STRUCTURE AND FUNCTION OF INVERTEBRATES AND VERTEBRATES

M.Sc. Zoology

Semester-I, Paper-I

Lesson Writers

Prof. V. Venkata Ratnamma
Department of zoology
University college of sciences
Acharya Nagarjuna university

Prof. P. Padmavathi
Department of zoology
University college of sciences
Acharya Nagarjuna university

Prof. K. Sunitha
Dept. Zoology & Aquaculture,
Acharya Nagarjuna University,
Guntur.

Prof. M. Jagadish Naik
Dept. Zoology & Aquaculture,
Acharya Nagarjuna University,
Guntur

Prof. G. Simha Chalam
Department of Zoology
University College of Sciences
Acharya Nagarjuna University
.

Editor

Prof. V. Venkata Rathnamma
Department of Zoology
University College of Sciences
Acharya Nagarjuna University

DIRECTOR, I/c.

Prof. V. Venkateswarlu
M.A., M.P.S., M.S.W., M.Phil., Ph.D.
Professor
Centre for Distance Education
Acharya Nagarjuna University
Nagarjuna Nagar 522 510

Ph: 0863-2346222, 2346208
0863- 2346259 (Study Material)
Website www.anucde.info
E-mail: anucdedirector@gmail.com

STRUCTURE AND FUNCTION OF INVERTEBRATES AND VERTEBRATES

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Prof. V. VENKATESWARLU
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FOREWORD

Since its establishment in 1976, Acharya Nagarjuna University has been forging ahead in the path of progress and dynamism, offering a variety of courses and research contributions. I am extremely happy that by gaining 'A+' grade from the NAAC in the year 2024, Acharya Nagarjuna University is offering educational opportunities at the UG, PG levels apart from research degrees to students from over 221 affiliated colleges spread over the two districts of Guntur and Prakasam.

The University has also started the Centre for Distance Education in 2003-04 with the aim of taking higher education to the door step of all the sectors of the society. The centre will be a great help to those who cannot join in colleges, those who cannot afford the exorbitant fees as regular students, and even to housewives desirous of pursuing higher studies. Acharya Nagarjuna University has started offering B.Sc., B.A., B.B.A., and B.Com courses at the Degree level and M.A., M.Com., M.Sc., M.B.A., and L.L.M., courses at the PG level from the academic year 2003-2004 onwards.

To facilitate easier understanding by students studying through the distance mode, these self-instruction materials have been prepared by eminent and experienced teachers. The lessons have been drafted with great care and expertise in the stipulated time by these teachers. Constructive ideas and scholarly suggestions are welcome from students and teachers involved respectively. Such ideas will be incorporated for the greater efficacy of this distance mode of education. For clarification of doubts and feedback, weekly classes and contact classes will be arranged at the UG and PG levels respectively.

It is my aim that students getting higher education through the Centre for Distance Education should improve their qualification, have better employment opportunities and in turn be part of country's progress. It is my fond desire that in the years to come, the Centre for Distance Education will go from strength to strength in the form of new courses and by catering to larger number of people. My congratulations to all the Directors, Academic Coordinators, Editors and Lesson-writers of the Centre who have helped in these endeavors.

Prof. K. Gangadhara Rao
M.Tech., Ph.D.,
Vice-Chancellor I/c
Acharya Nagarjuna University.

ACHARYA NAGARJUNA UNIVERSITY
M.Sc. ZOOLOGY
I st SEMESTER
PAPER -I
STRUCTURE AND FUNCTION OF INVERTEBRATES AND VERTEBRATES
CODE No. Z1.1

Course Objectives/Course Outcomes:

This course is designed to

CO: 1 Understand the general characteristics of all invertebrates of coelom and about the nutrition, digestion, respiration.
CO: 2 To discuss about Larval forms of free-living invertebrates and Minor phyla general characters.
CO: 3 Remembering the biology and life cycles of Parasites and insects and its importance in environment.
CO: 4 Elucidate the comparative accounts of respiratory and circulatory systems of vertebrates.
CO: 5 Comparative anatomy and function of Nervous, sensory and urinogenital systems among different vertebrates.

UNIT–I

1 .Invertebrates: General characters of invertebrates;Coelom-Originand functions, acoelomoates, pseudocoelomates and coelomates (Protostomia and Deuterostomia).
2. Nutrition and Digestion:Patterns of feeding and digestionin Cnidarians;filter feeding in Polychaeta, Mollusca and Echinodermata.
3. Respiration: Structure and function of respiratory organs in Annelida, Arthropoda and Moluccas-gills,lungs and tracheae.

