawn, below sordid white; wining of ears and extremities pale. Ears large hairy. Of the specimens jerdon seen the fur is soft and of a light sandy brown above and white below, very like mus bactrianus.

LEGGADA SPINULOSA

Habitat: Southern India

Description: Nearly affined to M.platy thrix, but of a darkdusky color above, with fulovus tips to the softer fur; below and all the feet dull whitish; upper rodential tusks orange, the lower white; whiskers long and fine, the posterior and longer of them black for the basal half or more, the rest white.

Size: Head and body 3 3/4 inches; tail 3 inches.

LEGGADA PLATYTHRIX

Habitat: Southern India

Description: Sandy brown or light brown fawn above, white underneath, with a band of pale fawn separating the two colors. The fur mixed with flat transparent spines, smaller beneath; head long; muzzle pointed; ears rather larter, oblong, rounded, about half and inch in length.

Size: Head and body 3 1/2 inches; tail 2 1/2inches.

LEPUS NIGRICOLLIS.

Habitat : Southern India

Description: Upper part rufescent yellow, mouled with black; single hairs annulated yellow and black; chin, abdome and inside of hin-limbs downy white; a black velvety spot on the occiput and upper part of neck exterding to near the shoulders; the spot under the neck is in some specimens of a bright yellow color; ears long, greyish brown, internally with white brings, at the apical part dusky, posteriorly black at the base; feet yellowish; tail above grizzled with black and yellow beneath white.

Size: Head and body 19 inches; tail 2 1/2 inches; ears 4 3/4 inches.

UNIT IV LESSON-4.3

AQUATIC ADAPTATIONS IN MAMMALS

4.3.1 INTRODUCTION

Adaptation may be defined as structural and functional characteristics which organisms have developed during the course of evolution enabling them into a environment, to survive and reproduce in a particular environment.

According to **Charles Darwin**'s view, as a result of over production and limited availability of food material and shelter there is a struggle for existence and only those animals which are able to adopt themselves according to the changing environmental conditions can survive. The adaptations are of different types, such as Aquatic, Arboreal, cave and Fossorial etc. Among all these, here we are confined to Aquatic environment in case of higher vertelrates i.e. Mammals and how the Mammals were able to live in Aquatic environment and what are the Adaptations in Mammals?

4.3.2 CONTENT

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

4.3.3 AQUATIC MAMMALS

Aquatic Mammals belong to several orders and may be put under two categories depending on their degree for Aquatic Adaptations. They are as follows: viz.,

1. Amphibious Mammals
2. Completely Aquatic Mammals

Let us consider, them as follows:

1. **Ambiphious Mammals:** These animals do not live permanently in water. They live on land but go into water for food and shelter. They show only partially aquatic adaptations, such as:
   (1) Small external ears
   (2) Webbed feet
   (3) Flattened tails
   (4) Subcutaneous fat

   Eg: *Minks, Seals, alters* and *walrus* (Carnivora);
   beavers (rodentia)

   hippopatamus (Artiodactyla);
   chironectes (Marsupialia);
   Ornithorhynchus (Monotremata); etc.

2. Completely Aquatic Mammals:

Members of two orders, viz.,
Cetacea – Whales, Dolphins and porpoises &
Sirenia – Manatees and Dugongs

These were essentially Aquatic forms; they never come to land and perfectly their home in water and have greater Adaptations. Accordingly, they are called as:

i.e. aquatic animals
i.e. aquatic animals

4.3.4 AQUATIC ADAPTATIONS (Fig.4.11)

(A) Modification of original structures:

1. **Body shape:** Body shape is of prime importance in aquatic animals. The external fish like form, elongated head and indistinct neck with tapering streamlined body offers little resistance, and swims rapidly through water.
   e.g. Cetacea, Sirenia, Pinnipedia and Ichthyasawia.

2. **Shortening of Neck:** The neck is shortened in aquatic animals and has a lot of significance, even though neck lost the power of mobility. In whales (Cetacea) cervical vertebrae are fused to form a compressed mass of bone.

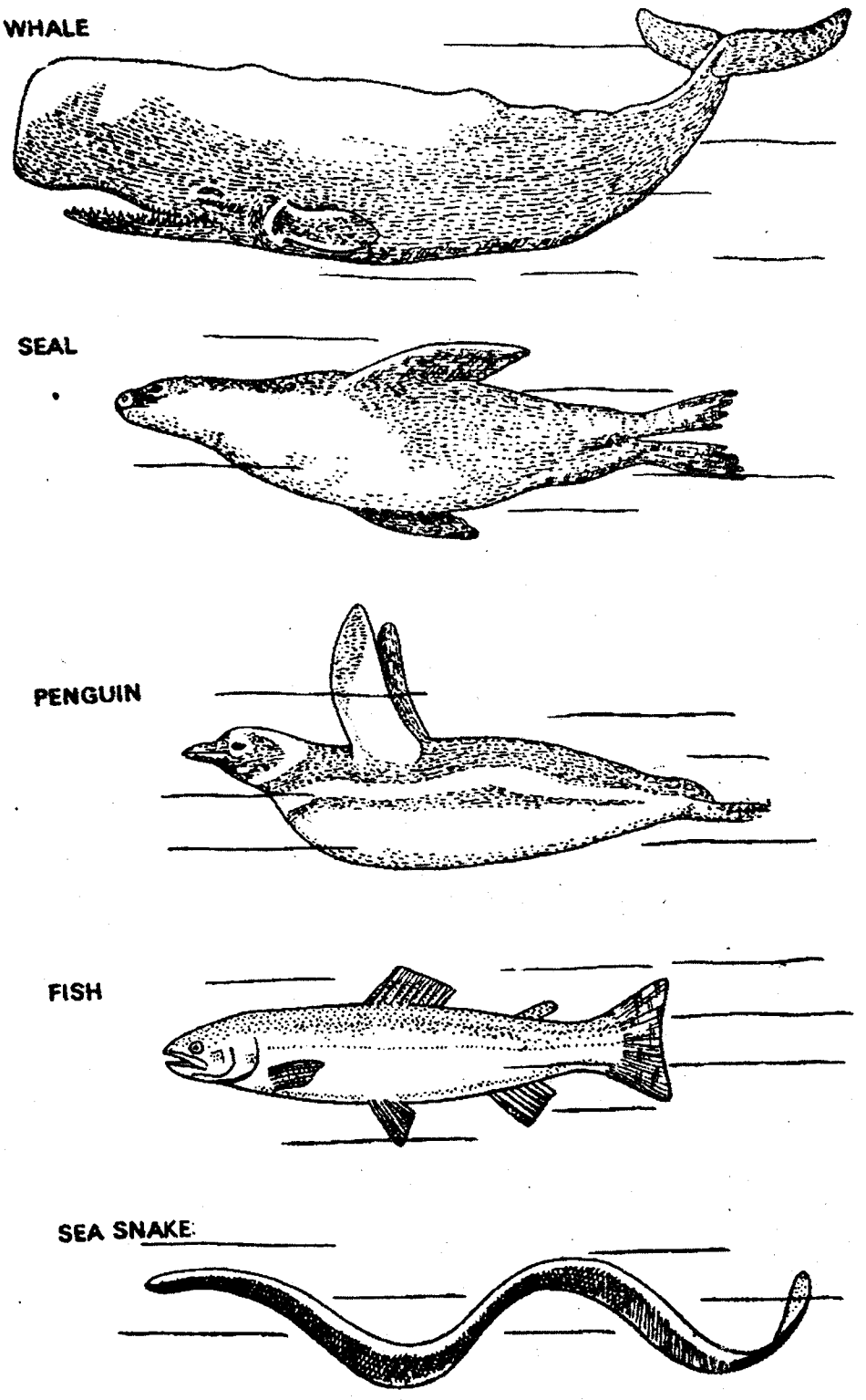

Fig. 4.11 Aquatic adaptations in different vertebrates

3. **Hyberdaxtyly and Hyberphalangy:** Extra digits (Hyberdaxytyly) and extra phalanges (Hyberphalangy), upto 14 or more in some cases, serve to enlarge the surface area of flippers for greater utility in water.
4. **Large size & Weight:** Whole bone, whole may group to 35 meters in length and weigh about 150 tons. Large size reduces the skin friction and heat loss, but creates no problem for support in water, due to buoyancy.

5. **Flippers:** Forelimbs are transformed into skin-covered unjointed paddles or flippers, having no separate indication of flingers. They can move as whole only at the shoulder joint. The broad and flattened flippers serve as balancers and provide stebility during swimming.

6. **Mamary ducts:** During laxtation, ducts of Mammary glands dilate to form large. Reservoirs of milk which is pumped directly into mouth of young by the action of special compressor muscle. This arrangement facilitates luckling of young under water.

7. **High & Valvular Nostrils:** Nostrils are placed far back on top of head so that animal can breathe air without raising head much out of water. Nostrils are also closed by values during dividing under water.

8. **The Respiration:** Cetaceans and sirenians have acquired certain specialization for respiration. Muscular flaps are developed to keep the Nostrils closed when the animals are in water. The epiflattis become tube like leading from internal Nostril to the larynx which act as respiratory passage. The lungs are greatly enlarged so that they receive large volume of air. This large amount of air enables them to live in water for a considerable time. The rate of oxygen consumption is reduced resulting in the low rate breathing.

9. **Oblique diaphragm:** Oblique diaphragm makes enorasic cavity larger, dorsal and barrel shaped, providing more space to lungs for expansion.

10. **Large lungs:** Large unedrulated and highly elastic lungs ensure taking down maximum air before submergence. Like swimblodders of fishes, the dorsal lungs also serve as hydrostatic organs in maintaining a horizontal posture during swimming.

11. **Endoskeleton:** Cranium becomes small but wider to accommodate the short and wide brain. Faxial part of skull projects forming elongated snout or rostrum (porpoise). Zygomatic arches are reduced. Cervical vertelirae are fused into a solid bony mass because of reduced neck. Zygaphophyses are reduced. Sacrum is also reduced. Fibs become arched dorsally to increase thorasic cavity. Bones are light, spongy and in cetacea, filled with oil.

12. **Intra-narial epiglottis:** Elongated tubular and intranarial epiglottis, when embraced by the soft palate, provides a continuous and separate air passage, thus allowing breathing and feeding simultaneously.

13. **Teeth:** In Toothed whales, teeth are *Monophydont; homodont*; and *Numerous*, as many as '250'. This helps in seizing the prey, prevents its escape, and swallowing it without mastication. Usually, the mobility of jaws is reduced as they have no function in Mastification. In Mastification, aspect-Aquatic Mammals has lost the power of Mastification except in sea-cows & walruses. In sperm whales teeth are present on lower jaw and in upper jaw, the teeth are replaced by baleenplates in baleen whales.

14. **Sense organs:** Eyes resemble the structure of eye in a fish. The corner is flat and lens is round dictitating membrane is lost/absent. The eyes are protected in water, from water by the secretion of Harderian glands. The external ears/pinnae are absent in Aquatic Mammals. The Tympanum is ethick and the ear assicles (*Malleus, Ioncus & Stapes*) are fused together and also with the *fenestra ovalis*.

15. **Limb bones:** Limb bones are short and compact, free movement of bones is laxking. *Hyperphalangy* (presence of additional digits), as mentioned is observed in few forms. Hind limbsa re absent but their remanants are present in the flesh.

16. **Fins:** In addition to forelimbs being modified into flippers, a dorsal fin is present in killer whale, in the form of a fold of integument. The tail is flat with a caudal fin. In Cetacea, the Caudal fin is bilobed, laterally expanded. In Sirenians, it is round or rhomboidal; the strokes of caudal fin make the animal to move forward in the water.

In addition to the modification of existing organs, for the Aquatic mode of life, the Aquatic Mammals too shows, formation of new structures, and loss of structures, too. All these will be discussed like these.

B. Loss of Structures: For Aquatic life

Skin surface usually remains smooth and glistering due to loss of hours, except for few sensory bristles on snout or lips in some cases. Pinnae are also absent. Presence of hairs and pinnae may impede or obstruct the even flow of water over body surface and interfere with speed and elegance of movement through water. Eye cleaning nictitating membranes, laximal glands, and all kinds of skin glands (sweat and sebaceous) are also absent because they would have been useless under water and due to thickening and immobility. Skin loses its muscles and nerves. Hind limbs are represented only by button-like knobs and in the foetus but disappear in the adult. Pelvis is also redimentary. Finger nails are absent except for traces in foetus. Scrotal sexs are also absent and testes remain inside abdomen.

These were some of loss of structures, which or otherwise may impede the water living, so has been last, as an adaptation for Aquatic life in Mammals.

C. Development of New Structures: (Fig. 4.12)

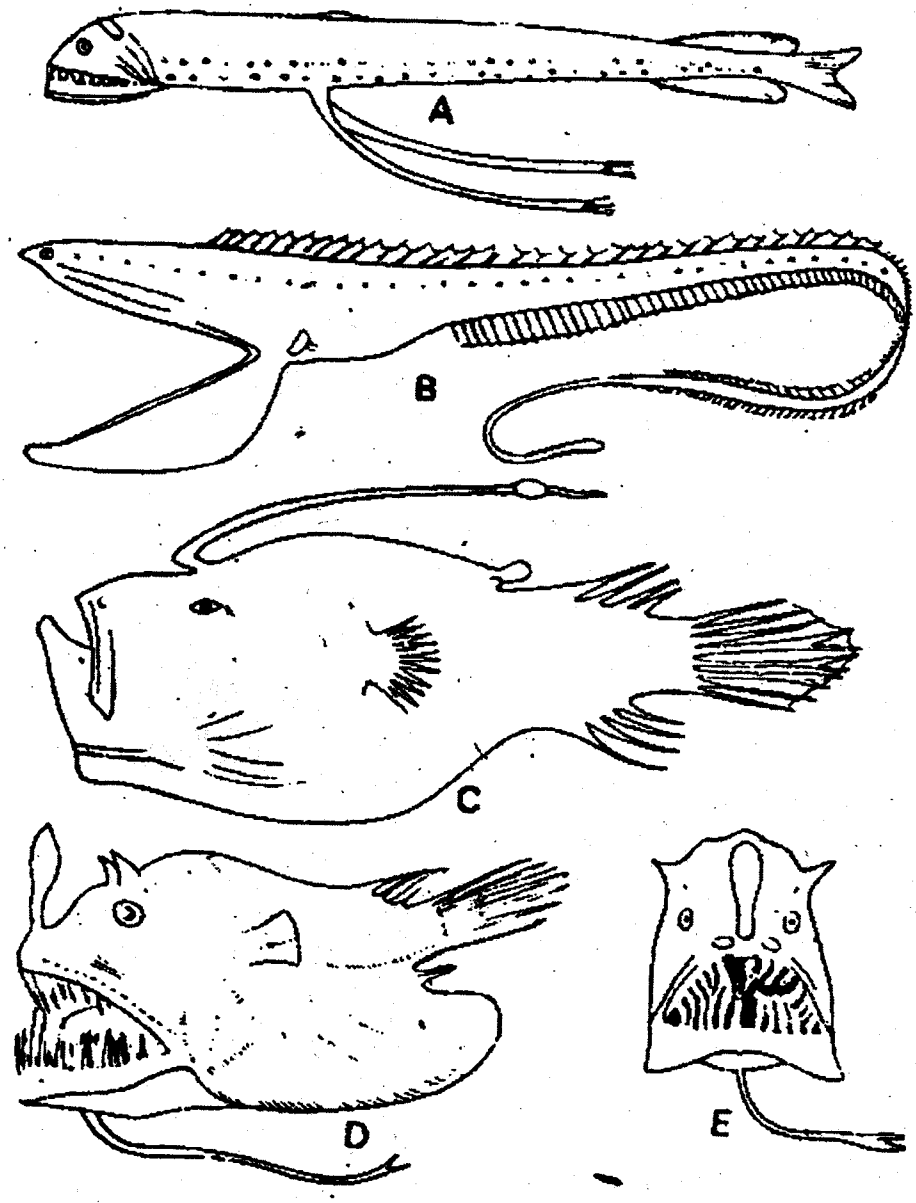

Fig. 4.12. Deep Sea Adaptations

A. *Phytostomias guernei*, **B.** *Idiacanthus ferox*, **C.** *Gastrostomus bairdii*, **D.** *Cryptopasrus couesii*, **E.** *Linohryne lucifer*

Tail flukes: Tail develops large, lateral or horizontal expansions of skin called *Flukes*. These are not supported by finrays. Their up and down strokes not only propel the body through water but enable rapid return to the surface for breathing after prolonged submersion.

1. **Dorsal fin:** Most Cetacea develop an unpaired adipose dorsal fin without internal skeletal support. It serves as a rudder or keel during swimming.

2. **Blubber:** Blubber is the thick subutaneous layer of fat which compensates for the lack of hair covering? Acts as heat insulator, it not only retains the warmth of body, but also provides a ready Reservoir of food and water during emergency. The fat also reduces the specific gravity of the animal, thus imparting the buoyancy. Blubber also provides an elastic covering to allow changes in body volume during deep living and also counteracts the hydrostatic pressure.

3. **Baleen:** In whole bone whales, teeth are absent. Instead, the upper jaw carries two transverse rows of numerous fringed horny plates of *baleen* or *whalebone*. These serves as an effective sieve for straining plankton (mostly *krill*) which forms their chief food.

4. **Foam:** Each middle ear cavity sends an inner pneumatic prolongation which meets with the fellow on the other side below the skull. These extensions contain foam which is a fine emulsion of fat, mucus and gas. It probably serves to insulate sound and improves audition or hearing under water.

5. **In** Sea cow (Dugong) – Skin is without hairs but the *Vibrissae* are present.

6. **In** Aquatic Mammals, external ear lobes are absent, as mentioned. The Auditary metus is filled with oily sections.

7. **Melon:** It is a receptor present in the front region of nostries or in front of Nostrils. It consist of a fatty mass transversed by muscle fibres. It possibly serves to detect pressure changes in water.

8. **Harderian glands:** Eyes under water remain protected by special fatty secretion of therderian glands. The secretions of these glands protects the eyes. In several aquatic mammals, bones are spongy in nature, and the bone are also filled with oily secretions.

4.3.5 SUMMARY

The animals which live in water, are called Aquatic animals. In general, under such category, the **iaquatic animals**, i.e., animals which never live on land, which complete and compete, the life history successfully in water are called so and Fishes falls as an example.

But, animals which are adopted to live in water but are derived from Terrestrial ancestors are called iaquatic animals.

Best examples: Mammals – *Whales*.

Thus, their ancestory is on land but merged to water and depending on the durati[illegible]ntact with water they were categorized as Amphibious Mammals & Completely Aquatic Mammals so as to live in water, to get protection, food, mate and for other purposes, the Aquatic mammals have got some spsecialized body posture differences and modifications, loss of some structures. Development of some structures as Adaptations.

4.3.6 EXPECTED QUESTIONS

1. Describe the aquatic adaptations in mammals.
2. What are the various aquatic adaptations found in mammals.

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UNIT IV LESSON 4.4

ADAPTIVE RADIATION IN MAMMALS

4.4.1 INTRODUCTION

From the theory of evolution, we know that species became adapted to their environments by a process of **Natural selection**. This adoption goes on within species as local populations adjust to local conditions. Some of the organisms, perhaps most of the organisms cannot survive if they are transplanted outside their observed habitat range. This means that they have not been adopted to biotic or abiotic limiting factor. The term **'Adaptation'**, describes the characteristic of living forms to survive and reproduce within the limits of a particular environment.

Newman defined adaptation as mutual fitness of organisms and environment. According to Conklin, the power of self-regulation, self-preservation and race perpetuation, by means of which living things are enabled not only to remain alive but also to adjust themselves to varied environmental conditions. Adaptation, as far as it involves the alteration of a species characteristics, is a facet of evolution. On the face of it, this raises a curious problem – Why has there not been more adaptation? Two points have to be considered here, as follows:

(1) We must distinguish adaptation toward biotic factors, and abiotic factors.

(2) Only phenotypic adaptation may be possible, because genetic-adaptation leads to formation of new species.

Adaptation of all organisms to the environment may be of great importance for the survival in the struggle of existence. In adverse conditions, the organisms first of all must achieve certain level of physical and physiological tolerance to enable it to gain a foothold in the new environment or locality. This phase is called "**Pre-adaption**". Then after it must have sufficient genetic variability to enable it to establish itself in the face of such selective agencies as the climate and competition from other animals. This phase is called "**Post-adaptation**".

4.4.2 CONTENT

In the early Palaeocene, the placental mammals were a rather uniform group, small and mainly insectivarous. They rapidly radiated into many adaptive zones, as herbivores and carnivores, arboreal and fossorial, in the air and in the sea. Such adaptive radiations are a common feature of the fossil record at different scales (Fig. 4.13).

Evolution of a diversity of species to fill a variety of niches is called Adaptive radiation. The process of speciation on a group of islands is a form of **Adaptive radiation.**

According to "Lull", adaptations in animals are of different types and some important types specifically in 'Mammous' are mentioned below:

4.4.2.1 'Arboreal' Adaptations in Mammals:

- Animals inhabiting trres, rocks and hilly areas are generally described as Arboreal Adaptations (or) sansorial forms. This line of adaptive radiation exhibited by mammals is for a tree dwelling or arboreal life, extreme instances being observed among the **identates** and **primates.**
- These are of basically two types, viz.

1. Terrestrio-Arborial forms
2. True-Arborial forms

Terrestrio-Arborial forms: The animals which are adapted to live both on land and also on trees are called **Terrestrial-Arborial forms**. These animals usually rest on trees and make periodical visits to ground for getting food materials. Members of **Carnivora** and **Rodentia** are good examples for these animal forms.