UNIT–II

1. Invertebrate Larvae: Larval forms of free-living invertebrates;
2. Larval forms of parasites.
3. Minor Phyla: Organization and general characters of Rotifera,Phoronida and Chetognatha

UNIT–III

1. Parasites: Life cycle and biology of Trypanosoma gambiense, Leishmania donovani, Wuchereriabrancrofit And Schistosoma haematobium.
2. Insects: Insects and diseases;
3. Economic importance of insects.

UNIT–IV

Vertebrates: Important characters, nature of vertebrate morphology.
Respiratory system: Comparative accountofrespiratory organs in vertebrates.
Circulatory system: Evolution of heart among vertebrates; Evolution of aortic arches and portal systems amongvertebrates.

UNIT– V

Nervous system: Comparative anatomy and function ofbrain and cranial nerves in vertebrates. Comparative anatomy of spinal cord, spinal nerves and autonomous nervous system in vertebrates.
Urinogenital system: Evolution of urinogenital systems among vertebrates.
Sensory organs: Olfactory and taste organs in vertebrate series; Lateral line system in fishes.

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M.Sc. DEGREE EXAMINATION
Centre for Distance Education, ANU
First Semester
Zoology
Paper - I - STRUCTURE AND FUNCTION OF INVERTEBRATES AND VERTEBRATES
(Model Question Paper)

Time: 3 hours **Maximum: 70 marks**

Answer ALL questions.
ALL questions carry equal marks.
Each question carries **14** marks.

1 (a) Write in detail about the origin, functions of various coelome.
(or)
(b) Explain the patterns of feeding and digestion in cnidarians.

2 (a) Give an account of free-living larval forms of invertebrates.
(or)
(b) Write a detailed account on organization and general characteristics of chetognatha

3 (a) Describe about the lifecycle and biology of wuchereriabrancrafti
(or)
(b) Give an account on insects and disease.

4 (a) Discuss about the important characters and nature of vertebrates
(or)
(b) Explain the evolution of portal system among vertebrates.

5 (a) Write an account of comparative anatomy of nervous system in vertebrates.
(or)
(b) Discuss about olfactory and taste organs in vertebrates series.

(101ZO24)

CONTENTS

LESSON - 1
INVERTEBRATE GENERAL CHARACTERS, NUTRITION AND ESPIRATION

OBJECTIVES

Understand the general characteristics of invertebrates
Students will understand Types of coeloms
Students will know about Feeding and digestion patterns
Structure and functions of invertebrate

GENERAL CHARACTERS OF INVERTEBRATES

1.1	**BODY CAVITY OF COELOM**
1.2	**TYPES OF COELOMS**
1.3	**PROTOSTOMIA AND DEUTEROSTOMIA**

More than 90% of the animals are invertebrates among the estimated 15-30 million animal species. Invertebrates exist about anywhere. All invertebrates do not have a spinal cord or vertebral column, instead, most of them possess an exoskeleton that encompasses the entire body. Normally, these are tiny and don't grow very large. Do not possess lungs since they respire through their skin. Since they cannot produce their own food, Invertebrates are heterotrophic. Reproduction occurs through fission of gametes.

Characteristics are: 1. Habitat 2. Numerical Strength 3. Shape 4. Size 5. Symmetry 6. Grades of Organization 7. Germ Layers 8.Integument 9. Movement 10. Segmentation and Others.