Eg: * Sloth bear (*Melurus wisinus*)

* Palm squirrel (*Funambulus*)

* Indian gaint squirrel (*Ratula indica*)

* Kashmir flying squirrel (*Tupatarus sinensis*)

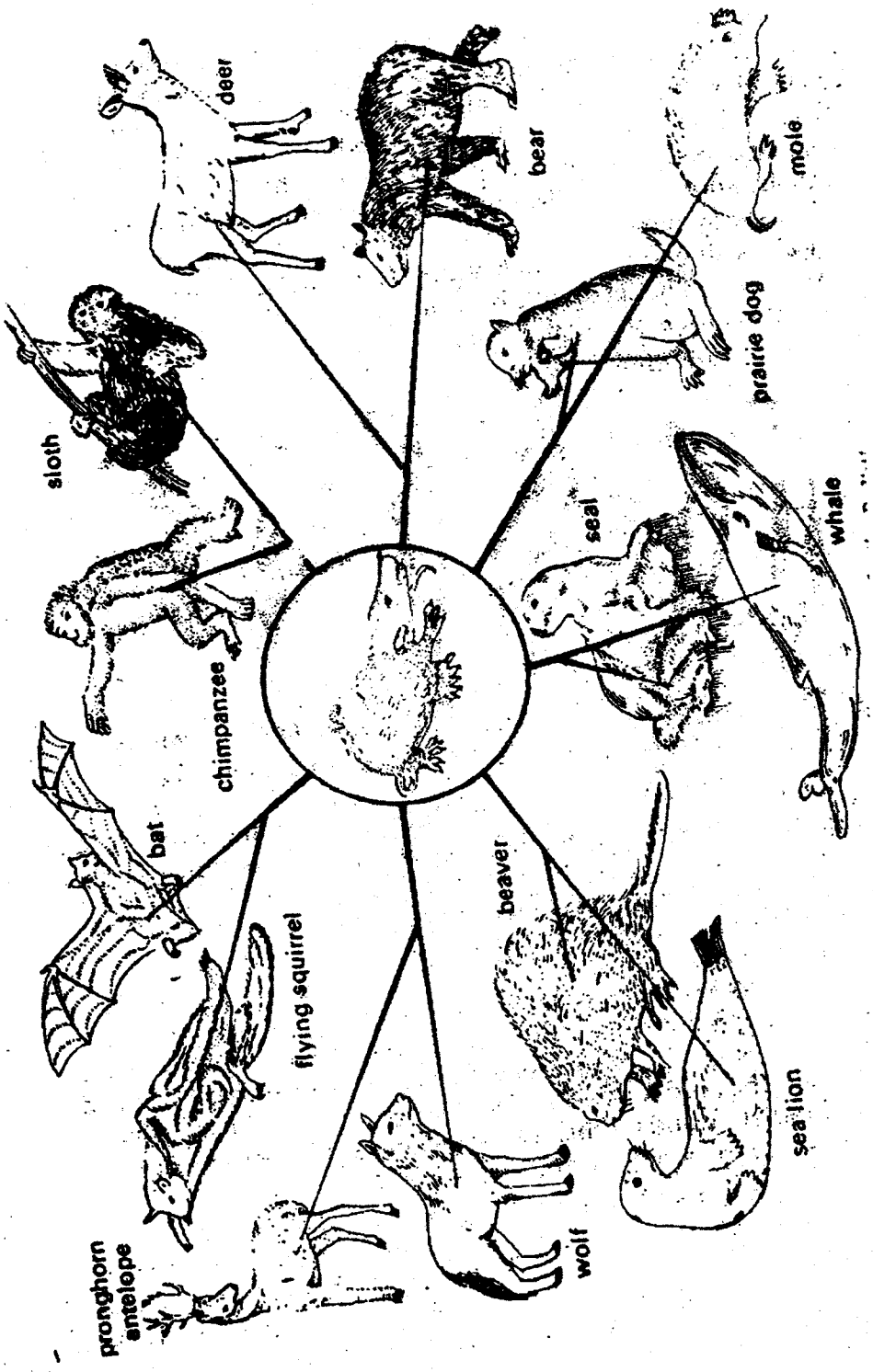

Fig. 4.13 Mammalian Adaptive Radiation

In the two toed and three toed sloths the hand and the feet are elongated and provided with powerful hook like claws which heep them to cling on to the branches. In the sloths which cling to the branches upside down the limbs shows the reduction of digits, there being only two toes in hand and three in the feet. In **Hylobates**, there is a great elongation of limbs, the knuckles of the hand touching the ground when the animal stands erect. In *Lemurs*, the hind limbs which are greatly elongated help in leaping and climbing. If non-prehensile, the feat are provided with claws. In the *Canadian porcupine* in addition to the claws, the sales of the feet are provided with spines and tubercles as well which assist in climbing.

2. True-Arborial forms:

These are the animals that have adaptations to lie on trees. These are again of 3 types, viz.

a) Branch Runner.
b) Forms suspended beneath the branches.
c) Forms swing with the help of fore limbs.

a) Branch Runner: Marsupiaes, are the good examples. These are capable of swift movement over the branches.

b) Forms suspended beneath the branches: These are incapable of running and walking on branches. Hence, they are suspended beneath the branches in upside down position. They have well developed claws with the heep of these claws they cling to the branches.
Eg: Bats

c) Forms swing with the help of fore limbs:

The **primates** are example for this category. They swim and swing easily from one branch to other with the help of powerfully built tail and fore limbs.

Adaptations for true Arboreal life:

(1) Body size: Arboreal habit imposes size limitation. Climbing activity involves greater muscular effect. Hence, majority of animals are comparatively small in size in order to subject less weight on branches.

(2) Thorax: In these animals, the thorax region is generally "sub-circular" in shape. Such shape provides support to the visceralogans when the animals are suspended beneath the branches.

(3) Girdles: The pectoral and pelvic girdles are powerfully built in the animals. In the pectoral girdle, **Clavicle** and **Scapula** are prominent. The clavicles are meant for withstanding the strain caused by compression of breast muscles. In the pelvic guirdle, the *Ilia* are very broad in size, such broad Ilia provide support to the visceral organs of the posterior abdominal regicn.

(4) Ribs: Ribs are very well developed in Arboreal farms. The number of ribs has been increased to give support to the visceral organs, when the animal is in inverted position. In these animals, the ribs leave greater curvature when compared to ribs of other animals.

(5) **Claws:** Development of claws is clearly seen in these forms. The claws are elongated and curved. In some animals claws are modified into hooks.
Eg: Sloths, Bats.

(6) **Prehensile tail:** The development of prehensile tail is very common feature in several Arboreal Mammals.

Eg: Arboreal Ant eaters, primates; in some it (tail) act as balancing organ too.

(7) **Parachuting Mechanism:** This has been developed in several forms. *Ptychozoon, Galeopithicus, Eupetarus* etc., contains a thin membrane so called *Petagium* which help in gliding from tree to tree.

4.4.2.2 Volant Adaptations:

The animals inhabiting aerial adaptations for aerial mode of life. Such animals are called **volant animals**, and the adaptations are called **flight adaptations**. Flight is of two types: viz.

- Active flight
- Passive flight

Typical valant forms are the **bats** (chiroptera) in which the framework of the wings is furnished by the forelimbs with their greatly elongated fingers.

Eg: The flying lemur galeopithecus (dermoptera)
The flying squirrel sciuropterus (Rodentia)
The flying phalangers (Marsupialia)

These 3 were capable of taking long flying leaps from branch to branch, or from tree to tree, the body being supported by wide folds of skin between sides of body and the extended limbs and in some instances the tail as well.

The flying mammals such as bats petagium heeps in gliding activity. Petagium is also supported by bones of forelimb.

In *Galeopithecus*, petagium reaches to its maximum development. It extends from posterior end of heard to tip of tail. Hence, the forelimbs, hind limbs and tail are totally covered by petagium. In these animals petagium also is a highly muscular in nature.

Anyhow, there are 3 possible modes of Aerial locomotion, viz.,

(i) Flight gliding
(ii) Soaring, and
(iii) Flapping

Gliding Mammals & Adaptations: Common examples are,

Order Marsupielia: Flying phalangers or possums (Petaurus) and feather tails (Acrabates).

Order Dermoptera: Flying lemurs (Cynocephalus)

Order Rodentia: Kashmir wally flying squirrel (*Eupetaurus cinereus*). Brown flying squirrel (*Petaurista phillipensis*).

Gliding adaptations: Elongated body, flattened and streamlined body, limbs are long and equal. Tail is long and gradually tapering. There is a double fold of furred skin, called **Patagium** or **Parachute** membrane. It is sometimes reinforced with a carbilaginous rod springing from the **elbow orurist.** When the animal is at rest, the parachute is scarcely. Visible as it remains tucked close to the body by its own elasticity.

'Flapping' or 'Flying' Mammals and adaptations:

1. **Bats**: Bats belong to order : **Chiroptera.** They are the only mammals with true and sustained flight effected by the flapping or up and down strokes of wings. They are built for flight and compete very well with the birds.

Flight adaptations of bats: Flight adaptations of bats for flight are infinitely more profound. Modifications are not so profound and conspicuous externally. However, radical changes have taken place internally in their skeleton and musculature. Their skull has been altered in the most exaggerated manner for special purposes.

a) Wings: Wings or patagia of bats are paper-thin, elastic membranes which are extensions of leathery skin from the lateral sides of body, legs and tail. Forearm is greatly elongated carrying a hand with 5 fingers. In small insectivorous *Michrochisoptera*, the first finger or pollex is short, free and sharply clawed. The other 4 fingers are clawless, enormously lengthened and embedded in the wing web to supportit, like the ribs of an umbrella, they open and close the wing and keep it tant when expanded. In large fruit-eating bats or Megachiroptera, the 2nd finger also ends in a claw. The 3rd finger is the largest, corresponding to the leading edge of the wing membrane.

In most bats, an inter-femoral membrane, also enclosing the tail wholly or partially, extends between the hind legs. It is also supported by spur of bone, the *calcar*, projecting from the tarsus of each fat. A similar **Ante-branchial Membrane**, connects the neck with the humerus bone of upper arm. Thus, there is a continuous and uninterrupted parachute of skin around the bat's body.

Bats' muscles and other body structures are specially designed to support and operate the wings. Bat has a *Capacious thorax*, containing remarkably large heart and lungs. The keeled sternum offers space for the attachment of great pectoral muscles which sustain the arms in flight.

b) Legs: Hindlegs are small, weak and with sharp curved claws on toes used for suspending the bat head down. Knee-joints are directed backwards, instead of forwards.

c) Tail: Variable. Large/small/scarcely visible. When well developed, the tail supports the inter femoral membrane which an acts as brake to flight, used as large pouch for holding prey or food, or aerial cradle for the reception of new born baby.

d) Teeth: Milk dentition of bats is curious in adaption to flight.

e) Senses: Bats are extremely modified for nocturnal flight. Bats are supersensitive to sound and possess a natural 'echo'-apparatus or Radar system of their own.

Sensitive accessory lobes on ears, called **'tragus'** help to pick up warming echos. Besides, certain bats have skin flaps around nose, i.e. **'Nose-leaf'** – its function was not well understood, probably acts as Antennae, for the perception of air vibrations.

Wing-webs – textile sensation.

So, incredibly sensitive are bats that thousands of them may swirl around for hours in total darkness in a cave without a single callision. The **'Aero-dynamics'** of bats drive engineers mad and are quite beyond us ordinary mortous.

4.4.2.3 Aquatic Adaptations:

The animals which lives in water are called aquatic animals and acquired adaptations are called Aquatic Adaptations, here with reference to Mammals (Fig. 4.11):

Three distinct Mammalian orders, viz.

The Catacea (Whales)

The Sirenia (Sea cows)

- The Seals (order: Carnivora), have secondarily become adapted to an aquatic mode of life. These animals fall under Aquatic animals i.e., animals which are adapted to live in winter but are derived from terrestrial ancestors.
- Some others such as *Ornithorhynchus* and *Chirorhynchus*, the aquatic shrews, the musk rats and the water rats which are partially aquatic exhibit only ~~partial~~ aquatic adaptations.
- In Aquatic Mammals exoskeletal structures are absent. The skin is very smooth and naked in nature.
- In Aquatic mammals, forelimbs are modified into flippers, whereas hind limbs are totally absent.
- In aquatic mammals, a subcutaneous layer, fatty layer, known as Blubber acts as thermal insulator.
- In Aquatic Mammals, external ear lobes are absent, the auditory structure is filled with oily secretions.
- Hardarian glands are present in eyes of Aquatic Mammals. The secretions of these glands protects eyes.
- In Whales, *Cervical vertebrae* are fused. In Whales teeth are completely absent. They contain Baleen plates as staining apparatus. They also heep in preventing the escape of prey.
- In several Aquatic Mammals, bones are spongy in nature, and the bones are also filled with oily secretions.
- In Aquatic Mammals, such as Whales dorsoventrally compressed bifid caudal fin is also present.
- The fact that all of the aquatic mammals breath by lungs but not gill breathers – indication of origin of Terrestrial mode of life.

Aquatic Mammals:

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

(1) Amphibious Mammals:

These animals does not live completely in water, they live on land, but go into water for food and shelter. They show only partial aquatic adaptations, viz.,

a) Small external ears,
b) Webbed feet,
c) Flattened tails
d) Subutaneous fat
e) Ectodermal variation
f) Eye variation

Eg: *Minks, seals, otters, walrus* (Carnivora)
beavers (Rodentia)
hippopotamus (Artiodactyla)
chironectes (Marsupialia)
ornithorhynchus (Monotremata), etc.

(2) Completely Aquatic Mammals:

Members of two orders viz.,

Cetacea (Whales, Dolphins and Porpoises) } Essential Aquatic forms.
Sirenia (Manatees, Dugongs)

They never come out of water. There perfect home is water.

Aquatic Adaptations:

The *Catacea* & *Sirenia* shows different adaptive features and they fall under 3 categories, viz.,

(1) Modifications of original structures
(2) Loss of structures
(3) Development of new structures

Let us consider the first aspect,

Modifications of original structures:

1. **Body shape:** External fish like, indistinct head ended region i.e. neck, stream lined body, offers little resistance and swims rapidly through water

2. **Large size & Weight:** Whale bone grows upto 35 m length and weigh about 150 tons. Large size reduces skin friction and heat loss, but creates no problem for support in water due to buoyancy.

3. **Flippers:** Forelimbs are transformed into skin covered unjointed paddles/flippers having no separation f indication of fingers. They can move as a whole only at shoulder joint. the broad and flattened flippers serve as balancers and provide stability during swimming.

4. **Hyperdaxtyly & Hyperphalangy:** Serve to enlarge the surface area of flippers for great utility in water.

5. **Mammary ducts:** During lactation, ducts of mammals glands dilate to form large reservoirs of milk which is pumped directly into mouth of young by the action of special compressor muscle. This arrangement facilitates suckling of young under water.

6. **Large lungs:** Large, unlobulated and highly elastic lungs ensure taking down. Maximum air before submergence. Like swim bladders of fishes, the dorsal lungs also serve as hydrostatic organs in maintaining a horizontal posture during swimming.

7. **Endoskeleton:** Small but wider uranium to accommodate the short and wide brain. Facial part of skull projects forming elongated snout/rostaum (porpoise). Zygomatic arches are reduced. Cervical vertebrae are fused into solid bony mass because of reduced neck. Zygapophyres are reduced. Sacrum is also reducfed. Ribs become arched dorsally to increase thorasic cavity. Bones are spongy, light, and in Cetacea, filled with oil.

8. **Teeth:** Numerous, Monophyodont, homodont, as many as **'250'**. They help in seizing prey, prevent its escape and swallowing it without mastification. Mobility of jaws is reduced, as they have no function in mastification.

B. Loss of structures:

Skin surface usually remains smooth and glistering due to loss of hairs except for a few sensory bristles on snout or lips in some. Pinnae are also absent.

- ❖ Nictitating membrane
- ❖ lacrimal glands
- ❖ sweat glands
- ❖ sebaceous glands and all other skin glands are absent.

Due to thickening and immobility, skin loses its muscles and nerves.
Hind limbs are represented only by button like knobs in the foetus but disappear in adults.
Pelvis is rudimentary.
Finer nails are absent except for traces in foetus.
Scrotal sacs are also absent and testes remain inside abdomen. All these changes triggers for effective swimming by clearing the obstacles physically as well as mentally.

C. Development of new structures:

1. **Tail flukes:** Tail develops large, lateral or horizontal expansions of skin called flukes. These are not supported by fin rays. Their up and down strokes not only propel the body through water but enable rapid return to the surface for breathing after prolonged submersion.

2. **Dorsal fin:** Most *cetacea* develops unpaired adipore dorsal fin without internal skeletal support. It serves as Rudder/Keel during swimming.

3. **Blubber:** Blubber is the thick subcutaneous layer of fat compensates for the lack of hairy covering. Acting as heat insulator, not only retains warmth of body but also provides a ready. Reservoir of food and water during emergency. Reduces specific gravity & imparts buoyancy. Blubber also counteracts Hydrostatic pressure.

4. **Melon:** It is a receptor present in front of nostrils. It consists of fatty mass transversed by muscle fibres. It possibly serves to detect pressure changes in water.

5. **Harderian glands:** Eyes under water remain protected by a special fatty secretion of Harderian glands.

4.4.2.4 Fossorial Adaptations:

The animals which spend most of their life in underground, are called sub-terranean forms. They are adopted for burrowing mode of life, accordingly their body structure was also modified. A number of examples can fall under this.

Eg: Echidna, Talpha, Rats and other Rodents.

(1) Body shape: Generally they shows the body shape, as slender or so.

(2) Head: In fossorial farms, head is narrow, pointed in nature. The tip of head is snout. Snout helps in burrowing habit.

(3) Eyes: In general, eyes are vestegeal as far as fossorial animals were concerned.
Eg: Talpha.

(4) Ears: Ears too very much reduced in size. In prototherians external carlobes are absent. The pinna has no importance in digging/burrowing, in fact becomes obstacle and soil get accumulated into it.

(5) Pectoral & Pelvic guirdle:

- In fossorial animals, clavicles of pectoral girdles are well developed.
- The clavicles and scapula are closely articulated with humurus and provide support during digging activity.

- The clavicles serve to strengthen to shoulders to withstand the immense muscular strain involved during the process of digging.
- The ilia of pelvic guirdle also fused with vertebral column and provide support to post-end of body during burrowing activity.

Generally, Adaptations for fossorial life are found among the moles (insectivora) and Ant-eaters (identata) which exhibit a number of modifications that help in burrowing. The law of adaptive radiation, as postulated originally by "Osborn", refers not only to radiation with respect to limb structure, but also to dentition.

In addition to, the above said fossorial adaptive mammalian structures. Coelomic fluid as Hydraulic fluid, Hibernation, Aestivation, Nocturnal life, Vertebrae, Fore limbs and Hind limbs also enhance and put their hands by spreading their igniting acts on adaptations of mammals.

Dentition: Arrangement of teeth on jaws, called dentition and is very from spp to spp.

4.4.2.5 Carnivorous type of dentition:

Eg: Cats (30) – Malars are absent.

4.4.2.6 Herbiverous type of dentition:

Canines are absent.
Anyhow, the dental formulae of different mammals, can be seen as:

Typical horse, pig & mole $= \frac{3.1.4.3}{3.1.4.3} = 44$

Kangaroo $= \frac{3.1.2.4}{1.0.2.4} = 34$

Rabbit $= \frac{2.0.3.3}{1.0.2.3.} = 28$

Rat $= \frac{1.0.0.3}{1.0.0.3.} = 16$

Elephant $= \frac{1.0.0.3}{0.0.0.3.} = 14$

$$\text{Man} = \frac{2.1.2.3}{2.1.2.3.} = 32$$

4.4.2.7. Adaptive radiation in Marsupials (Fig. 4.14):

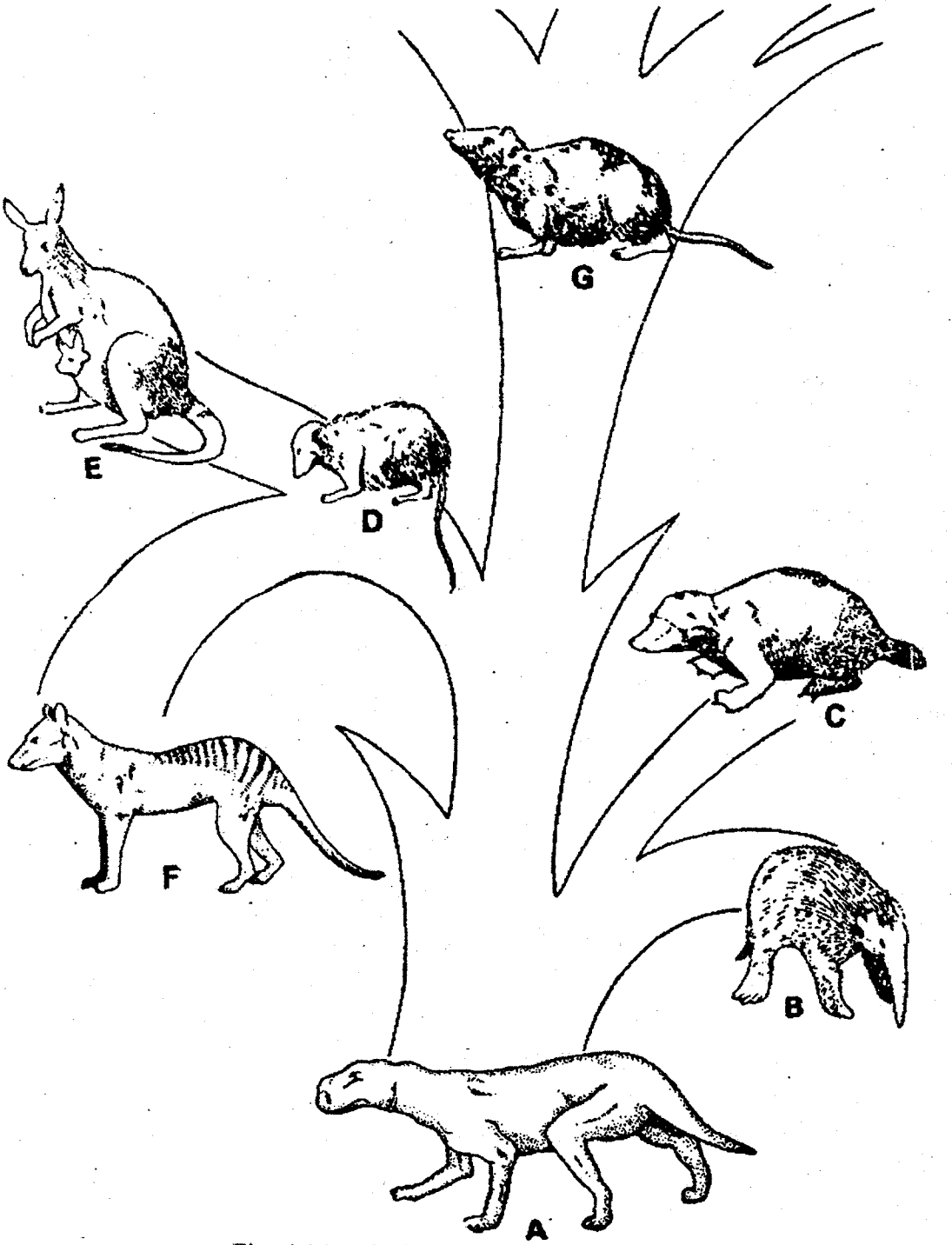

Fig. 4.14 Adaptive Radiation of Marsupials

The Marsupious of Australia have flourished and diverged along different lines to gives rise to arboreal, frugivorous, growing, ant eating, insectiverous and carnivorous forms, all due to their isolation coupled with the absence of predaceous mammals. **Dendralagus**, the tree kangaroo is arboreal in habit while the **flying phalanger** is a volant form resembling the flying squirrels, with a membranous patagium extending between the fore and hind limbs and assisting in gliding.

The *Tasmanian woef* is carnivorous form resembling true volves and myrmecabius is an ant eater remarkably similar to placental ant eaters. Chironectes is an aquatic form about the size of a musk rat and has webbed feet. The phenomenon of Adaptive Radiation is thus amply exemplified by marsupious of Australia which also exhibit several instances of close parallelism with the more advaned placental mammous.

According to 'Romer' 1966: Fossil Marupious can be identified by skeletal characteristics, especially their teeth. The first marsupious seem to have been Arboreal opposum like creatures. They may well have evolved in South America, but had a wide spread distribution as a similar fossils have also been found in North America/Europe. They seem to have reached Australia via Antarctica. Australia then became isolated from further invarions, before placental mammals reached it. The marupial group then evolved into many forms to fill available niches in continent, first as browsers of leaves and later, as the drier grass lands developed as grazers.

4.4.3 CONCLUSION

During mesozoic era, the age of reptiles, mammals were small, generalized and rare. By the end of mesozoic or beginning of coenozoic, the dinosaurs vanished and the mammals suddenly expanded into varied evolutionary patterns. Early in cretaceous period, placental mammals became distinct from Marsupious. During Eocene and aligocene, most of the orders of mammals originated moving into habitats and ecological nitches vacated by the extinct dinosaurs.

This evolution from a single ancestral species to a variety of forms which occupy different habitats is called Adaptive radiation (or) divergent evolution. The concept of Adaptive radiation in evolution was developed by H.F. as born in 1898; examples often cited as evidence include Darwins' finches of the Galapages Islands, varied limb structure of Mammous, Australian Marrupious, etc.

The adaptive radiation in Mammalians based on limb structure too, showed a primitive common ancestor was a land animal, like Modern Shrews, with short 5-toed platigrade limbs with no particular specialization. From this stem mammal various modern types have evolved by the modification of limbs and other structures adopted to a wide variety of habitats.

The five basic patterns of locomotion are:

- Running (cursorial)
- Burrowing (Fossorial)
- Treeclimb (Arboreal)
- Flying (Volant)
- Swimming (Aquatic)

Their other modifications are: **walking, leaping, graviportal, hanging, gliding, amphibious,** etc.

Finally, this evolution of a diversity of species to fill a variety of nitches/nitches is called **'Adaptive Radiation'**. Here under the heading **"Adaptive Radiation in Mammals"**.

4.4.4 EXPECTED QUESTIONS

1. "Adaptive Radiation in Mammals" – Explain.
2. What is Adaption? And what are the Areal Adoptions adopted by mammals, describe with proper examples?
3. What are arboreal adaptations in Mammous explain briefly with examples?
4. What are volant Adaptations? Explain with examples of Mammals?
5. What are Aquatic Adaptations of Mammous?
6. What are fossorial adaptations? Explain clearly the different types with proper examples from Mammals?
7. Write the evolutionary significance of Adaptive Radiation?

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Dr. K. Veeraiah

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UNIT V

LESSON 5.1

SPERMATOGENESIS AND OOGENESIS

CONTENTS

5.1.1 Introduction

In animals, the functional male germinal element, or gamete, is the *spermatozoon,* and the organ giving rise to the sperm is the male gonad, the *testis*. The functional female gamete is the *ovum,* and the organ giving rise to the ova is the *ovary.* The morphology of these organs varies somewhat according to the animal, but the gonads of all vertebrates share certain characteristics. Both the testis and the ovary have two primary functions. They produce the gametes and they secrete the sex hormones appropriate to the male or female. Here primary consideration is given to their cardinal role in the production of the gametes.

5.1.2 Spermatogenesis

In most vertebrates the testis is composed of *seminiferous tubules,* enclosed within connective tissue and separated by *interstitial tissue.* Special cells located within the interstitial tissue secrete those hormones which account for development and maintenance of the male secondary sexual characters these secretions are produced by the seminiferous tubules or both tubules and interstitial tissue cells. Regardless of a possible role in elaboration of male sex hormones, the seminiferous tubules clearly produce the spermatozoa. The seminiferous tubules communicate through a series of smaller ducts with the *ductus deferens,* which transports the sperm to the exterior.

The sperm are formed within the walls of the semeniferous tubules. The tubules reveal a microscopic pattern of organization that relates clearly to their function of producing large numbers of spermatozoa, thus they contain a variety of cell types, including sperm cells at different stages in their development. The most important of the cells in the tubules are the *germ cells,* or *primordial germ cells,* located within the cellular layer along the periphery of the tubules. It is quite possible that all the spermatozoa produced within the testis arise from the primordial germ cells. The other cells within the tubule wall serve either a supportive or a nutritive role and do not form any germinal elements.

At some time a primordial germ cell may begin to enlarge and to reveal increased internal activity, as it does so, it tends to move inward from the periphery of the tubule becomes increasingly basophilic, that is, stains readily with basic dyes, and eventually undergoes a mitotic division. The daughter cells of this division are known as *spermatogonia.* A spermatogonium itself may now undergo a division that produces two *spermatocytes.* The division of a spermatogonium, itself a product of mitotic division, to form two primary spermatocytes is another mitotic division. The spermatocytes, however, undergo two divisions that are peculiar to sex cells in process designated *meiosis.* The distinctive feature of these meiotic divisions is the reduction of the chromosomes to one half the normal numbers. Thus the spermatogonium of the human normally contains 46 chromosomes. This is of the primary spermatocytes derived from the spermatogonium, because this is mitotic division. Following the meiotic divisions of the spermatocytes, however, the resulting *spermatids* contain one half the normal chromosome complement, the *haploid set.* Thus each diploid spermatocyte generates four haploid spermatids. An understanding of the general sequence of events may be gained from the reduction of chromosome number in gametogenesis obviously is responsible for the constancy of chromosome numbers and kinds in species. When a haploid sperm eventually unites with a haploid ovum, the fertilized egg is a diploid cell. Meiosis is comparable in the male and female.

5.1.3 Morphology of the spermatozoan

The completed spermatozoan may reveal great variation among animal classes, but it appears to possess a basic morphological plan that relates to the functional aspects of sperm viability and fertilization. The sperm may be divided into four parts; head, neck, middle piece, and tail The head is composed of an *acrosome* and a larger *nucleus.* It is self derived from the golgi apparatus of the spermatic, the acrosome forms, in addition to a compact mass atop the nucleus, a double-layered membrane, which covers the external surface of the acrosome itself and extends downward along the outer surface of the nucleus to form the *head cap* of the sperm. The acrosome appears to play an important role in the penetration of the ovum at fertilization and in stimulating, or activating, the egg to further development. The acrosome in some species, mostly marine invertebrates, actually releases an acrosome *filament* upon contacting the ovum. The nucleus of the sperm contains the male hereditary material in the form of dense *chromatin,* which appears to be concentrated deoxyribonucleoprotein, all else having been eliminated from the sperm during its formation from the spermatid.

The *neck* of the sperm is primarily the location of *proximal* and *distal centrioles.* The two centrioles lie at right angles to one another. The distal centriole forms and gives attachment to the *axial filament* of the sperm tail; the proximal centriole assumes great importance in the first division of the fertilized egg.

The middle piece of the spermatozoan is composed almost entirely of *mitochondria.* The mitochondria in some animals form compact, isolated clumps throughout isolated clumps throughout the middle piece; in many others the mitochondria form a compact sheath surrounding the distal centriole and the proximal part of the axial filament. The mitochondria are carriers of the oxidative enzymes and the enzymes responsible for oxidative phosphorylation. The middle piece of the sperm, are primarily related to the metabolic and energetic aspects of sperm function.

The axial filament forms the main element in the tail of the sperm. It is surrounded by a small amount of cytoplasm and the cell membrane. Mammalian sperm contain additional, smaller fila-

ments surrounding the axial filament. The tail provides the basis for motility of the sperm. The sperm must travel varying distances to encounter an ovum; its means of locomotion is whipping, lashing, or undulating motion of the tail.

5.1.4 Factors controlling spermatogenesis

Foremost among the external influences upon the testis of vertebrate animals are the endocrine glands, in particular the *pituitary gland,* or *hypophysis.* This gland is located at the base of the brain, where it is attached by a stalk to the *hypothalamus,* the ventral most area of the portion of the forebrain known as the diencephalon. The pituitary gland is composed of two major divisions, an *anterior lobe,* or *adenohypophysis,* and a *posterior lobe,* or *neurohypophysis.* Both divisions of the pituitary secrete a variety of hormones that affect most parts of the organism. An important group of hormones secreted by the anterior lobe (adenohypophysis) is that of the *gonadotrophic hormones.* Among other effects, the gonadotrophins maintain the gonads at a level of optimal function. The onset of spermatogenesis and its completion occur under the influence of the pituitary-produced gonadotrophins.

It has long been known that light exerts a profound effect upon the pituitary gland and the levels of gonadotrophin activity. It is now clearly recognized that in birds and rodents, among other vertebrates, gonadotrophin secretion and gonadal activity is influenced by the length of day.

In many vertebrates the influence of light upon gonadal activity is mediated through a series of neural structures, beginning with the retinal layer of the eye. Neuronal relays in the basal parts of the forebrain (telencephalon and idiencephalon), in particular the hypothalamus, culminate in an active process of neurosecretion. Neurohumoral elements liberated from the localized groups of nerve cell bodies termed *hypothalamic nuclei* affect the secretion and release of the gonadotrophic hormones of the adenohypophysis and thus gonadal activity.

5.1.5 Origin of the germ cells

Cells which give rise to eggs and sperm are referred to as primordial germ cells. Among the invertebrates the early origin or segregation of the germ cells remains obscure in coelenterates and annelids. In other invertebrates, notably the dipterous insects and the ascarid worms, there is early segregation of the germ cells.

In teleost fishes the germ cells arise early in development from the endoderm (the innermost germ layer) and migrate from there through the endoderm and overlying mesoderm to their final location within the developing gonad. Thus in *Fundulus* the germ cells have been identified early within the endoderm lateral to the posterior half of the body; from this location they migrate to the mesodermal anlagen of the gonad. A similar pattern has been described for the guppy, *Lebistes.*

In amphibians the germ cells have an early, extragonadal origin. The specific site of origin varies according to the taxonomic order. In urodele amphibians the germ cells originate in the poster ventral part of the lateral mesoderm, later migrating to the gonad. In anuran amphibians the germinal cytoplasm appear to originate before cleavage within the subcortical area of the vegetal or lowermost pole of the egg; during cleavage these cells migrate into the endoderm of the embryo, passing from there to the dorsal mesentery to the gonad. Recent experimental evidence supports the view that in anurans the gametes are produced by germ cells identifiable within the endoderm by the neurula stage. Most cells in the normal embryo of the South African clawed toad, *Xenopus laevis,* bear two nucleoli per nucleus. By an appropriate mating of normal and mutant frogs it is possible to obtain *Xenopus* embryos in which the constituent cells contain only one nucleous per nucleus. This is a *nuclear marker;* which provides a morphological criterion distinguishing cells derived

room a normal embryo and cells derived from a marked embryo. A natural marker of this variety greatly enhances experimental design and study of fates of cells, artificial markers (for example, radioisotopes) usually have certain disadvantages, and the embryologist is well advised to exploit a natural marker whenever possible. In *Xenopus*, following transplantation of tissues from a normal (two nucleoli per nucleus) to a marked (one nucleous per nucleus) embryo, any cell arising from the transplanted material, regardless of its final location, may be identified by the presence of two nucleoli in its nucleus. Using this method it has been demonstrated that when posterior endoderm containing primordial germ cells is transplanted from a normal *Xenopus* neurula to the same site in a marked *Xenopus* neurula, the germ cells migrate into the gonad and later produce functional gametes.

In birds and reptiles also the germ cells have been assigned an extragonadal origin. In the chick, the germ cells are said to originate from the endodermal layer of the extraembryonic part of the blastoderm just anterior to the head region of the embryo. It is believed that these cells migrate into the developing gonad via blood vessels. Experiments in which these germ cells have been destroyed by cauterization or irradiation prior to their migration reveal that, under these circumstances, the fully formed gonad contains no primordial germ cells.

Studies have been performed on various mammals. The germ cells of the mouse originated from the germinal epithelium of the gonad; recent studies, however, suggest that in the mouse, as in other vertebrates, the germ cells originate in the endoderm before migrating into gonad. Thus, utilizing the marking capacity of the high alkaline phosphates content of the germ cells, it was possible to determine their location within the caudal endoderm and their subsequent migration into the developing gonad.

The germ cells appearing very early in embryonic development degenerate, and new germ cells arise from the ovarian or testicular tissues. Degeneration of embryonic cells before they give rise to functional structures is common in development; the primitive kidney of the chick embryo, for example, degenerates and the functional kidney arises from other cells. Similarly, the blood vessels of certain aortic arches degenerate in the embryo.

5.1.6 Oogenesis

In female vertebrate animals ovulation involves a seasonal or a rhythmic process in which the egg is liberated from the ovary into the body cavity. From there the ovum is transported into the oviduct and thence, by means of ciliary movement and or peristaltic motions of the oviduct, to the uterus or the exterior. The preovulatory egg develops in the ovary from a very small oogonium to a large egg, which at ovulation may be in one or another of the stages of maturation, depending upon the species. This maturation process involves, first, a reduction in the number of chromosomes in the egg **Fig 5.1**. Attendant upon this reduction in chromosome number there is, as in the sperm, a segregation of the hereditary units, a phenomenon which assures that eggs of different genetic composition are produced within the same species. In some species the sex chromosomes seggregate during maturation, giving rise to two types of sperm.

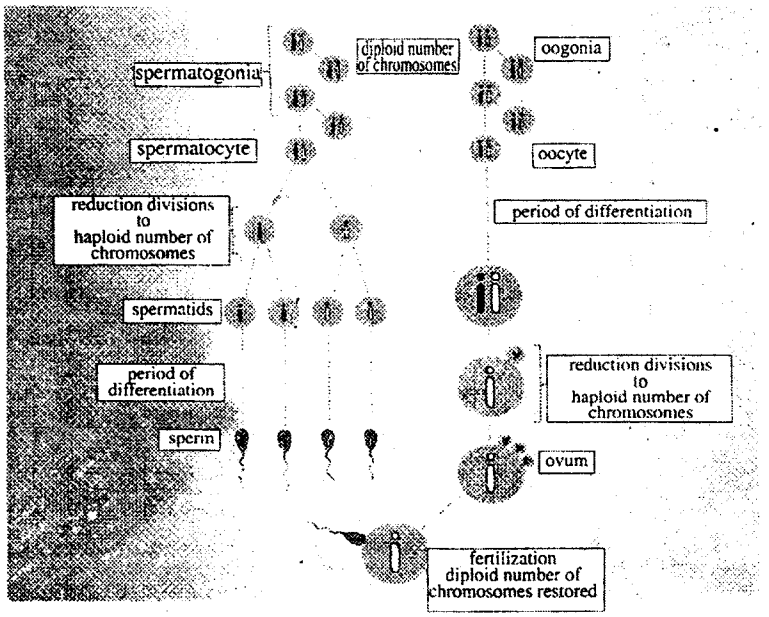

Fig. 5.1 Maturation of the germs cells and the combinations of chromosomes at fertilization

Growth of the ovum is the most striking aspect of maturation. Most of the primitive germ cells are approximately 10 microns (0.01 millimeter) in diameter, the size of an average body cell. In mammals such cells increase to a size that in some species may reach a diameter of 200 microns. In the frog the increase is up to a diameter of 2000 microns; in birds the diameter of the ovum is as large as 40,000 microns. This tremendous increase in size results primarily from the deposition of yolk, which, because it is rich in fats, carbohydrates, and proteins, constitutes a useful energy source and a source of raw materials for the synthesis of protoplasm. The large size of eggs, then, reflects not so much an increased amount of protoplasm as an increased amount of stored food materials. The organization of the ovum is discussed. At this time only the yolk and its formation will be outlined.

Yolk is the usual form of food storage in the egg. Most eggs contain some yolk, which is similar in composition to that of the hen. Normally in the form of yolk granules or platelets it is composed primarily of proteins, phospholipids, and neutral fats. In the mature amphibian egg, for example, protein yolk represents roughly 45 percent of the dry weight of the egg, lipoids 25 percent, and glycogen approximately 8 percent. Yolk may occur within the cytoplasm of the egg, as in many invertebrates, lower chordates, and amphibians, or it may be more or less seggregated from the cytoplasm, as in bony fishes, reptiles, and birds.

The yolk itself in some, perhaps all, cases is not synthesized within the oocyte. Yolk components are produced at a site external to the oocyte and transported in soluble form via the blood stream to the oocyte, where they are converted, through the activity of the mitochondrial enzymes, into insoluble yolk granules. There is good evidence in vertebrates, for example, that egg proteins and phospholipids are synthesized in the liver and then transported to the oocyte. Quantitative radio assay experiments in the bird reveal that the incorporation of radioactive precursors is highest initially in the liver and lowest in the oocyte. Within 12 hours after injection of the labeled compounds, however, the radioactivity of the liver decreases by approximately 40 percent, whereas the radioactivity of the oocytes increases by more than 80 percent, indicating the initial synthetic process in the liver and the later transfer of these compounds to the oocytes. This scheme is slightly complicated by the close relation between the oocytes and the surrounding follicle cells. In most animals microvilli emerge from the surface of the oocyte, interdigitating with microvilli derived from the adjacent

follicle cells. The latter represent an intermediary whereby intercellular transfer of materials may occur. In some invertebrates (some insects, annelids, and mollusks) special *nurse cells*, acting in conjunction with follicle cells, play an important role in providing nutrition for the growing oocyte. Various building materials pass into it from the nurse cells and follicle cells. And follicle cells. These cells should, then, be considered an integral part of the metabolic apparatus of the oocyte.

5.1.7 Ovulation and egg transport

After the egg has deposited all its yolk and passed through the necessary phases of maturation it is ready for ovulation and, in higher animals, transport into the obviduct. The time of ovulation is directly related to the breeding cycle of the animal involved; thus the timing and control of ovulation are important biological problems. These appear to be, in general, two quite different controls for ovulation. One is an environmental control, as a result of which animals ovulate during a brief period once a year, according to the season. The other type of control is an internal control that establishes a rhythm, independent of season, so that the animals ovulate once a day, once every 5 days, once a month, or once in any given period. There are a few exceptions to this pattern of rhythmic, spontaneous ovulation: the ferret, cat, and rabbit, for example, ovulate shortly after copulation with the male, in these cases the control is a particular stimulus, copulation, which elicits release of the egg from the ovary.

The large ovary, containing approximately 2000 eggs, is attached by a membrance to the body wall. The ova inside the ovary are almost 2 millimeters in diameter and lie enclosed within membranes that form a follicle. After attaining maximal size, the eggs break out of their restraining follicles and fall into the body cavity or coelom. The coelom is lined with peritoneum, a thin cellular layer with cilia covering its surface. A rhythmic, synchronized beating action of the cilia literally sweeps the ova forward from the vicinity of the ovary to the opening of the *oviduct*, which lies dorsal to the lung. The eggs, then, traverse a large section of the general body cavity before entering the opening (ostium) of the oviduct. As it passes through the oviduct, each egg is covered with various coats of jelly, finally coming to rest in the enlargements of the oviducts called *uteri*. Each ovum undergoes this process until about 2000 eggs have accumulated in the uteri. The entire mass of eggs is released at the time the time the male liberates sperm, and fertilization occurs externally in the water. After ovulation the small germ cells in the ovary begin to grow, and next year's eggs are formed.