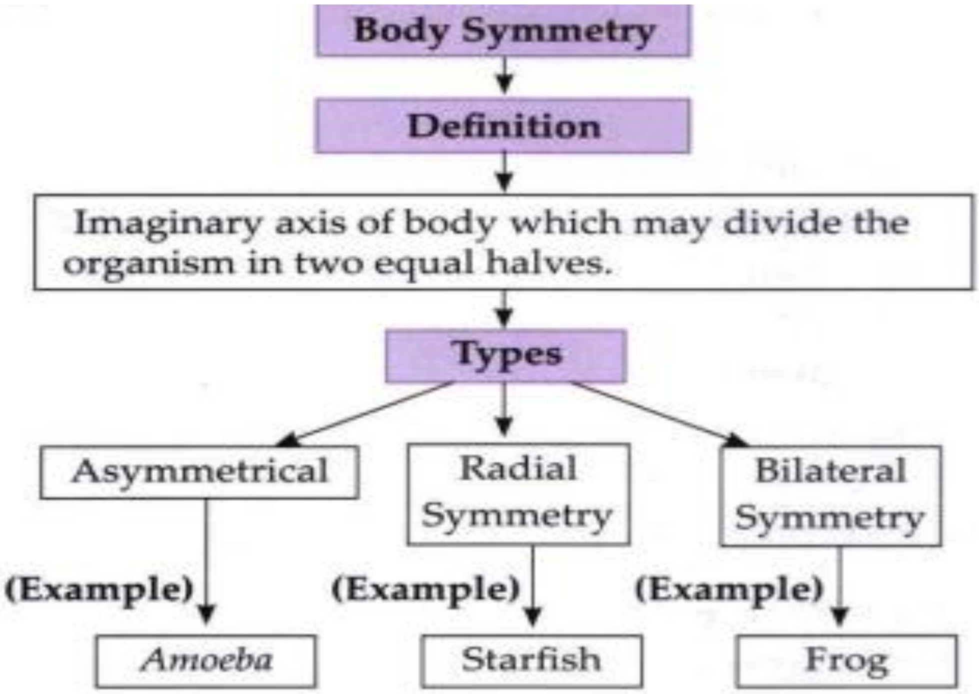
1. **Habitat:** All the 30 phyla most probably originated in the sea, but not all have successfully invaded the land or its freshwater habitats. About 80 per cent are found in the terrestrial habitats.They are found in seas, freshwater, air, land from snow to desert. 80% are found in terrestrial habitat.Most successful invertebrates of the lands are Arthropods. Protozoans are free-living, parasites or commensals.Sponges and Coelenterates are aquatic animals.

2. **Numerical Strength**: At present nearly one million living species of animals are known, out of which about 95 percent are the invertebrates. It has been estimated that the number of extinct species is around seven times more then number of living species.

3. **Shape:** Animals of varied shapes are included amongst the invertebrates. Amoeba possesses an irregular ever-changing body shape, sponges and coelenterates display plant-like appearance, flatworms are leaf-like and ribbon-shaped and annelids, nemertean's and nematodes are vermiform, while the starfishes are star-shaped, etc., display spectra of body shape.

4. **Size:** The invertebrate animals exhibit a great variation in size. They range from microscopic protozoans to large-sized cephalopods. The malaria parasite is at the lowest extremity. It occupies only about one-fifth of a human red blood corpuscle (RBC). The uppermost extremity is occupied by a species of the giant squids of North Atlantic, Architeuthis, has been reported to have attained a total body length of 16.5 metres including tentacles.

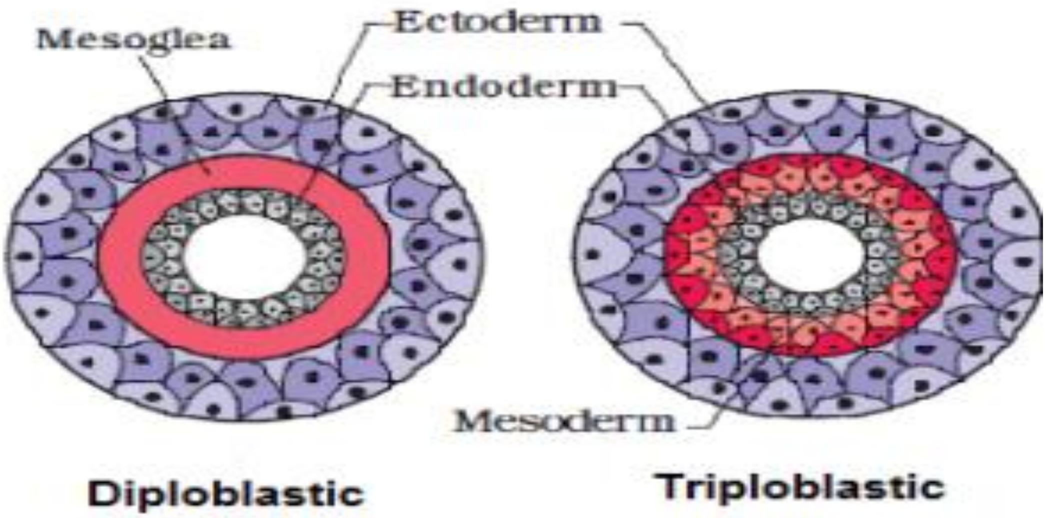
5. **Symmetry:** Invertebrates represent all types of symmetries. Protozoans display bilateral as well as radial symmetry. Some are asymmetrical. Sponges are either asymmetrical or radially symmetrical. Coelenterates are radially symmetrical. Ctenophores exhibit biradial symmetry. The members of the remaining phyla are mostly bilaterally symmetrical. Invertebrates also represent spherical symmetry, principally in spherical protozoans such as Heliozoa and Radiolaria.