The general events of ovulation and egg transport in mammals **(fig. 5.3)**

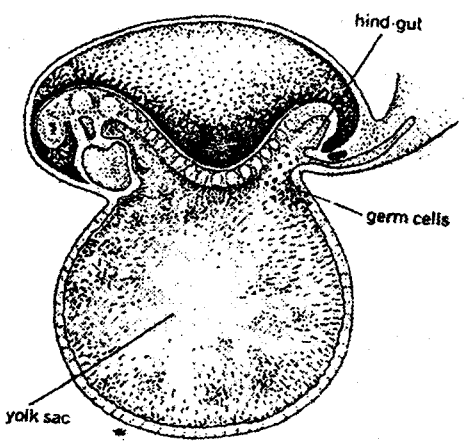

Fig. 5.2 A human embryo (ca. 4 weeks old) showing the original position of the primordial germ cells. The germ cells (black dots) are located in the ventral wall of the hind-gut and in the adjoining region of the yolk sac.

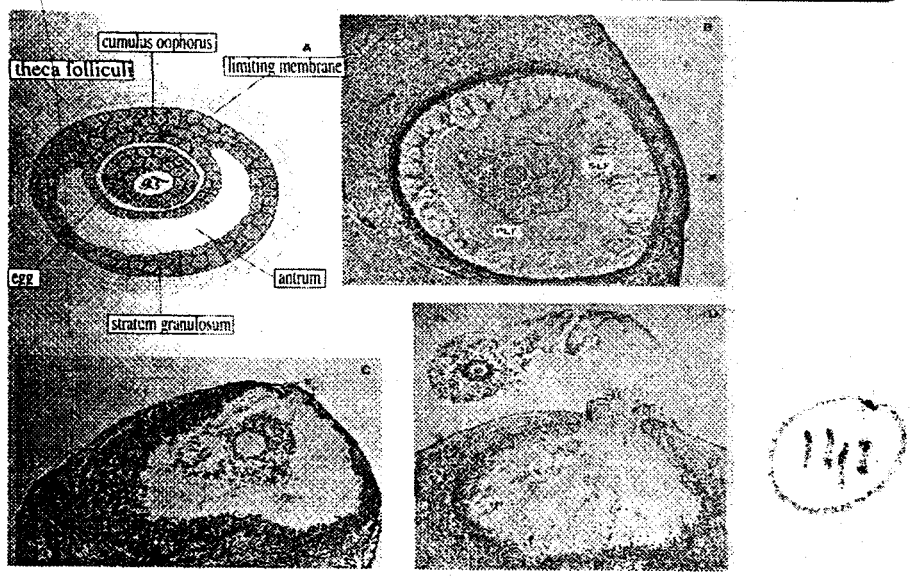

Fig. 5.3

A : Drawing of a mammalian egg contained within its follicle and illustrating the relationships of the various cellular layers to the ovum and the follicle. B : Section of a preovulatory follicle of the rabbit showing loosened cumulus oophorus, the primary liquor folliculi (PLF) and secondary liquor folliculi (SLF) which is secreted just before ovulation. C: An ovulatory follicle of the rat at the moment of rupture. Stigma (S) is liftng away from the surface. and the cumulus oophorus is moving toward the stigma. Note the follicular fluid tension lines directed towards the stigma D: Section through an ovulatory follicle of the rabbit. The follicular contents remain adherent to the stigma; the cumulus cells are widely dispersed and the cells of the corona radiata are still intimately adherent.

In the mammal each egg matures within a *follicle* composed of cubodial epithelium cells. As the follicle grows, a cavity or *antrum* develops within the follicle, and eventually the ovum, surrounded by follicular cells, extends into a large, fluid-filled cavity **(fig. 5.3)**. When the mature ovarian follicle reaches such a size that it bulges from the surface of the ovary, changes occur in one or several small areas of its surface. A small area of the follicular wall becomes deprived of its vascular supply, and soon thereafter the wall raptures at this point (the stigma) **(fig. 5.3)** releasing the ovum, still surrounded by some follicular cells, into the coelom **(fig. 5.3)**. In mammals the ostium of the oviduct (uterine tube) lies near the ovary. As the time of ovulation approaches, the oviduct displays increased motility, so that it tends to move about the surface of the ovary. The mammalian ovum is released, as is that of the frog, directly into the body.

Cavity, although the distance from the ovary to the ostium of the oviduct play an important role in transport of the ovulated eggs into the tube. Increased peristaltic motility of the oviduct ensures their passage to the uterus. Fertilization in the mammal is internal, usually occuring in the oviduct. After ovulation the collapsed ovarian follicle shrinks and becomes filled with cells to form a solid body, the *corpus luteum.* In the absence of pregnancy, the corpus luteum increases in size for awhile, but it finally degenerates, and a new ovarian follicle begins to enlarge in some other region of the ovary. This new follicle grows, develops an atrium, forms a stigma, and finally another ovulation occurs. This cycle is repeated regularly, but if pregnancy occurs, the corpus luteum is maintained and the ovulatory cycle is suspended until after parturition.

5.1.8 Hormonal regulation of ovulation

One of the most important agents regulating ovarian function and ovulation in vertebrate animals is the pituitary gland. Removal of the pituitary gland of the frog prevents ovulation; indeed, the cycle is completely halted, and eggs are neither produced nor liberated. Reimplantation of the pituitary gland or injection of extracts of the gland into a hypophysectomized animal will, however, induce ovulation. This is true of many other vertebrates. The influence of pituitary is, then, necessary for ovulation. The gonadotrophic hormones

are responsible for ovarian function and ovulation in vertebrates and the primary factor in establishing the ovarian cycle and inducing ovulation appears to be the regulated secretion of these hormones by the pituitary gland. It is appropriate now to inquire into the relation between the gonadotrophic hormones and the specific events of the ovarian cycle and ovulation in mammals.

There are two distinct processes in the ovarian cycle of mammals:

(1) A growth of the follicle culminating in ovulation

(2) The formation of the corpus luteum.

These two processes are believed to be controlled by three gonadotrophic hormones produced by the pituitary gland. One hormone, the follicle-stimulating hormone (FSH), induces ovarian follicular growth in immature or hypophysectomized female mammals as well as the intact adult animal. A second pituitary hormone, the luteinizing hormone (LH), acting alone, has little or no effect on ovarian size or follicular growth, but when acting synergistically with a small dose of FSH it elicits follicular maturation, ovulation, and the formation of corpora lutea. A third hormone, the luteotrophic hormone (LTH), is responsible for milk secretion and for maintaining the corpus luteum in a functional, secretory state.

The rhythmic nature of ovarian activity cannot be explained solely on the basis of hypophyseal dominance; the pituitary in turn is influenced by two ovarian hormones, estrogen and progesterone. The relation between hypophyseal and ovarian hormones illustrates admirably the close interdependence of organic elements regulating reproductive functions the manner in which the two ovarian hormones and the three gonadotrophic hormones act reciprocally and jointly to establish the rhythmic cycle is not completely known, but it is believed to occur according to the following general scheme. The pituitary hormone FSH, especially with the synergistic effect of a little LH, stimulates follicular growth and the production of estrogen in the ovary. The estrogen acts upon the hypophysis to stimulate secretion of increased amounts of LH and LTH, and to cause a decreased secretion of FSH. Under such conditions, ovulation and formation of corpora lutea occur. The corpora lutea, which produce the progesterone, are activated and maintained by LTH. When the corpora lutea begin to regress, the amounts of ovarian hormones are reduced, with the result that the pituitary again produces FSH to initiate repetition of the ovarian cycle. During pregnancy, when the corpus luteum persists because of the presence of an embryo, there is no follicular growth or ovulation, and placental hormones replace the ovarian hormones.

5.1.9 Neural control of ovulation

The nervous system is profoundly involved in regulation of pituitary activity. Neural fibers emanating from hypothalamic nuclei are known to course in the pituitary stalk to that portion of the pituitary (neurohypophysis) that is concerned with functions other than secretion of gonadotrophic hormones. There is no satisfactory evidence that the anterior lobe of the pituitary (adenohypophysis) receives any fibers from the hypothalamus. There is, however, good evidence that venous connections *(hypophyseal portal system)* establish a functional relationship between these two structures **(fig. 5.4)**

Transplantation experiments, which show that the adenohypophysis must establish a vascular relationship with the hypothalamus before normal gonadotrophic functions are restored. The hypophyseal portal system provides a structural base for the humoral regulation of pituitary function.

Pituitary secretion of FSH and LH and their accurately phased secretion rates appear to be controlled by a hypothalamic neurohumoral activity. Specific hypothalamic centers appear to be concerned with stimulation of FSH secretion, others with LH secretion, others with inhibition of LH

secretion. These hypothalamic centers, in turn, are affected by circulating ovarian and other hormones and metabolites. A direct-acting luteinizing hormone-releasing factor (LHRF) which is capable of inducing ovulation in an ovulatory rat has been isolated from the hypothalamus of sheep and cattle. A center concerned with the inhibition of LH release has also been proposed, and there have been suggestions of an FSH releasing center.

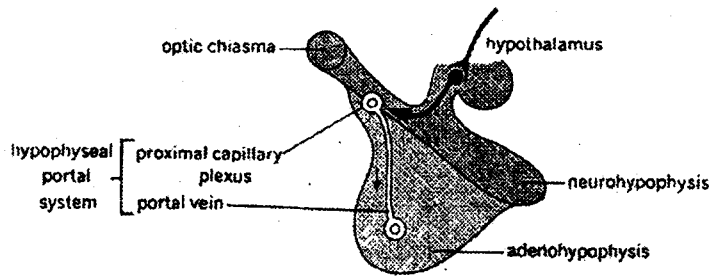

Fig. 5.4 A possible pathway for the stimulus which r ing hormone (LH) from the anterior lobe of the pituitar acetylcholine in the hypothalamus, passes over a synap This nerve has its terminus around the proximal cap portal vein. At this point the adrenaline-like substar blood stream and flow through the portal vein to the a there stimulate the release of LH.

Ovulation normally occurs subsequent to copulation in rabbits, ferrets, cats, and in some other animals' species. The inciting stimulus in these animals is in part neural; the semen does not contain an ovulation inducing factor. The neural stimulation attending mating does not involve the ovaries directly. Transplanted ovaries deprived of their normal innervations will not provoke ovulation. The stimulus of copulation acts upon the pituitary to release an ovulation-stimulating hormone. Supporting evidence comes from the demonstration that removal of the pituitary of the rabbit 1 hour after copulation does not suppress ovulation, whereas removal of the gland immediately after copulation does prevent follicular maturation and rupture. Two neurochemical agents have been implicated in this process. The application of acetylcholine to the pituitary glands of rats has resulted in pseudopregnancy, and the injection of epinephrine into the pituitary gland of the rabbit has induced ovulation. In addition, the injection of drugs that inhibit adrenergic activity inhibits ovulation in rabbit's consequent to mating.

5.1.10 Conclusion

The number of functional gametes produced is not necessarily large. In the ovarises of human infants, for example, there are 100,000 to 1,000,000 oocytes, and yet it is estimated that in 30 years of reproductive life a maximum of 390 of these ova are actually ovulated. Further experimentation, taking advantage of various cell markers, and studies involving transplantation of individual germ cells may contribute to the establishment of the lineage of the gametes and clarification of a possible direct c respondence of germ cells and the total number of functional gametes. Some insight may be gained through a more adequate understanding of the behavior and the developmental possibilities expressed in tissue culture by germ cells removed from embryos at various stages of development.

5.1.11 References

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5.1.13 Expected questions

1. Describe the process of spermatogenesis.
2. What are the factors that influence the process of spermatogenesis?
3. Give an account on oogenesis.
4. Describe the role of hormones in the regulation of oogenesis.
5. Explain the process of neural control of ovulation.

Dr. K. Veeraiah

UNIT V LESSON 5.2

FERTILIZATION

Contents

5.2.1 Introduction

The union of the spermatozoon and ovum inaugurates the process of embryonic development. The action of the sperm upon the egg stimulates the latter to development of its organization. Fertilization, then, exercises an activating effect upon the egg. Another and quite different aspect of fertilization is the addition of the paternal chromosomes to the egg. In this discussion, however, attention will be focused upon the activating aspect of fertilization rather than upon its genetic aspects.

5.2.2 Viability of eggs and sperm

The lifespan of eggs and sperm is quite limited. The length of life of an egg and the length of its fertilizability are quite variable in different species. Most invertebrate eggs and eggs of aquatic vertebrates must be fertilized almost immediately after ovulation. The period during which and egg may be fertilized after its release from the ovary in mammals is difficult to ascertain, but in general the mammalian egg appears to remain fertilizable for approximately 24 hours. This does not necessarily reflect the period of time it takes for the sperm to traverse the female reproductive tract. In the mouse and hamster, for example, the sperm may arrive in the oviduct and fertilize an ovum within minutes after deposition in the vagina.

It is relatively easy to determine the viability of sperm by motility or potential motility. Yet it should be remarked that the lifespan of a sperm is not an index of its fertilizing power. A sperm may be active and apparently normal and yet be incapable of fertilizing an egg. Sea urchin sperm will live for several days, but the fertilizing capacity of active sperm is usually lost within 12 hours, the maintenance of fertilizing capacity by mammalian sperm in the female reproductive tract is also measured in hours. The rapid aging of both sperm and egg imposes demands for fertilization soon after their release. Hence it is not surprising that in some marine animals spawning of the female stimulates the release of sperm from the male. This situation increases the likelihood of fertilization by ensuring the liberation of sperm and eggs into the water almost simultaneously. In other species simultaneous shedding of gametes is stimulated by light or the lack of light, tides, and other environmental factors. Self-inactivation of sperm by their own extracts has been believed to prolong sperm longevity by

keeping them in a quiescent state until they are activated, as by the presence of the egg. Such a mechanism makes less astounding the survival of bat spermatozoa in the female reproductive tract during the water hibernation period or the prolonged retention of spermatozoa in the male and female reproductive tracts of fishes and amphibians without loss of capacities for motility and fertilization.

The length of life of the sperm and their fertilizing power are functions of a number of variables, many of which are still unknown. One known variable is the concentration of the sperm. Sperm must be concentrated in a thick suspension to survive for an appreciable length of time. If diluted with fluids they lose their fertilizing power. Another important factor in survival of sperm is the hydrogen-ion concentration of their medium. In a more alkaline environment sperm become more active, but they deplete their reserve supplies of energy and die early.

Artificial insemination in domestic animals is quite common, and a great deal has been learned about sperm metabolism through the studies conducted by livestock breeders. Concentrated in their own fluids, sperm will remain active for many hours, and various artificial fluids, sperm will remain active for many hours, and various artificial fluids have been devised to prolong activity. Another factor identified through studies of artificial insemination is the temperature at which the sperm are kept. The sperm of even a warm-blooded animal will survive longer at a lower temperature. Rate of cooling is also an influential factor. The importance of the hydrogen-ion content of the medium has already been mentioned; carbon dioxide concentration is also important; sperm, by producing carbon dioxide, tend to reduce their own activity, thus prolonging their life. It has been found that the age of the sperm is a factor that determines whether or not fertilization will be normal. The concentration of sperm is important to fertilization, as well as to the survival of sperm. If the number of spermatozoa per unit volume falls below a certain level no fertilization will occur, even though millions of sperm are present.

In actual practice of artificial insemination of mammals, sperm are collected in a rubber tube or another form of artificial vagina. After it is collected the semen is cooled gradually to approximately 40°F for storage or shipment. The semen may be diluted and injected into the oviduct or uterus of the female and fertilization effected as long as I week after collection of the ejaculate. In recent decades there has been remarkable success in maintaining mammalian and avian sperm in a viable condition at extremely low temperatures. Semen, to which has been added glycerol in concentrations of 10 to 20 percent, has been stored for varying periods at temperatures of -79° to -196°C. Bull spermatozoa have been stored successfully in this manner for as long as 6 years. Artificial insemination with previously deep-frozen, thawed sperm has resulted in conception and viable young in a number of animals. Indeed, pregnancies have been reported for several women inseminated with spermatozoa treated in this manner. Artificial insemination has great economic importance and clinical significance. The economy of the practice may be emphasized by citing a case in which, by this means, a single ram sired 2500 lambs in one season. The knowledge acquired through study of the biology of sperm and the practice of artificial insemination possesses clinical importance, and artificial insemination has been practiced on numerous occasions in cases of couples childless because of borderline fertility or actual sterility of the male.

5.2.3 Events of fertilization

A characteristic of reproduction in all animal species is the liberation of an excessive number of sperm relative to the number of eggs. The ejaculate of a fertile man, for example, contains a total of approximately 350 million sperm. If the concentration of sperm is less than 60 million sperm per milliliter or the total sperm count is 150 million or less, the fertilization capacity is drastically reduced. The excess of sperm is, then, only apparently wasteful; it relates to fertilizing capacity. All the reasons for this relation are not clear; it is true, however, that the environment, including the interior of the female reproductive tract, is often inimical, and millions of spermatozoa perish without ever approaching the egg. Even in animals with internal fertilization, the number of sperm that actually arrives at the site of fertilization is impressively low. In rat, for example, approximately 70mililion sperm are ejaculated at mating, but 12 hours later less than 50 sperm may be found at the fertilization site in the oviduct. It has been suggested that in some lower animals the egg emits a substance that attracts and guides the sperm toward the egg (*chemotaxis),* but the experimental evidence supporting this contention is equivocal. Movements of the sperm appear to be random and the effective union of the sperm and egg a matter of probability, low in the case of those animals that spawn in the open sea, higher in animals in which fertilization is internal. The large number of sperm relative to the number of eggs is such that probability favors a random collision of egg and sperm **(fig. 5.5)**

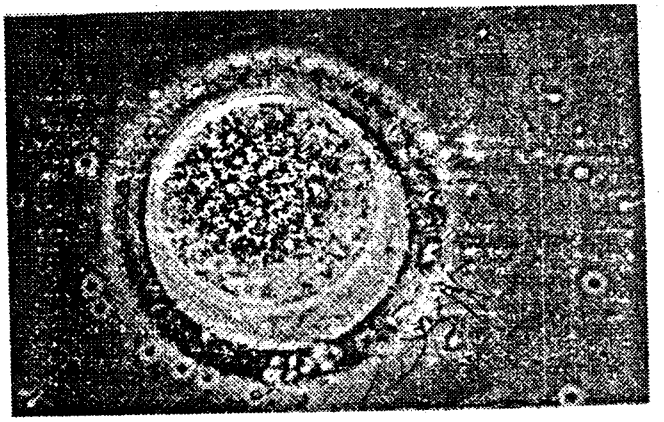

Fig. 5.5 Human egg and sperm

Regardless of any other meaning, the disproportionate number of sperm is quite necessary to increase the chance of fertilization.

There is considerable evidence that in some animals (echinoderms, mollusks, annelids, tunicates, and vertebrates) the egg is equipped with a mechanism that causes the sperm to adhere to its surface. This chemical device is best demonstrated in sea urchins **(fig. 5.6)**

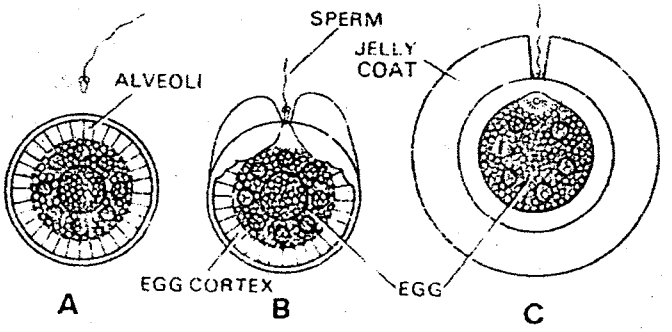

Fig. 5.6 Some effects of egg jelly and sperm extract

The jelly coat of the sea urchin egg contains a gel-forming glycoprotein with a molecular weight of approximately 300,000. This substance possesses the capacity to cause clumping, or *agglutination,* of sperm of that species; hen e in the presence of the egg, or in water in which the eggs have resided, the sperm tend to agglutinate. In general, the sperm of one animal species will not adhere to or penetrate the eggs of another species. It was this specificity of fertilization and the discovery of agglutination of the spermatozoa of some marine animals following addition of supernatant of a suspension of eggs of the same species that led F.R. Lillie to formulate 50 years ago .the first modern theory of fertilization. Lillie called the agglutinating substance *fertilizin* and assigned it a central role in a theory of fertilization based upon immunological analogies. According to the modern form of this theory, fertilizin from egg water is multivalent, each molecular site linking to spermatozoon. Fertilizin in the jelly coat normally would cause a species-specific attachment to spermatozoa. There is evidence that fertilizin is also located in the egg plasma membrane and acts as a receptor for antifertilizin, an acid protein located on the surface of spermatozoa. It is the union of fertilizin and antifertilizin that accounts for the initial attachment of the sperm and represents the functional event of fertilization. The reaction between the two molecules is considered similar to the 'lock and key reaction between antigen and antibody, and the binding of the two complementary substances is supposed to derive from the spatial pattern of atoms on certain parts of the fertilizin and antifertilizin molecules. There is clear evidence for the existence of various fertilizins specific for various species; the evidences for antifertilizin is less clear, although proteins have been extracted from sperm that fulfill the functional criteria of antifertilizin. It should be noted that fertilizin, even if it accounts for sperm attachment in some animals, may not be an absolute requirement for fertilization itself. It would, then, be premature to conclude that the fertilize-antifertilizin theory expresses a critical process in fertilization with universal applicability throughout the range of animals groups.

It will be recalled that, with few exceptions, the eggs of animals re surrounded by a noncellular coating external to the plasmalemma of the egg. The mammalian zone pellucid and the jelly coat of the sea urchin egg, just discussed, represent such membranes. The presence of these layers external of the surface of the egg, the sperm must penetrate the envelopes with which it is surrounded. In most animals the sperm must make its way through the egg envelopes without the benefit of a special structure, but in some animals, largely, if not exclusively, marine invertebrates, a straight, rigid *acrosome filament* (or filaments) pierces the envelopes to reach the egg proper, and the sperm follows along a path created by the filament. The sperm of various species of invertebrates and vertebrates are known to contain lytic agents capable of causing dissolution of these outer membranes. These agents, known as *sperm* lysins, are localized within that part of the sperm known as the *acrosome.* In mammals the sperm must penetrate a variable number of layers of granulosa cells adhering to the egg *(cumulus oophorus)* as well as the zona pellucida and vitellus. An enzyme belonging to the *hyaluronidase* group is believed to aid sperm penetration by depolymerizing and hydrolyzing the intercellular cement uniting the granulosa cells. The acrosome has been suggested as its carrier, but to data this enzyme has not been accurately localized within the sperm itself. Nevertheless it is assumed that the enzyme is an integral part of the cell which is liberated in a relatively localized region as the sperm progresses through the cumulus.

The general events of fertilization are sum. irized in **fig. 5.7**

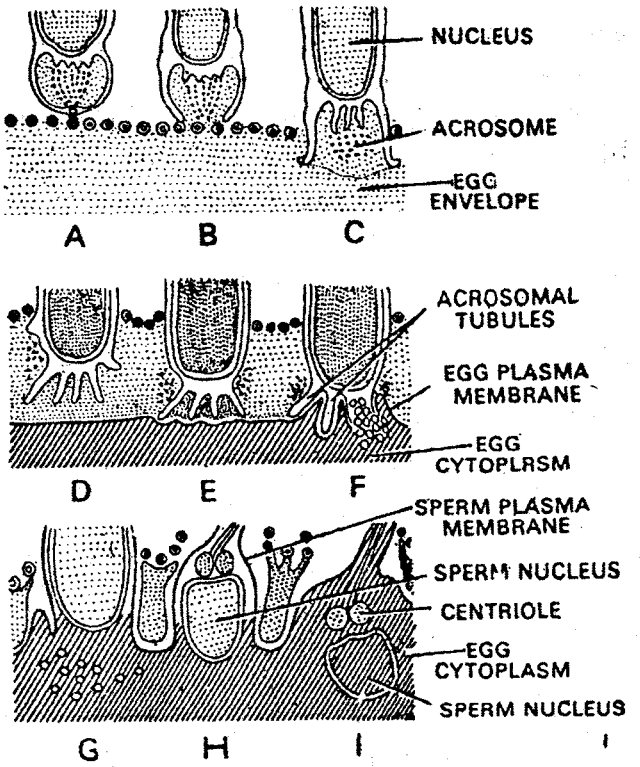

Fig. 5.7 **Sperm-egg association during fertilization in a polychaete Hydroides hexagonus (After Austin).**

he fine details of the penetration of the egg are summarized in **fig. 5.8**

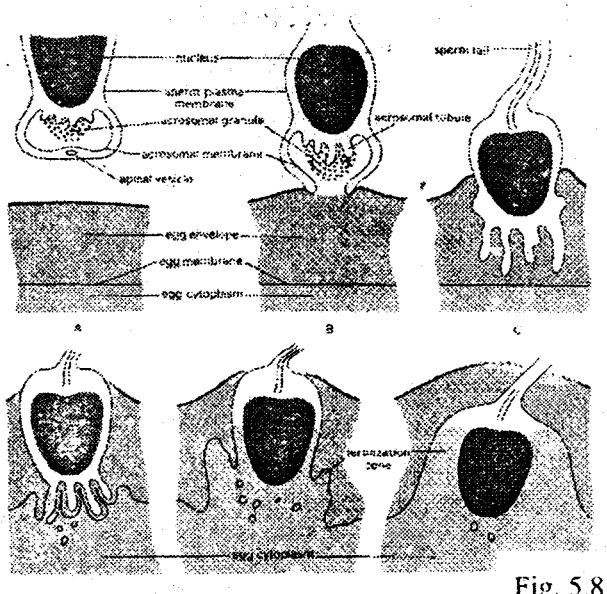

Fig. 5.8 The sequence of events in the union of sperm and egg cells. The diagrams illustrate the approach of the intact sperm (A) and the opening of the sperm tip following upon contact with the egg envelope (B). When the acrosomal and sperm plasm membranes (cf. Figs. 2.3 and 4.5) become continuous (B), the acrosomal membrane everts (C). The subsequent disintegration of the acrosomal granule is believed to release a lytic enzyme which destroys the egg envelope ahead of it, thus preparing a route for the sperm. Sperm and egg plasma membranes interdigitate and then fuse, and the fertilization cone rises (D, E); the sperm and egg are no longer separate cells, and the sperm nucleus has come to lie in the egg cytoplasm (F).

when the sperm contacts the outer envelope of the egg; a series of changes is set into motion. Recent studies indicate that the tip of the acrosome is disrupted upon contact with the outer egg envelope and the acrosome membrane thereupon becomes continuous with the sperm plasma membrane **(figs. 5.8 B).**

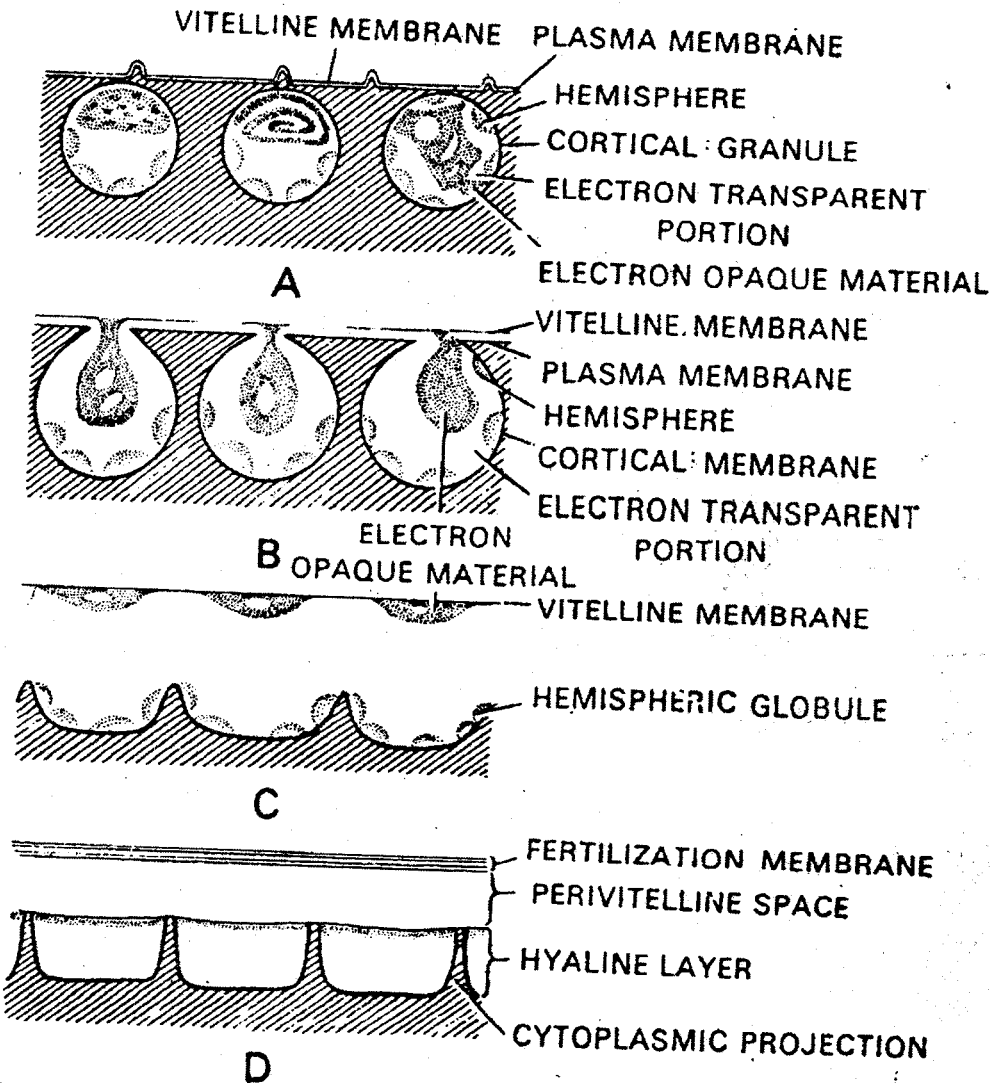

Fig. 5.10 . **Changes in the cortical region of egg cytoplasm and formation of fertilization membrane in sea urchin egg under high magnification.**

As the sperm progresses through the egg envelope the acrosome granule gradually disappears. Its disintegration is presumably associated with the release of a lytic enzyme. When the sperm (or acrosome filament) first contacts the plasma membrane of the egg, the latter protrudes outward toward the sperm head to form a *fertilization cone;* the membranes of the egg and acrosome then fuse, beginning the process whereby the interiors of the sperm and ovum become continuous. A well-defined fertilization cone has not been described in all animals; in mammals, for instance, the sperm appears to invade the egg without being actively engulfed by the ooplasm of a fertilization cone. In either case, through a beautifully coordinated series of events that occur in some animals in matter of seconds, the separate gametes combine into one cell. After the head and middle piece (and, notably in mammals, the tail) of the sperm enter the egg, the nuclei of the sperm and egg approach one another; in some species a fusion; nucleus forms; in others the sperm nucleus loses its membrane as it approaches the egg nucleus, and its chromosomes, along with those form the egg nucleus, align themselves on a spindle formed in association with the centrosome of the sperm (fig. 4). When this union of nuclear material is effected, fertilization is complete and a diploid zygote has been formed, ready to undergo cleavage and begin the long, complex process of development into a complete organism.

5.2.4 Changes at fertilization

Entry of the sperm into the egg initiates a series of processes in which the components of the egg and sperm interact to actuate development of the fertilized egg. The chain of reactions induced in the egg by penetration of the sperm or by certain other stimuli is known as *activation* of the egg.

One of the first indications of activation is the *cortical reaction* and formation of the *fertilization membrane* **(figs. 5.10).**

The cortical reaction has been studied most intensively in echinoderms. In sea urchin eggs granules are visible within the cortical layer immediately subjacent to the egg membrance. Following sperm penetration of the egg cell membrane a change sweeps over the surface of the egg, radiating outward from the site of sperm entry. The cortical granules appear to disintegrate, and a detectable color change progresses over the egg. Attendant upon this cortical change the vitelline membrane lifts from the cortical surface of the egg. Creating the *perivitelline space.* At this time a dense lamellar material derived from the cortical granules accumulates along the inner surface of the vitelline membrane. The latter membrane, now 500 to 900 angstroms in thickness, is called the *fertilization membrane.* A tin, extra cellular *hyaline layer* forms also along the external surface of the egg itself. The cortical reaction, that is, the breakdown of the cortical granules, spreads over the surface of the egg in a wavelike progression within 10 to 20 seconds; the fertilization membrane has formed within 1 to 3 minutes after insemination. Several other phenomena have been described in association with the cortical reaction. There are detectable changes in the *birefringence* of the cortex and fertilization membrane during the cortical reaction. An increased *viscosity* of the cortex and an increased *permeability* to water and potassium ions have been demonstrated. There is, furthermore, a rapid change in the *membrane potential* of the cell. The potential difference between the inside and the outside of the cell is 30 to 60 millivolts before fertilization; immediately after insemination the potential decreases by about 10 millivolts, returning to its original value in about 20 seconds. A depolarization of the cell membrane resulting from cortical changes is also known to occur in fish eggs. Others changes are associated with the cortical reaction, but this brief list should suffice to reveal the intensity and the breadth of changes induced within the egg by the activating influence of sperm penetration.

In mollusks, reptiles, and birds it is routine for more than one sperm to enter the egg; in most animals, however, after one sperm has gained entry to the egg the entrance of additional sperm appears to be blocked. The cortical reaction has often been assigned a role in prevention of *polyspermy*. There are several reasons to doubt this. The cortical reaction and formation of the fertilization membrane are not similar in all aspects throughout the animal kingdom. Fertilization membranes are characteristic of echinoderms, fishes, and frogs, but no new membrane is formed at fertilization in mammals. Cortical granules are absent from the eggs of some animals (for example, insects), and in these eggs there is no apparent cortical reaction comparable with that of echinoderms. In addition, the cortical granules present in the hamster egg disappear following fertilization, but they are apparently not associated with the block of polyspermy. There is also some question whether the speed of the cortical reaction is sufficient to provide an effective block to polyspermy. In the absence of more adequate information, it is perhaps best to view the cortical reaction less as the block to polyspermy than as a most substantial expression of the profound alterations in the egg attendant upon its activation.

5.2.5 Significance of activation

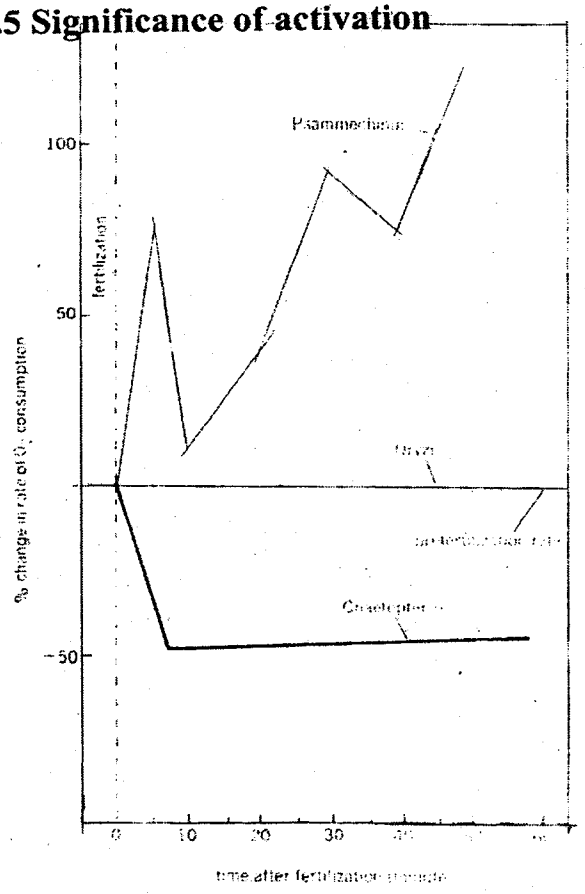

Fig. 5.11 . composite diagram indicating the changes in the rate of oxygen consumption in the egg during the first 60 minutes following fertilization in *Psammechinus* (sea urchin), *Oryzias* (fish), and *Chaetopterus* (marine worm).

The activation of the egg provoked by its fertilization produces some profound alterations in the metabolism of the egg. Immediately after fertilization it is possible to detect in the sea urchin and other, but not all, eggs a dramatic increase in the rate of oxygen uptake and heat production. Other demonstrated changes upon activation include an increased phosphorus uptake, increased utilization

of glycogen, and an increased incorporation of amino acids and synthesis of proteins. There is evidence also that at least three proteolytic enzymes are strongly activated at fertilization. Thus, in many cases, in addition to physical changes, there is a significant augmentation of the metabolic activity of the egg at fertilization.

The above observations represent a fraction of the many alterations in the metabolism of the egg consequent to fertilization. Increased metabolic activity has been stressed, but it is important in this context to note that immediately prior to fertilization the egg is a special kind of cell. The oxygen consumption of the egg drops substantially during its maturation phase, and the oxygen consumption of the mature egg is almost one third that of the primary oocyte. Fertilization of the mature egg restores the high respiration rate characteristic of the egg before maturation. The great initial increase in oxygen consumption, then, reflects, at least in part, return from an abnormally low respiration rate. The substantial increase in oxygen consumption consequent upon fertilization of the sea urchin egg is not a universal phenomenon. In some amphibians and fishes (*Bufo* and *Fundulus*) oxygen consumption appears unchanged following fertilization, and in some invertebrates (*Chaetopterus)* the rate of oxygen consumption is drastically reduced during the first few hours after fertilization **(fig. 5.11).**

There appears to be a relation between the postfertilization oxygen consumption and the stage of maturation of the egg at fertilization. Thus at the time of fertilization the sea urchin egg has completed maturation, the egg of *Bufo* is at the second maturation division, and the *Chaetopterus* egg is at the first maturation division.

The unfertilized sea urchin egg is capable of some synthetic processes, but, although it is able to take up amino acids, there appears to be little or no incorporation of amino acids into the proteins of ht mature egg. Experiments with labeled amino acids reveal an augmented uptake and incorporation of amino acids into the total proteins and subcellular fractions of the egg within minutes after fertilization, thus indicating the onset of protein synthesis and /or turnover.

The accelerated metabolism of the activated egg may be in part a recovery form a depressed metabolic state. It has been suggested that a metabolic block, established within the egg sometime during maturation, is removed by the stimulus of fertilization. According to this view, fertilization represents a release mechanism whereby the physiological elements of the egg are unmasked or removed from inhibition. Activation may represent the release of enzymes or enzyme systems already present in the egg but in an inactive or inhibited state. For example, sperm penetration might remove an enzyme-inhibitor complex from the egg cortex, and the enzymes thus released could initiate a chain of reactions producing the many and diverse events associated with activation.

It is generally accepted that new proteins are synthesized by a rather complex mechanism involving DNA, RNA, adenosine triphosophate, special activating enzymes, amino acids, and the ribosome in the cell cytoplasm. The role of DNA is discussed more fully later, but it is appropriate now to summarize briefly the current conceptual scheme of protein synthesis.

According to the scheme, DNA as the genetic material of the cell specifies the structure of a form of RNA by serving as a model, or template, according to which the RNA mononucleotides are assembled into a continuous chain molecule. Because it carries information transcribed by the DNA,

this form of RNA is known as *messenger* RNA. Passing into the cytoplasm the messenger RNA becomes associated with the *ribosomes,* intracellular particles 150 to 250 angstroms in diameter, composed of approximately equal parts of protein and another form of RNA called *ribosomal* RNA. The ribosomes, or groups of them known as *polyribosome,* are usually associated with the membranes of the *endoplasmic reticulum,* but in embryonic cells they are most often free. In the synthesis of a protein the ribosomes and messenger DNA collaborate to assemble a molecule according to the structural pattern determined by the nuclear DNA.

Each nucleic acid is composed of molecules: a *sugar,* deoxyribose in DNA, ribose in RNA; a *phosphate group;* and *nitrogen* and *bases*, either double-ring purines or single-ring pyrimidines. DNA contains the purines *adenine* and *guanine,* and the pyrimidines *thymine* and *cytosine;* RNA contains adenine, guanine, and cytosine, but in place of thymine, RNA contains *uracil.* A molecule containing a sugar molecule, a phosphate group, and one of the four possible bases constitutes *nucleotide;* linked together these nucleotides from either DNA or RNA. Following simplified structural formulas illustrate the arrangement of molecules within a nucleotide containing adenine and the way these are linked together to form the continuous chain molecule of a nucleic acid.

The exact sequence of bases along the DNA molecule is transcribed to the messenger RNA molecule, and this sequence determines the structure of the particular protein synthesized. Proteins are synthesized from 20 kinds of amino acids, linked together end to end, in various combinations, to form the long polypeptide chains of the protein molecule. Each protein has a characteristic sequence of amino acids. This is established during synthesis of the polypeptide chains by the specification of a set of three bases, called a *triplet code,* in the molecular chain of the messenger RNA.

Elements other than messenger RNA and the ribosomes enter into this process. Another variety of RNA, called *transfer* RNA, plays a critical role in protein synthesis. Special activating enzymes, one for each kind of amino acid, in conjunction with adenosine triphosophate, prepare an amino acid to the ribosome. Each molecule of transfer RNA is a short started of RNA mononucleotides, bearing its own triplet of bases, called an *anticodon,* which may form a temporary bond with the complementary sequence of the codon in the messenger RNA. The ribosome presumably functions to position the arriving transfer RNA molecules and to hold the polypeptide chain being synthesized. The amino acids are thus transferred from the transfer RNA to the appropriate site in the synthesized protein according to the pattern specified by the messenger RNA.

Activation of the egg may reflect an alteration in the machinery for protein synthesis within the egg. The augmentation of protein synthesis and/or turnover in the egg following fertilization suggest that the mechanism outlined above is either activated or released from inhibition. Probably messenger RNA is produced during oogenesis and exists in an inactive state before fertilization. In some way the messenger RNA may be released from inhibition or brought to an active state at fertilization it is also possible that there is some structural peculiarity of the ribosomes in the unfertilized egg that makes them incapable of interacting with messenger RNA. It has been shown that purified RNA extracted from unfertilized sea urchin eggs can stimulate amino acid incorporation into proteins by rat liver ribosomes; and yet the same RNA, or RNA from rat liver, very active on liver ribosomes,

does not stimulate amino acid incorporation by ribosomes from unfertilized eggs. It may be, then, that some structural rearrangement of the ribosomes after fertilization enables them to function properly with messenger RNA and initiate the active incorporation of amino acids into proteins. It is perhaps significant that the unfertilized egg contains no activated amino acid. Activated amino acids appear soon after fertilization, however, and they appear in proportion to the increased amino acid incorporation and protein synthesis. Fertilization may bring about the formation of activated amino acids, thus setting into motion the complex chain of events characterizing protein syntheses and the initiation of development.

5.2.6 Artificial parthenogenesis

The changes elicited within the egg by sperm penetration can be produced artificially in the egg of many animals, including mammals. *Parthenogenesis* is reproduction by development of an egg without its being fertilized by a sperm. The development of an unfertilized ovum initiated by artificial means, such as mechanical or chemical stimulation, is known as *artificial parthenogenesis.* A cortical reaction and elevation of a fertilization membrane are easily obtained by treating the unfertilized with a variety of agents. Complete embryonic development has been successful provoked in the eggs of several animal groups by a wide variety of artificial treatments. Sea urchin eggs, immersed for a few minutes in hypertonic sea water, will, following their return to normal sea water, often develop into normal larvae. Similarly, normal frogs may develop from eggs pricked with a needle coated with blood serum.

In a variety of invertebrate animals (for example, rotifers, aphids, bees, wasps, and ants), the parthenogenetic eggs usually develop into males, the fertilized eggs into females. Natural parthenogenesis has been described in some vertebrate species, notably the domestic turkey. Approximately 40 percent of the eggs laid by females in isolation from males undergo development, some to the hatching stage. All the young are males. It may be noted that eggs do not always remain haploid after parthenogenesis; some natural parthenogenesis and most artificial parthenogenesis are followed by duplication of he chromosomes, yielding a diploid adult.

Whatever its mechanism and subsequent adjustment of chromosome content, artificial parthenogenesis emphasizes the fact that all the factors necessary for development reside in the egg. The egg may, then, be regarded as a reaction system that is all ready to operate; it needs only some external stimulus. Evidently the stimulus provided by the penetration of the sperm is not specific; very diverse and dissimilar external stimuli may produce the same result.

Parthenogenetic development shows that the egg chromosomes suffices in many instances to carry the egg to the adult stage. This sort of reproduction is not more common. Most organisms have evolved some sort of sexual reproduction, and even those species in which budding predominates exhibit sexual reproduction as well. Actually the union of two sets of chromosomes from different individuals results in greater possibilities of variation in structure and function of the offspring as compared with haploid development. This variation provides a greater opportunity for the action of evolutionary factors and presumably enhances the survival of the species. There appears to be a real advantage to cross fertilization on a long-term basis. Even species in which both male and female

reproductive systems are present in the same individual often evolve mechanisms whereby they becomes self- sterile, permitting cross fertilization.

5.2.7 Conclusion

Fertilization is a most complex phenomenon. It is obvious that far more must be known of the process and its many effects before it will be possible to approach a complete explanation of activation. Study of the chemical events associated with fertilization and continued analysis of its metabolic changes offer promise for amore complete understanding.

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5.2.9 Expected questions

1. Describe in detail the events that take place in the process of fertililzation
2. Explain the significance of activation in fertilization
3. Describe the process of artificial parthenogenesis

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UNIT V

Lesson 5.3

TYPES OF EGGS, PATTERNS OF CLEAVAGE, GERM LAYERS AND GASTRULATION

Contents:

5.3.1 Introduction

This lesson provides the information regarding the cleavage patterns of the fertilized eggs. Gastrulation in different phylogenic organisms was illustrated with neat diagrams. Detailed information in concise. From was provided to make the reader easy to understand about the lesson. In the text through discussion was made on the variations between different phyla of both vertebrates and invertebrates. Suitable diagrams for different stages of development were given to understand the variations early.

After fertilization the egg undergoes cleavage, dividing the egg or part of the egg into increasingly smaller entities, and through a series of mitotic divisions, which initially may be synchronous, the zygote becomes partitioned into a large number of cells or *blastomeres.* Cleavage results in formation of a blastula which normally contains a cavity, or blastocoel; the blastula is sometimes represented by a layer or mass of cells, the *blastoderm.* The blastula represents the culmination of processes operative during cleavage, and it is the stage immediately antecedent to gastrulation. Gastrulation is dynamic process whereby the component areas of the blastula are rearranged and reorganized to provide the basis for development of the body plan. Before proceeding to a more extensive review of the development of the amphibian embryo and an analysis of the significance and mechanics of gastrulation, a brief comparative survey of the salient characteristics of cleavage and gastrulation will provide insight into the common and diverse features of these processes among representatives of various animal groups.

5.3.2 Types of eggs

Embryology is a study of development of animals dealing with changes through which a fertilized egg must pass before it assumes the adult state. Fertilizations of an ovum by an sparmatozoon results in the formation of a zygote. Development of single celled zygote into an adult involves a serious of steps or stages resulting in the gradual increase in the complexity of structure. The stages of embryonic development differ in various chordates, yet the chief phases are basically similar in all. The differences are related primarily to the amount of yolk present in an egg, the inert yolk is lecithin furnishes nourishment for the developing embryo.

Yolk: The amount of yolk varies in the eggs of different chordates; it determines the size of the egg and pattern of early development. The eggs are classified according to the quantity of yolk into two main types, namely, isolecithal or telolecithal eggs.

A. Isolecithal eggs:

5.3.3 Patterns of cleavage

Cleavage is universal among multicellular animals, yet various patterns of cleavage occur among various animal groups. A few distinct types of cleavage are 1). *Radial cleavage* is characteristic of Vertebrata, Echinodermata, Porifera, and possibly Cnidaria, although the latter have a highly irregular cleavage pattern. The radial pattern has already been described in the sea urchin eggs **fig .5.12.**

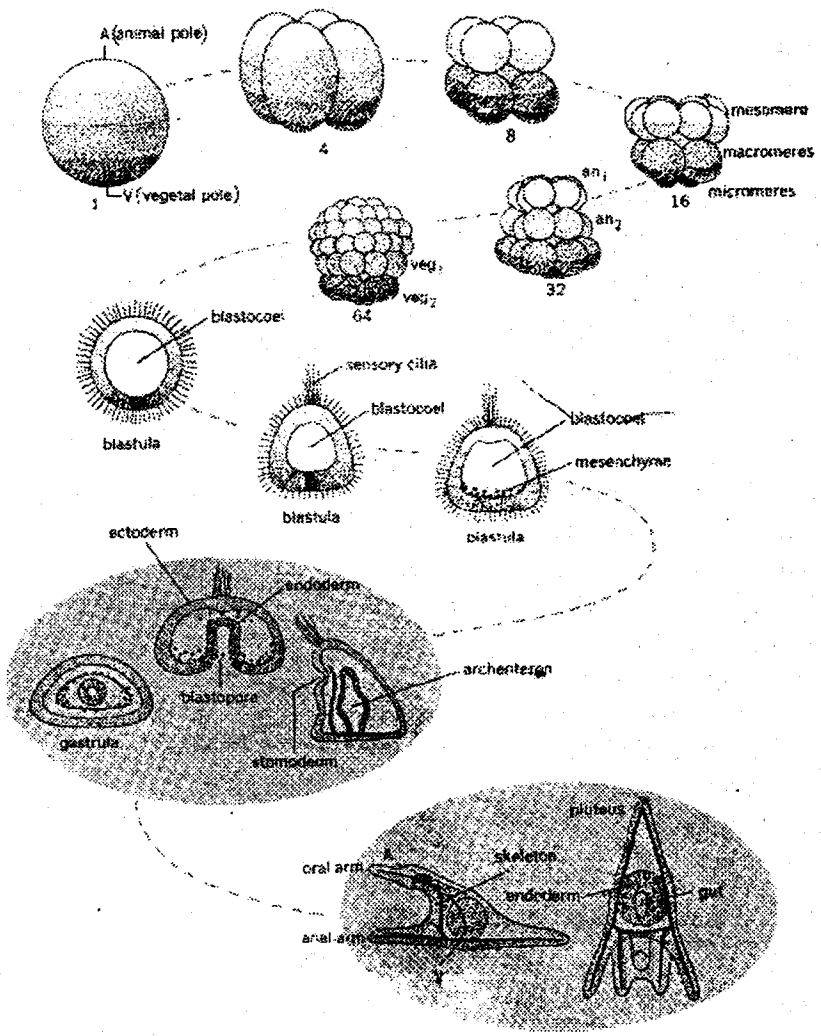

Fig. 5.12 Cleavage and development in sea urchin

In *radial cleavage* the successive cleavage planes pass straight through the egg, perpendicular to one another and disposed symmetrically around the polar axis of the egg. In *bilateral cleavage* there is a rotational movement of cell parts around the egg axis **Fig – 5.13**

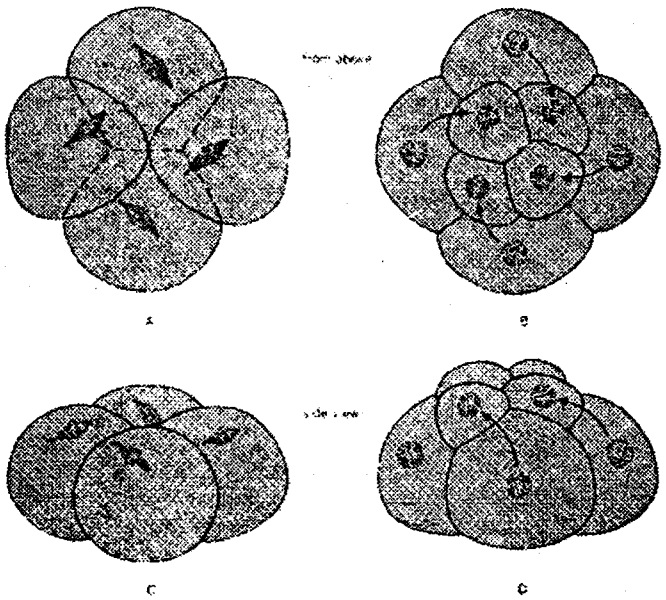

Fig. 5.13 Bilateral cleavage

The cleavage plane, instead of passing straight through the egg becomes oblique relative to both the axis and equator of the egg; both vertical (meridional) and horizontal (equatorial) planes are converted into spiral cleavage becomes modified into bilateral cleavage at some stage of development. In gastropods and annelids the ectoderm derives from three quartets of cells given off in successive oblique cleavages from the first four blastomeres. Cleavage in nematoda follows a precise but unique pattern of its own.

The amount and distribution of yolk, in part, at least, account for other varieties of cleavage. In *Amphioxus* and amphibians the cleavage furrows bisect the entire egg **Fig – 5.14**

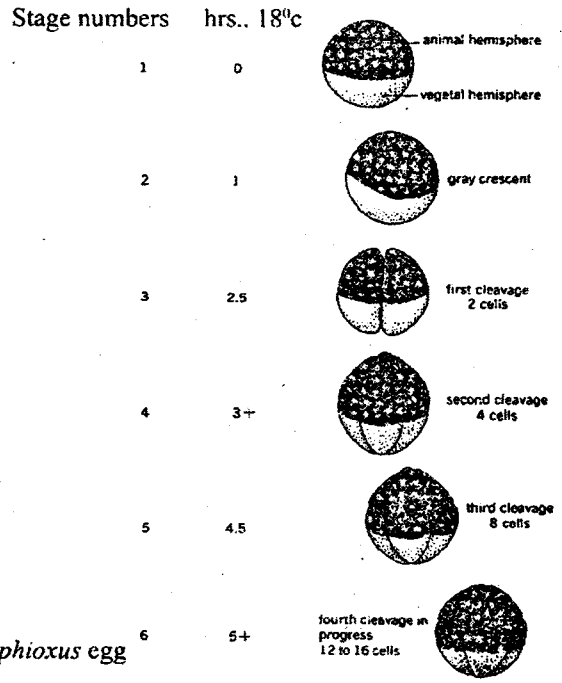

Fig. 5.14 Cleavage pattern in *Amphioxus* egg

This is a complete cleavage, known as *holoblastic cleavage.* In the eggs of teleost fishes, reptiles, and birds, the yolk constitutes a large proportion of the egg, and the embryo develops from a restricted mass of protoplasm located at the animal pole. The yolk is not segmented during cleavage in these animals. Eggs of this variety are characterized by an incomplete, *meroblastic cleavage* **Fig – 5.15**

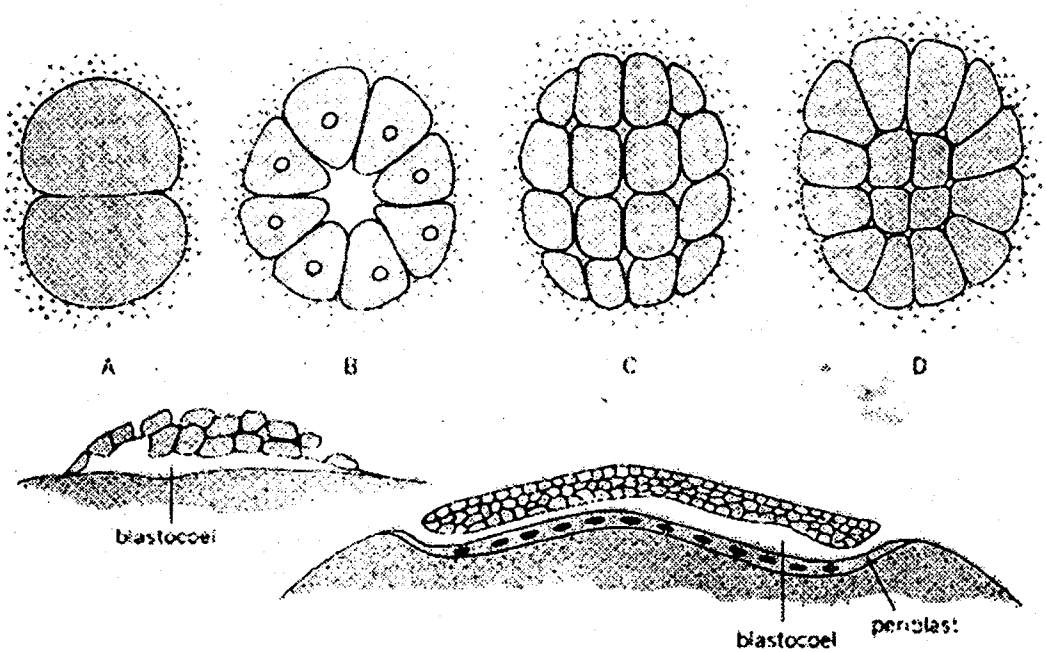

Fig. 5.15 Meroblastic (incomplete) cleavage, characteristic of eggs in which there is segregation of yolk from the cytoplasm. It occurs in elasmobranchs, ganoid and teleost fishes, birds, and reptiles. *Top :* Series of cleavage stages of the egg as seen from the animal pole. Only cytoplasm segmentation is represented ; the yolk is peripheral to the cleaving cells in all illstrations. *Bottom :* Sections through the early blastula, showing segregated cells separated from the yolk. Between the yolk and cells is the centrally located blastocoel or segmentation cavity.

Only the protoplasmic disk at the animal pole is affected by the cleavage furrows that pass through it superficially or almost entirely. *Superficial cleavage* occurs in some invertebrates, notably insects **Fig – 5.16.** A distinctive feature of superficial cleavage is an initial series of nuclear divisions without cytoplasmic partitioning. Small amounts of cytoplasm soon become associated with these nuclei and form "islands." These islands migrate from their original central position to the periphery of the egg and there fuse with the superficial cytoplasm. The cytoplasm later divides, forming the equivalent of blastomeres.

The amount and distribution of yolk obviously bear some relation to the cleavage pattern and the configuration of the blastula. In certain animals, for example, synchrony and equality of division would be predicted were yolk the only determining factor; and yet deviations are quite usual and apparently not dependent upon yolk distribution. Similarly, in the amphibian egg the higher yolk content of the vegetal blastomeres appears directly linked to their lower mitotic rate and large size, but in other cases varying rates of cleavage fail to fit such a direct correlation. Further, the inequality in size of daughter blastomeres in annelids

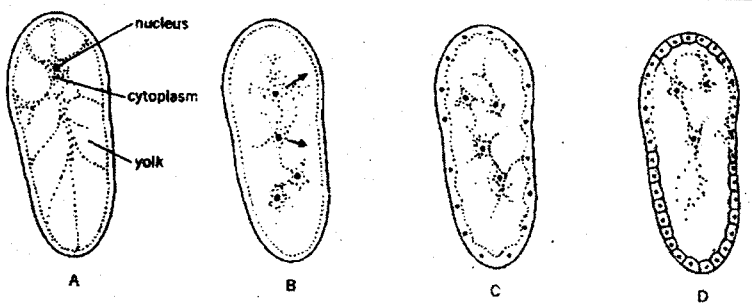

Fig. 5.16 Superficial cleavage. It occurs in insects and many arthropods. It is a variety of meroblastic cleavage in which the original nucleus divides many times at first without cytoplasmic divisions (B), and thus many nuclei are embedded in a large central mass of cytoplasm. The central nuclei move to the periphery (arrows) of the egg (C), where discrete cells are finally established (D).

cannot be easily explained on the basis of the yolk distribution, and the pattern of spiral cleavage must be imposed by variables other than yolk.

Various factors are known to influence cleavage pattern. One factor is the mitotic apparatus of the cell. The chromosome movements characteristic of cell division occur in association with the mitotic spindle and asters. The long axis of the spindle usually coincides with the longest diameter of the cytoplasmic area in which it lies, and the cleavage furrow passes through the middle of the spindle perpendicular to its axis. The relative constancy of this relation suggests that factors influencing the orientation of the spindle within the egg might influence the pattern of cleavage. A cleavage furrow generally forms at right angles to the axis of cellular elongation, and in most cases elongation of the cell depends upon stretching of the spindle. Elongation does not ensure a furrow, but its suppression prevents cell division. When stretching of the spindle in its long axis is prevented, it may spread laterally, elongating the cell in a direction perpendicular to its normal axis. Then a cleavage furrow appears vertically to the new direction of elongation, indicating a direct relation between spindle alignment and the location of a cleavage plane. Orientation of the spindle can also relate to the size of blastomeres produced during cleavage. When the spindle lies in the center of the cell blastomeres of equal size form; but an assymmertically situated spindle results in unequal blastomeres displacement of the maturation spindle in the molluscan egg by centrifugation produces two giant polar bodies. Elements other than the spindle can affect cleavage patterns. In the blastomeres of eggs in which the asters are very large, mitotic elongation and cleavage may occur in the absence of the spindle. The cell cortex, too, must be considered as a factor influencing cleavage pattern. The viscosity of the cortex increases before cleavage, forming a cleavage furrow as a gel like localized thickening of the cortical layer. The cortex appears to be essential to cytokinesis; only egg fragments containing cortical material can divide. Furrow formation can occur independently of both spindle and aster. In sea urchin eggs the displacement of the aster to one side does not affect the position of the cleavage furrow. The independence of the cortical layer in formation of a cleavage furrow is manifest also by experiments with the frog egg demonstrating that a furrow isolated from the interior of the egg by a cellophane strip continues to grow and deepen. Not only mechanical factors but also the distribution of materials within the ooplasm may possibly determine cleavage pattern. The possibility, if not the mechanism, is easily envisaged in such a rigidly defined and regular cleavage as that evident in the

eggs of molluscs, where a precocious segregation of cytoplasmic substances and unequal developmental potentialities exist from an early stage. And in eggs of other type, an extensive redistribution of substances transpires during early development that may bear upon the location of cleavage furrows.

There is little growth during cleavage; it is a phase characterized by cell division, which provides a mass of small cells and a dramatic increase in the total number of cell surfaces. In addition, partitioning of cells permits segregation of cytoplasmic materials and continued development of regional differentiation of the egg cytoplasm, as noted earlier.

A limited amount of development may occur without cleavage. Thus *Chaetopterus* eggs in which cleavage was suppressed developed external cilia and revealed some segregation of internal contents. This was a very limited development, however, perhaps resulting from cytoplasmic organization present in the uncleaved egg. The entire spectrum of events associated with cleavage, ranging from the simple division of the egg into manageable building units to the evolution of complex cell groups of differing physicochemical properties and divergent potentialities, appears to be necessary for normal development.

The configuration of blastulae varies as much as cleavage patterns, but, despite the absence of a blastocoel in many cases, the basic anatomy of the blastula stage of development is comparable **Fig. 5.17**

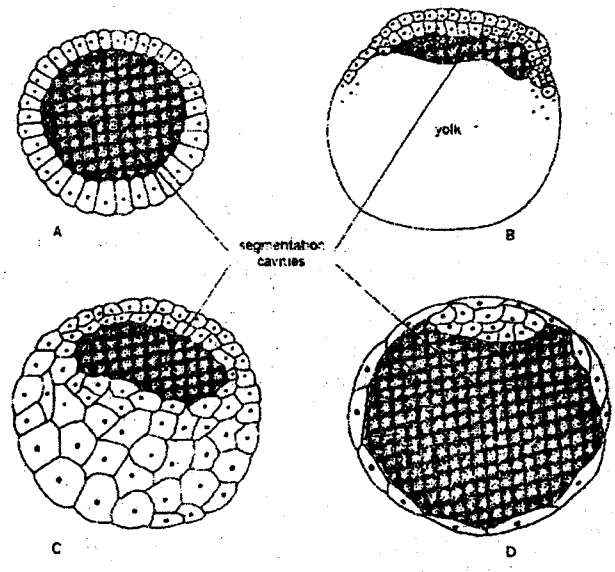

Fig. 5.17 Blastular configuration

In some animals it is a cohesive hollow ball of cells; in others the cells are fairly loosely arranged. The shape of the blastula is influenced by mechanical factors. The extra cellular hyaline layer, when present, as in the echinoderms, appears necessary for normal blastula formation. When this layer, which is located on the protoplasmic surface of the egg, is absent, the blastula is abnormally flattened. A comparable role in strengthening the union of blastula cells has been suggested for the "superficial germ layer" and "cortex" of amphibian and teleost eggs, respectively. Intercellular cytoplasmic bridges (plasmodesms), spindle remnants that remain for time after completion of a mitosis, and intercellular cement provide other recognized mechanisms accounting for cohesion of the blastula and its configuration.

5.3.4 Germ layers and gastrulation

Gastrulation is a series of morphogenetic movements that locate the prospective tissues of the body in their appropriate places in the structural plan. At this time only the general process, as it occurs in various phyla, will be discussed as a background to more detailed consideration of its many important phases in selected animals.

The process of gastrulation in sea urchins and the cephalochordate *Amphioxus* is simplest. The essential features of gastrulation are revealed in the eggs of these animals in a relatively straightforward process. In the sea urchin the onset of gastrulation is indicated by an indentation at the vegetative pole of the blastula **Fig. 5.12** Some cells detach from the epithelium to migrate into the blastocoel and form the primary mesenchyme. The indentation deepens to form the archenteron opening to the exterior at the blastopore. The cells of the archenteron wall are the endoderm; the cells remaining on the surface are the ectoderm. When the archenteron is approximately one half the diameter of the blastula, cells located at its tip emit long processes that attach to the inner surface of the ectoderm at the animal pole; contraction of these pseudopodia pulls the archenteron toward the animal pole. At the same time, the pseudopodia-bearing cells migrate from the archenteron wall to form secondary mesenchyme, establishing an embryo with three germ layers.

Gastrulation in *Amphioxus* differs somewhat, but generally it compares with sea urchin gastrulation. The process begins with invagination of prospective endoderm near the vegetative pole **Fig. 5.18**

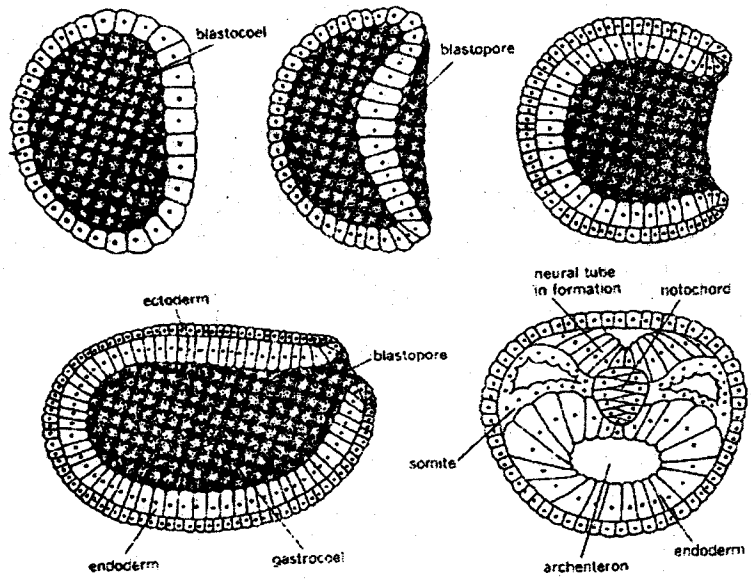

Fig. 5.18 Grastrulation in *Amphioxus*

This invagination, the archenteron, which opens at the blastopore, eventually, becomes apposed to the inner surface of the cells of the animals hemisphere. This forms a cuplike gastrula, consisting of an outer ectoderm and inner endoderm. The mesodermal cells and notochordal cells, originally part of the rim of this cup, migrate into a position along the dorsal inner wall (archenteron roof) of the gastrula. Later the notochord folds out dorsally from the archenteron roof and the mesoderm segments evaginate into individual somites. The somites expand to form muscle segments and the walls of the coelom, or body cavity. Above the notochord the ectoderm undergoes a series of changes resulting in the formation of the neural tube. **Fig. 5.19**

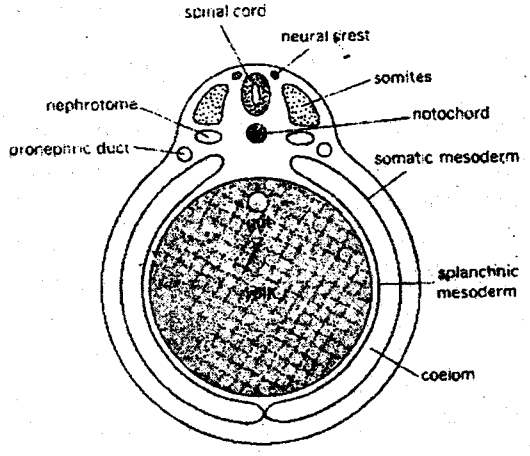

Fig. 5.19 A digram of a cross section of an embrao. In such a position the structures can be identified by the shape, size and relative positions

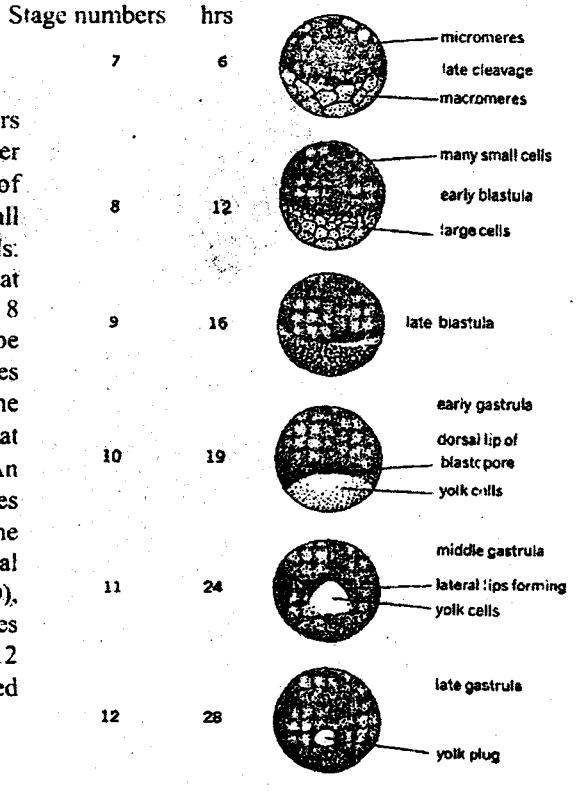

Fig. 5.20 Stages of development of *Rana* sp from 6 to 28 hours the period is carectorised by a tremendous increase in number and rearangement of cells comprising the phenomenen of gastrulation. Between stages 7 and 8 the cells become so small that it is no longer possible to represent all the individual cells. The cells at the vegetal pole are many times larger than those at the animal pole and thus are pictured in the drawings of stages 8 and 9 by stage 10, even these vegetal cells are too small to be illustrated, and they are represented by light stippling in stages 10, 11 and 12. At stage 10 a dark line of pigment appears on one side of the egg. This is the first sign of gastrulation. It means that some cells have changed shape and are migrating internally. An overgowth of the white yolk by the pigment cells accompanies the internal migration. The overgrowth results in a sharp line between pigmented and white cells which marks the blastoporal lip. First there is simply a dorsal lip of the blastopore (stage 10), the lateral lips form (stage 11); and finally the ventral lip completes a circular blastopore, which is plugged with yolk cells (stage 12 by this means the yolk cells are completely covered by pigmented cells.

In the amphibian embryo **fig.5.19** a blastopore forms at the dorsal side of the blastula in the vegetative field, and as this invagination deepens, an archenteron is formed . As a result of this invagination, material originally on the surface of the blastula is transported into the interior at the blastopore. The invagination spreads laterally, and all along the margin of the blastopore marginal material moves inward. Eventually the sides of the blastopore approach one anther and fuse. Simultaneously the uninvaginated material of the animal half of the blastula expands to cover the outer surface of the gastrula. and a three-layered embryo is formed. Teleost fishes display a somewhat unusual morphological pattern during gastrulation **Fig. 5.21**

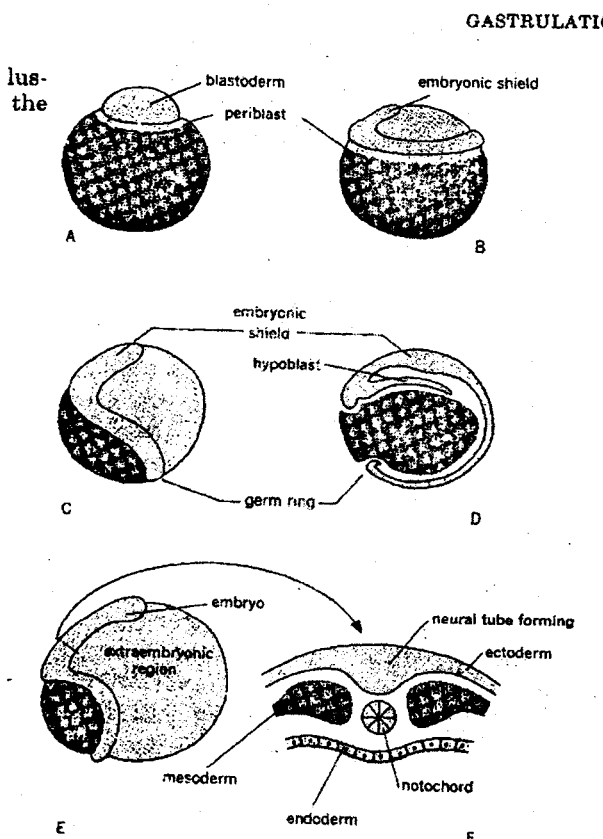

Fig. 5.21 Gastrulation in a teleost fish. illustrating the extreme modification of the primes by a massive amount of yolk

During cleavage the teleost blastoderm is a structureless mount of cells atop a great mass of yolk. The blastoderm is anchored to the yolk by the *periblast,* a peripheral continuation of its epithelial cellular envelope onto the yolk syncytium. The teleost blastula is thus composed of an apical cellular cap, the blastoderm, and an underlying periblast, closely associated with the yolk. As gastrulation approaches, the blastodisc thins and its entire outer rim thickness to form a *germ ring*. At the caudal edge of the blastoderm the germ ring thickening is more pronounced, extending centrally for some distance toward the animal pole at the middle of the blastoderm. This posterior widening of the germ ring is known as the *embroyonic shield.* As gastrulation begins, a caudal thickening of the blastodisc, the *hypoblast.* is identifiable as cells extending forward between the blastodisc and the periblast. As gastrulation proceeds, the germ ring and outer, extraembryonic regions of the blastodisc gradually

spread over and enclose the yolk mass. The edges of the germ ring gradually converge, ultimately fusing at the caudal trunk region of the embryo. In terms of its temporal relations and its functional implications to gastrulation, closure of the germ ring is the equivalent of closure of the amphibian blastopore.

In teleost embryos the rudiments of the prechordal plate, notochord, and mesoderm reach their destination in the embryonic axis by in turning movements from the surface at the rim of the blastodisc in a manner comparable to the invagination of chordamesoderm in amphibians. There is neither an in turning nor a delamination of cells to produce the hypoblast in *Salmo* the hypoblast originates from an outward migration of deep central cells located within the blastodisc associated with epiboly of the whole disc. Formation of the axis is the resultant of outward migration and axial convergence of the deep cell layers. The general pattern of gastrulation, allowing some qualification for teleosts, is one in which surface cells move into the interior of the embryo at a relatively circumscribed blastopore. A contrasting situation exists in birds and mammals. An open blastopore does not exist in these animals, but, instead, surface cells move into the interior through an elongated *primitive streak.* Mammalian gastrulation has not been observed experimentally, but the situation appears to be comparable with that obtaining in birds, despite the reduction of yolk.

5.3.5 Conclusion:-

The present lesson deals certain gross similarities in the events of gastrulation among varied animals groups. It is possible to overemphasize the similarities, but, nonetheless, gastrulation in all classes involves a massive structural rearrangement of the embryo, through cell movements, selective associations, at least in the echinoderms, cell contractility. It is a highly critical phase of development of the embryo.

5.3.6 Expected Questions:

1. Briefly describe different types of cleavage in various multicellular organisms with neat diagrams.
2. Give an account on gastrulation in protochordates.
3. Describe the gastrulation process in fishes.
4. Write an essay on gastrulation in amphibians with detailed illustrations.

5.3.7 References

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Dr. K. Veeraiah

LESSON 5.4

THE OESTROUS CYCLE

Contents

5.4.1 Introduction

The protection, nourishment, and care of the young within the uterus are ensured in placental mammals by the close integration of ovulation and fertilization with events that prepare the uterus to receive the embryo. The necessary changes in the female constitute the *oestrous cycle,* culminating in ovulation, which in many species is timed to occur close to a period at which the female will receive the male thus ensuring fertilization.

In the mouse, ova remain fully 'active' for only about 6 hours after ovulation and sperms are not found motile in the oviduct later than 12 hours after copulation. In bats copulation occurs in the autumn, but fertilization not until the following spring. It is obvious that in this field conclusions must not lightly be carried over from one species to another; exact statements can be made only about phenomena known to take place by careful observation of each type of animal.

In spite of the variety in the sexual cycles of various female mammals we can recognize a pattern common to all. Several influences control the female sex cycle, one or another predominating in each species, but probably all act to some extent in every female mammal. Thus, in the rabbit ovulation only occurs after copulation, whereas in women it usually occurs as a result of endocrine factors on or about the fourteenth day after the beginning of the previous menstrual flow, irrespective of mating.

5.4.2 The oestrous cycle

In mammals, as in other vertebrates, the secondary sexual characters and condition of the genital ducts are regulated by secretion from the ovary and this is influenced by pituitary secretions, which are in turn influenced by the ovarian hormones. The female reproductive system, therefore,

does not remain at a steady level of activity but undergoes cyclical changes. The period of oestrus or heat is the time of sexual activity of the female, occurring either rhythmically throughout the year or at one or more seasons. At the time of oestrus the eggs are shed from the ovary and the female's desire and will receive the males.

At the time of oestrus the desire and attractions of the females, reacting with those of the males, may produce very violent behavior in individuals and in herds of mammals. Human social organization is possible because men and women instead of these sweeping changes of desire, experience attractions that are more persistent if somewhat less insistent. Man and old-world monkeys are peculiar in this respect; in most mammals mating only occurs at the times when oestrus overtakes the female. Thus the cat and bitch come on heat two or three times a year and these periods of oestrus are separated by long periods of *anoestrus,* in which the reproductive system is quiescent and the female will not mate. In other mammals the oestrous periods follow each other in regular cycles, either throughout the whole year (man) or during a certain breeding season (many rodents). Animals of the type with single periods of heat are said to *monoestrous;* those with a succession of cycles are *polyestrous.* The condition is not rigidly fixed for any one species and the surroundings and nutrition after the sexual cycles markedly. Conditions of domestication seem to increase the number of periods of oestrus, thus wild sheep and goats only have a single mating season, in the autumn, and but a single oestrous period in that season. Domesticated sheep and goats may show several oestrous periods in the autumn and winter, also an extra breeding season in the spring or even, in the case of Australian merino sheep, a regular series of cycles throughout the year.

In spite of these variations we can give the following general statement about the breeding seasons of the various mammalian orders. Marsupials breed once or twice a year and are monoestrous or polyestrous. Insectivora, the most primitive placentals, are polyestrous; thus in the shrew, cycles a few days in length succeed each other throughout a long breeding season, in the course of which several litters may be born. The same condition is found in rodents and primates, groups that remain close to the insectivoran stock. Thus the rat shows cycles 4-5 days long. Old-world monkeys, like man, have cycles of about 28 days, with a special condition of menstrual bleeding. In some bats copulation occurs in the autumn but fertilization is delayed implantation, the blastocyst lying dormant in the uterus.

Perissodactyla are mainly polyestrous. The mare in domestication experiences a series of cycles throughout the spring and early summer, each lasting 19-23 days. In the wild state the season is probably shorter but includes several cycles. Artiodactyls are frequently monoestrous in the wild state, and it is in these animals, especially those living in herds, that the 'rutting season' produces the greatest disturbance in the lives of both sexes. The males experience a season of rut, corresponding to the oestrus of the females, and animals such as the bison congregate into great herds of fighting and copulating individuals.

Carnivora are also monoestrous in the wild state, but the fact that they, like the artiodactyls, become polyestrous in captivity suggests that the primitive state for mammals is one in which at the appropriate time of year several successive periods of oestrus occur. We have therefore to look for the basic changes that produce this rhythmicity.

5.4.3 Proestrus the follicular phase

The various types of cycle do not differ fundamentally and we can recognize a series of events common to all mammals. In monoestrous species there is a period of *anoestrus* during which the female reproductive organs are quiescent. Then follows a gradual ripening of follicles in the ovary, quickening under the influence of external stimuli such as light, acting through the pineal gland. Thus anoestrus passes into *proestrus*, in which the ova in the follicles of the ovary ripen rapidly. This is the period of 'coming into heat' which precedes the true oestrus.

5.4.4 The ripening of ovarian follicles

Each ovary of a new-born child contains some 2000 000 oocytes, which have migrated into it from their origin in the embryonic endoderm. Their number decreases throughout life. Thus, for example, by the age of seven years the member has decreased to 3000 000. Later some mature and are shed, but far more undergo degeneration (atresia). Each oocyte is at first surrounded by a single layer of follicle cells. The oocytes in these primary follicles by the time of birth have all entered the prophase of their first meiotic division and they only complete this at ovulation. Maturation consists in mitosis of the follicle cells to give several layers surrounding a fluid-filled cavity, forming a structure which is known as a Graafian (ovarian) follicle.

When about six layers are present the surrounding stromal cells become differentiated to form a case, the *theca*, around them. The inner layers are now known as the *membrana granulosa* and they show little further development during the first or follicular phase of development, lasting in a woman for about 11 days. During this time, however, the thecal cells undergo rapid development and produce the oestrogens characteristic of this phase of development. Their secretion thickens the wall of the vagina in many mammals, in preparation for copulation. They also begin the preparation of the uterus to receive the embryo. The thecal part of the follicle is very vascular but the vessels do not penetrate to the granulosa cells because of a thick *membrana propria*, separating the two regions. The granulosa cells probably produce progesterone, which is present only in small amounts during the follicular phase. After ovulation blood vessels penetrate the membrana propria and the granulosa cells from the corpus luteum.

The oocyte grows meanwhile and acquires a non-cellular special membrane, the zona pellucida. As the follicle becomes bigger still sacs appear within it, filled with a liquor folliculi. In the ripe follicle the oocyte is suspended near the centre by a cord of cells, the cumulus. Usually only one follicle ripens each month in a woman, the process taking 10-14 days. The ripe follicle bulges at the surface, and finally bursts, discharging the oocyte into the coelomic cavity, where it is taken up by the fimbriated funnel. The remains of the cumulus cells form a corona radiata around the oocyte, which completes its maturation and becomes an ovum.

5.4.5 The oviduct

The oviduct is specialized to receive the ovum and allow its fertilization and transport to the uterus. The outer end of the oviduct, the ampulla, or fimbriated funnel, consists of elaborate folds, covered with cilia. The tube itself is also ciliated and in addition contains glands which in the rabbit provide the egg with an aluminous coat and, in monotremes and some marsupials, also a shell. There

are coats of smooth muscle and at the time of ovulation the oviduct shows active movements. At this time the blood-vessels of the funnel are engorged so that its fimbriae embrace the ovary. The cilia beat towards the uterus and they and the movements transport the ovum. The tubes must carry the sperms in the opposite direction but it is not known how the reversal occurs. The tubes receive autonomic nerve fibres.

5.4.6 The uterus

The wall of the uterus contains a thick muscle coat, the *myometrium,* and a glandular mucous membrane, the *endometrium.* The latter undergoes a cycle of change throughout each monthly period in a woman. It consists of a surface columnar epithelium invaginated as a series of simple glands. During the follicular phase of the cycle these glands proliferate by mitosis and the endometrium increases 2-3 times in thickness, and becomes more vascular.

5.4.7 Oestrus

Proestrus is succeeded by the climax of the cycle, oestrus proper. During this time ovulation usually occurs, either spontaneously or, in some species (rabbit, cat, ferret), only if there is copulation. The distended Graafian follicle bursts, washing out the enclosed ovum, still surrounded by some of the cumulus cells. The ovum is thus shed close to the opening of the oviduct, whose fimbriated funnel is provided with cilia. The eggs pass down the oviduct partly by ciliary, partly by peristaltic action. It is during this period of oestrus that the female of many species is receptive to mating. The vaginal wall is now thick and often highly cornified and a smear preparation of the vaginal contents shows cornified epithelial cells that have been shed, but no leucocytes.

Marked changes of electrical potential, as recorded between the abdominal wall and the vagina, take place at the moment of ovulation. This sign has served to confirm that ovulation occurs in women near the fourteenth day after the beginning of the previous menstrual flow. At this time pains are sometimes felt, some women experience characteristic sensations and claim that they know the time of ovulation; is also sometimes alleged that desire is then increased. A change in body temperature also occurs at the middle of the human menstrual cycle. There is a drop on about the fourteenth day, followed by a rise, so that the temperature is generally higher during the second half of the cycle than the first.

There is considerable variation in these matters and clearly the climax of oestrus is less marked in women than in most mammals. In some monkeys the time of ovulation is indicated by sharp changes in the coloration of the face and buttocks and in other secondary sexual characters. In the baboon these changes were early used in demonstrating that ovulation occurs at the middle of the menstrual cycle (zuckerman 1932). In other mammals various phenomena of receptivity are seen at the height of oestrus, the virginal lips become tumid and special secretions are formed that attract the males, for instance to a bitch on heat. In some animals there is slight bleeding from the vagina either just before or at the height of oestrus. It was natural to compare this with menstrual bleeding; leading to the erroneous view that ovulation occurs soon after menstruation. Bleeding in the middle of the month sometimes occurs in women and would correspond to this oestrous bleeding of animals.

In women the follicles begin to ripen after the menstrual flow. This period may therefore be characterized as the follicular phase of the cycle. The oestrogens produced by the developing follicle cause proliferation of the wall of the uterus and cornification of cells of the vagina. This part of the cycle culminates in ovulation, usually on about the fourteenth day after the beginning of the previous menstrual flow.

5.4.8 The menstrual cycle

The regular menstrual rhythm of a woman is therefore a series of oestrus periods. Following the flow, proestrus, the follicular phase of the cycle, prepares the body for ovulation, which occurs about 14 days after the beginning of the previous flow. The remaining in which the uterine growth continues, making preparation for the fetus and ending only if the latter fails to arrive

This interpretation of the menstrual cycle as a combination of follicular and luteal phases has been challenged on the ground that in monkeys and perhaps also in the adolescent human, menstrual cycles without ovulation may occur.

5.4.9 Oestrogenic hormones of the ovary

The ovary itself is a major source of oestrogenic hormones (female sex hormones). The two chief active substances obtained from the ovary are *oestrone* and oestradiol. There are also many other naturally occurring and synthetic substances that have oestrogenic activity. *Stilboestro* is one of these: it is not destroyed by digestion and there fore can be taken by mouth. Though the formula of stilboestrol as written has some resemblance to that of naturally occurring oestrogens the substance is not chemically very similar. Its action may be compared with that of a skeleton key and the similarity is certainly suggestive, but the mode of action of synthetic oestrogens remains uncertain.

In mammals the oestrogenic hormones play a major part in the control of the secondary sexual characters. Following removal of the ovaries there is a loss of the sexual instinct of the female, and indeed a loss of activity in general, as measured in rats in a revolving cage. The operation is also followed by reduction in size of the uterus and vagina, reduction of the glands of the uterus, reduction in the mammary glands, and changes in many of the soft parts and skeleton. Removal of the ovary produces changes in the anterior lobe of the pituitary, which is one of the main influences controlling the ovary (see blow). Injection of ovarian extracts or oestrogens is able to reverse all of these changes. The uterus becomes hyperemic and distended with secretion, following multiplication of the gland-cells by mitosis, while the vaginal epithelium becomes thickened and cornfield.

The changes characteristic of the proestrus phase of the oestrous cycle are produced by the oestrogens secreted by the ovary. The main source is the cells of the theca interna of the ripening follicle, large cells containing fatty substances and with a rich blood-supply. The oestrogenic substances are present in considerable amounts in the liquor folliculi. Small amounts of oestrogens are probably produced elsewhere in the ovary but the theca interna is the main source and the phase of the cycle in which it is active is therefore appropriately referred to as the follicular phase.

Oestrogens also have many other effects throughout the body, maintaining the secondary sex characters peculiar to the female. In some species certain characters become specially accentuated at the height of oestrus, serving as signals to attract the males. Thus the colouring of the buttocks, genitalia, and face of some female monkeys reaches its full development just before ovulation.

The secretion of oestrogens is also responsible for the later stages of development of the genital ducts before puberty. The vagina of the rat remains a solid cord of cells until maturity, which occurs at two months after birth, it can be made to open at one month or earlier by injection of oestrone. The constancy of this reaction throughout vertebrates is remarkable, oestrone also causes opening of the genital ducts of immature lampreys (young 1962).

5.4.10 Changes in hormone levels during oestrous cycles

The control of reproduction of all vertebrates is operated by a complex system if interactions involving the hypothalamus, pituitary, and gonads. Some hypothalamic lesions or pituitary removals prevent maturation of the gonads of young mammals and are followed by atrophy of those of an adult. Other lesions or implants of pituitary tissue cause precocious development of the gonads. Conversely the action of oestrogens or androgens upon the hypothalamus are necessary for the proper development of adult sexual functioning.

These immune assays depend basically on using a pure gonadotropin as an antigen injected into a rabbit. Serum from this animal will then contain antibodies that will cause coagulation of latex particles which have been impregnated with the gonadotropin to be assayed. The changes have been followed in detail through the menstrual cycle of normal women. Plasma FSH and LH are measured by radio-immune assay and expressed by reference to a standard of international Units (I.U). The steroids are measured by competitive protein-binding assays with an exactitude reaching to a coefficient of variation of 8 per cent at 30 mg ml^{-1} of plasma.

The FSH increases in the first part of the follicular phase, but falls at the end of it. The secretion of it. The secretion of oestrogens increases throughout the follicular phase slowly at first, then rapidly reaching a peak on the day before the LH peak. This is paralleled by the rise in 17-hydroxyprogesterone, the steroid measured in the study shown in, whose function is not known. Meanwhile the LH remains constant and low. Then just before ovulation there is a rise in FSH and a very large one in LH. These rises are presumably a result of some action of the increasing oestrogenic steroids upon the hypothalamus, overcoming its inhibition of the production of releasing factors. The joint rise in LH and FSH is probably necessary to trigger ovulation, perhaps by causing secretion of fluid into the follicle. After these surges both hormones fall to low levels, the FSH in particular. The LH now causes development of the corpus luteum and secretion of progesterone. In the absence of pregnancy and hence stimulation by chronic gonadotropin the corpus luteum begins to regress after about 8 days and as the progesterone falls the uterine mucosa breaks down and the cycle terminates in menstruation. The fall in progesterone seems to be the factor that triggers the next rises in FSH and LH, which begin before the onset of the menses, perhaps by removal of an inhibition of the production of FSHRF and LHRF.

5.4.11 Conclusion

The organization of the ovarian and pituitary secretions of mammals therefore ensures a cyclical hypertrophy of various tissues of the uterus and vagina, so timed as to allow fertilization to take place when the uterus is ready to receive the embryo. These cycles may go on regularly and continually throughout the reproductive life of the individual, as in the case of women. There are, however, two influences that intervene most powerfully in this rhythm in most mammals, namely, the seasons

and the males. In nearly all animals there is one or more breeding seasons, during which complete cycles are produced. For instance, in macaque monkeys menstrual cycles continue throughout the year, but for much of the time they occur without ovulation; only in a limited breeding season can conception occur. In many rodents oestrous cycles occur only at certain seasons and, as we have seen, in monoestrous species, such as the wild sheep, there may be only a single heat period in each year (Bullogh 1961).

Various factors in the environment produce these seasonal changes. Nutrition certainly plays a part, both by the total quantity of food taken and the presence of essential vitamins. Inadequate nourishment readily distrubs the menstrual cycles of women, and species that are monoestrous in nature become polyestrous with the better food supplies available in domestication.

Changes in the length of day is a dominant factor responsible for producing the onset or regression of breeding. The light acts by altering the secretion of melatonin by the pineal. However, even under conditions where change in length of day is slight, animals may show a sharply marked breeding season. For instance, bats in the New Hebrides all become pregnant once a year, though their island is only 16^0 from the equator and shows a nearly constant rainfall, while they themselves live all day in dark caves with almost constant temperature. Right on the equator, however, they breed all the year round, although groups within the colony show synchronized breeding, perhaps by social stimulation. There is still much to be learned about the control of breeding seasons.

5.4.13 Expected questions

1. Explain the role of uterus in the oestrous cycle.
2. Give an account of hormones and their role on the oestrous cycle.
3. Explain the mammalian menstrual cycle.
4. Describe the changes in the hormone levels in the oestrous cycle.

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LESSON 5.5

PHYSIOLOGY AND EVOLUTION OF THE PLACENTA

Contents:

5.5.1 Introduction

The blastocyst grows freely in the cavity of the uterus, its trophoblast in contact all over its surface with the endometrium. First contact, leaving free surface projecting into the uterine cavity. In yet other types, including man, the whole blastocyst sinks into the endometrium and becomes surrounded by maternal tissues, the interstitial from of palcentation.

Whatever the means by which the first attachment is made, there soon develops an organ allowing for interchange between mother and foetus over part or all of the surface of the trophoblast. This organ, the placenta, thus consists of the intimately apposed or fused foetal and maternal tissues, which allow the interchange. On the foetal side the extra-embryonic ectoderm of the trophoblast (chorion) is connected with the blood-stream of the embryo either by contacted with the blood-stream of the embryo either by contact with the wall of the yolk-sac (*vitelline placenta*) or allantois *(allantoic placenta*). In the latter condition the outer covering is often known as the allanto-chorion and this name is used also when, as in man, the blood-vessels come from the precociously developed measoderm of the allantois, although the cavity of the alter fails to develop. The events of early palcentation in man have recently become clearer, through the finding by Hertig and Rock (1945) of an embryo about 71/2 days old, actually in process of embedding. The trophoblast in this specimen is greatly thickened on one side and its cells are so active in division that cell boundaries are not reformed and a *syncytiotrophoblast* results. This tissue, rapidly invading the uterine wall, has already destroyed the maternal epithelium and is proliferating in the endometrium beneath. The remainder of the surface of the blastocyst still projects into the uterine cavity and consists of a relatively thin layer of *cytotrophoblas*
fig. 5.22

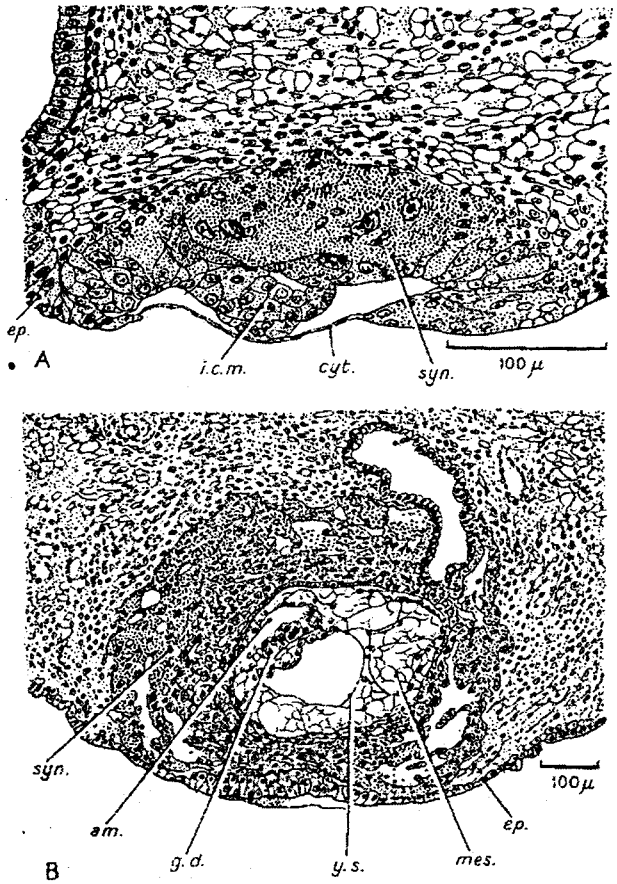

Fig. 5.22 Early stages of implantation in man.

Hertig-Rock embryo 7½ days; B, 11½ days. *am.* amnion; *cyt.* cytotrophoblast; *ep.* uterine epithelium; *g.d.* germinal disc; *i.c.m.* inner cell mass; *mes.* primary mesoderm; *syn.* syncytiotrophoblast; *y.s.* yolk sac. (After Hamilton, Boyd, and Mossman.)

In man the blastocyst rapidly sinks into the endometrium and becomes surrounded on all sides. Although it is usual to ascribe this implantation to enzymatic invasion by the trophoblast it is possible that the uterine wall at this stage readily undergoes erosion on contact with any foreign object. In higher primates especially, the presence of the coiled arteries close to the endometrial surface gives the latter very peculiar properties; it may be regarded as an unstable system, ready to react. The decidual reaction, a change of the endometrium produced by contact with an embryo, can be made to occur by mechanical stimulation of the progestational uterus by such objects as glass beads or suture threads. In other mammals the action of the trophoblast on the uterine tissues is less violent than in primates, but in all the blastocyst comes into contact with the uterine epithelium over part or the whole of its surface.

The reaction of the uterus to the embryo is therefore an important part of the mechanism of palcentation, but the trophoblast itself is very active. This has been shown by planting fertilized mouse ova into the anterior chamber of the eye and watching their development (Runner, 1947). The trophoblast of this implant develops well for as much as three weeks, forming phagocytic trophoblastic giant cells, which penetrate the epithelia of the eye and produce extravagation of blood.

5.5.2 Physiology of the Placenta

During the first few weeks of the embryonic period nutrition of the embryo depends upon the diffusion of materials from the endometrium and upon absorption of materials produced by the local destruction of uterine tissue (decidua basalis). By the end of the second week the embryo is dependent upon transmission of metabolites to it through the syncytiotropohoblast from the maternal blood circulation through the intervillous spaces of the developing placenta. About 26 days post ovulation; movement of blood through the embryonic heart changes from an ebb and flow pattern to a unidirectional flow, and circulation of fetal blood through the villi of the placenta may be assumed to begin about that time. The nutrition of the embryo is dependent upon the placenta and the functional relationship established therein between fetal and maternal vascular systems.

The placenta mediates the metabolic exchange between mother and fetus. It provides for the nutrition and respiration of the fetus, and it functions as an avenue for excretion of fetal waste products. It synthesizes a variety of materials, including hormones and enzymes, and it serves as a barrier between the fetal and maternal blood streams. At the end of the first trimester of pregnancy, when it has attained maturity, the cake like placenta occupies about one half the inner surface of the uterus; as term it covers about one third of the surface. The breadth of the placenta at term is about 7 inches and it weighs approximately 11/4 pounds. The surface area of tissue mediating the fetal- maternal physiological relationship is impressive: The total surface area of the villi approximates 30 miles. For the most part, the important site of exchange is between the fetal capillaries of the villi and the intervillous space, and most of the terminal villi through which exchanges between fetal and maternal blood occur are in that half of the placenta toward the maternal surface. The layers intervening between the fetal and maternal blood in a terminal villous may be no more than the thin outer covering of syncytiotropohoblast and the double-layered basement membrane and endothelium of the fetal capillary. This is the thinnest portion of the placental barrier.

Many substances traverse the placental barrier at different rates and in different ways. Abundant microvilli covering the syncytium may engulf whole droplets of maternal plasma and transfer them to the fetal capillaries by *pinocytosis.*

Water, gases, and simple solutes diffuse across the semi permeable placental barrier at varying rates. Water molecules are exchanged more rapidly than any other substance. It should be noted that water also reaches the fetus by way of the gastrointestinal tract, which is necessary because the fetus drinks about one fourth of the amniotic fluid volume each day.

Substances other than water which transfer across the placenta with great rapidity and by the mechanism of diffusion are urea, uric acid, simple amines, oxygen, and carbon dioxide. Carbon dioxide diffuses easily and rapidly, and a high concentration gradient is therefore unnecessary to facilitate its transfer. Oxygen is not so easily diffusible, and to ensure an adequate supply of oxygen to the fetus the oxygen tension on the maternal side of the barrier must be considerably higher than that on the fetal side. This gradient is facilitated by the specific hemoglobin of the fetus, which has a dissociation constant for oxygen that is different from that of adult hemoglobin. Fetal hemoglobin possesses the capacity to bind more oxygen than maternal hemoglobin at the same oxygen tension, and it combines with or releases oxygen at lower concentrations than does adult hemoglobin. The

distinctive fetal hemoglobin constitutes about 75 percent of the total hemoglobin in the newborn infant. The remaining 25 percent is adult hemoglobin. The fetal hemoglobin disappears rapidly after birth, and is entirely supplanted by adult hemoglobin by 6 months postpartum.

The rates of placenta transfer of sugars, essential amino acids, and the water-soluble vitamins are rapid, but diffusion seems secondary to their *active* or *facilitated transfer* by enzymatic carriers. The enzymes responsible for active or facilitated transfer of material across the placental membrane are probably resident in the cytoplasm of the syncytiotropohoblast. These selective enzyme carriers affect the transfer of essential sugars, amino acids, and vitamins between the surfaces of the trophoblastic layer. The carriers have not yet been identified, but the operation of this active transport system and its selectivity is well demonstrated for the amino acids. L. page has shown that following administration of two optical isomers, D- and L- histidine, the natural L-histidine is transported to the fetus several times faster than the unnatural D-histidine. This transfer system can account for the fact that the essential amino acids, so vital to protein synthesis in the rapidly growing fetus, are maintained in higher concentrations in the fetal plasma than in the maternal plasma. The transfer of glucose is also apparently facilitated by an active transport mechanism. Lipids in the intrauterine state are synthesized and stored by the fetus, but they do not appear to be utilized as a primary fuel. Until 6 to 8 hours after birth, carbohydrate is apparently the main source of energy during intrauterine life. The utilization of carbohydrate as a primary fuel can account for the fact that the concentration of glucose is usually lower in the fetal blood than in the maternal blood. Fructose, which exists in higher concentrations in the fetal blood, is synthesized by the placenta. Water-soluble vitamins such as thiamine, pyridoxine, riboflavin, and ascorbic acid are relatively concentrated in fetal blood and been shown that a precursor of riboflavin enters the placental membrane, is enzymatically split into its component parts, and is then transferred to the fetal circulation, Similar systems probably exist for the transfer of such metals as iron; magnesium, and calcium, which are all carried in complex molecules.

Na^+ active transfer mechanism has been demonstrated for the various steroid and protein hormones concerned with maintenance of pregnancy or modification of fetal growth. These relatively large molecules diffuse slowly, if at all. Adreno-cortico steroid hormones, thyroxin, and chorionic gonadotrophin appear to traverse the placental membrance in small quantities by diffusion. Placental transfer of various pituitary hormones is still an unsettled question.

Some enzymes produced by the placenta subserve a protective function preventing transplacental passage of material potentially dangerous to the fetus. Given sufficient time and appropriate concentrations, almost anything may pass the placental barrier unless it is inactivated or destroyed during its passage. Sometimes relatively simple diffusible molecules are enzymatically destroyed before they are able to enter the fetal circulation. Thus histamine is easily capable of diffusing across the placental barrier, but is dominated and detoxified during passage by a placental enzyme, diamine oxidase. Rapid, enzymatic deamination of other potentially harmful amines (for example, epinephrine, nor epinephrine, and serotonin) apparently detoxifies them completely during transplacental passage.

Cells and such large molecular materials as plasma proteins, antigens, antibodies, and various drugs are generally denied passage through the placental membrane. Antigens appear to be among those substances destroyed by the syncytiotropohoblast. However, small quantities of certain mater

nal plasma proteins and maternal antibodies do reach the fetus, and drugs such as analgesics and antibiotics may also pass the placental barrier. The site of transfer of proteins and antibodies in the human placenta is not known. In the monkey, on the other hand, there is evidence that the route of antibody transfer may be transplacental, perhaps by pinocytosis or by passage through prose or through pathological breaks in the membrane.

The penetration of some viruses and antibodies through the placental barrier has several important consequences. Active antibody formation occurs in postnatal life as a reaction to various microbial and other antigenic stimuli to which the organism is deposed. Antibody formation begins before birth in some animal species (for example, sheep and monkey), and active antibody formation may begin in the human before birth. Nevertheless, the transplacental passage of antibodies during prenatal life confers some immunity during the first few months of the postnatal period. The antibodies against measles, hepatitis, and to a certain extent various viral diseases, including polio and German measles. For example, empirical observations indicate that protection against measles is usually complete for another 2 months after birth.

Not all maternal antibodies transferred to the fetus are beneficial. A considerable number of transferred antibodies are apparently innocuous, but some are likely to have an adverse affect upon the fetus. The maternal antibodies against the Rh factor may produce fetal erythroblastosis, and if a mother contracts German measles during the first 8 weeks of pregnancy the virus may affect the fetus, causing congenital cataract, heart disease, deafness, and central nervous system damage.

The placenta is one of the most important organs of pregnancy. It not only maintains the fetus but is almost solely responsible for the intrauterine welfare of the fetus. Investigation of the physiological and biochemical aspects of placental function, particularly in the human, is one of the more pressing needs of developmental biology in general and human embryology in particular.

5.5.3 Evolution of the placenta

It is equally difficult to correlate placental structure with our knowledge of the affinities of the mammalian orders based on other evidence. The diffuse and epithelio-chorial type of palcentation is primitive; but it is found among the most specialized mammalian orders. The insectivores, shown both by their anatomy and geological history to be an ancient group, are said to have discoidal haemochorial palcentation! If our ideas of affinity were based on palcentation alone we should include lemurs with 'ungulates', because their placentae are epithelio-chorial, and the conies (Hyracoidea) with the insectivores, primates, and other haemo-chorial types. A classification based on palcentation would put the sloths among man's nearest relatives.

5.5.4 Summary

In addition to acting as an organ of transfer the placenta has many other important biochemical properties, for instance it stores much glycogen. Various special types of cell develop in the placenta, presumably in connexion with these metabolic processes. The decidual cells are connective tissue cells of the endometrium that become loaded with glycogen or lipoids. They are usually prominent

early in pregnancy but are lacking altogether in some placentae. The giant cells, which may be mono or multinuclear, develop from the trophoblast, their function is unknown but they may be phagocyte.

The placenta is also the seat of production of a surprising variety of hormones. The substances known as *chorionic gonadotropins*, which resemble pituitary hormones, are present in large quantities and are excreted in the urine during pregnancy, at least in some species. Their presence is the basis of a test for pregnancy in women. During the second month large amounts of a substance able to stimulate ovulation are excreted and the test consists of injecting urine samples into rabbits and later examining the ovaries.

5.5.5 Conclusion

The placenta therefore contains a range of hormones even greater than that of the pituitary. Their significance for chemical signaling is not understood but it is reasonable to suppose that they interact with the hormones produced in the permanent ductless glands to ensure proper adjustment of metabolism during pregnancy; the placenta becomes a master gland overriding even the pituitary with a massive and integrated output of chemical signals.

5.5.6 Expected questions:

1. Give an account of the physiology of the placenta
2. Write briefly about the phylogenetic evolution of the placenta.

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(కత్తిరించి పంపవలెను)

అధ్యాపకులు, విద్యార్థుల సలహాలు, సూచనలు :

అధ్యాపకులు, విద్యార్థులు ఈ స్టడీ మెటీరియల్‌కు సంబంధించిన సలహాలు, సూచనలు, ముద్రణ దోషాలు తెలియపరచినచో, పునర్ముద్రణలో తగుచర్యలు తీసుకొనగలము. తెలియపరచవలసిన చిరునామా : **డిప్యూటీ డైరెక్టర్, దూరవిద్యాకేంద్రం, ఆచార్య నాగార్జున విశ్వవిద్యాలయం, నాగార్జున నగర్ - 522 510.**

Course	Year	Paper No. & Title

(కత్తిరించి పంపవలెను)

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