6. **Grades of Organization:** Invertebrates display all grades of organization. The protoplasmic grade is seen in Protozoa, as all activities at this level are carried on within the limits of plasma membrane (plasma lemma). The cellular grade is characteristic of sponges. In sponges only, the cells exhibit division of labour for performing various specialized functions. The cell-tissue grade is observed in coelenterates as their cells are not only specialized for different functions but also certain similar cells gather together to form tissues as well. The tissue-organ grade is exhibited by flatworms with arrangement of tissues to form organs. The organ-system grade organization is characteristic of all higher invertebrates. In this type of organization, organs join together in a system to perform some functions.

7. **Germ Layers:** The germ layers or embryonic cell layers are absent in Protozoa due to its uni-cellularity. All other invertebrates are either diploblastic, i.e., they are derived form two germ layers, an outer ectoderm and an inner endoderm or triploblastic with an extra third

layer, the mesoderm. Sponges and coelenterates are diploblastic, whereas other invertebrates are triploblastic.



8. Integument: The body covering with simple integument. In protozoa, it is a delicate plasma membrane, while some Invertebrates represents protective covering, pellicle. Most invertebrates possess an outer protective epidermis, which is made of single layer of cells, while in others have further added a non-cellular cuticle or chitinoid covering secreted by underlying epidermis.

9. Movement: Various devices for movements found in invertebrates. Some invertebrate animals are sessile, such as sponges and corals, while others move from one place to another. Protozoa move by pseudopodia, flagella and cilia and contractile monements . Coelenterates and molluscs exhibit tentacular movements. Annelids move by setae, parapodia and suckers. Arthropods move with jointed legs, while echinoderms take the help of arms which are with or without tube feet, for their movement.

10. Segmentation: Several invertebrate phyla are characterised by segmentation in their bodies. Certain flatworms exhibit pseudo segmentation, as their long bodies are made up of numerous sections. True segmentation is found in Annelida and Arthropoda. The body is divided into more or less similar segments.

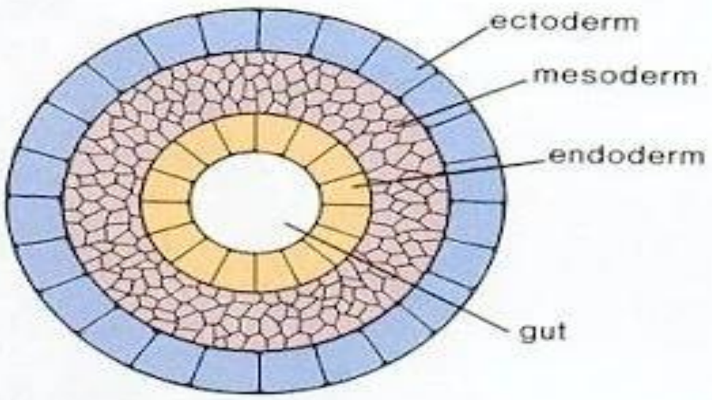
11. Endoskeleton: The invertebrate animals do not possess any kind of rigid internal skeleton to give support to the body and provide surface for attachment of muscles. Many invertebrates are soft bodied, while some, like arthropods and molluscs, possess hard exoskeleton for supporting and protecting their body.

12. Classification of invertebrates Invertebrates can be classified into several main categories, some of which are taxonomically obsolescent or debatable, but still used as terms of convenience. Each however appears in its own article at the following links.

The most familiar invertebrates include the

- Protozoa,
- Porifera,
- Coelenterata,
- Platyhelminthes,
- Nematoda
- Annelida,
- Arthropoda.(Arthropoda include insects, crustaceans and arachnids)
- Mollusca
- Echinodermata,

13. Coelom: In sponges and coelenterates, the body is a double-layered sac surrounding a single cavity, which opens to the outside through a mouth. Such animals are acoelomate as they have no coelom. Other invertebrates possess a cavity in between the body wall and the gut. This cavity is called pseudo-coelom in nematodes as it is not lined by mesoderm. In higher invertebrates, the coelom is lined by mesoderm and, hence, it is the true coelom.



Acoelomate
(no coelom)

14. Dorsal Gut: The alimentary canal is either absent or partially formed or complete. In case, it is present, it lies dorsal to the nerve cord, and runs from the anterior terminal mouth up to the posterior terminal anus. The gill-slits are never formed in the pharyngeal wall.

15. Digestion: In invertebrates, the digestion of food takes place within the cell (intracellular digestion) as well as outside the cell (extracellular digestion). In protozoans and sponges, the digestion of food takes place intracellularly. In coelenterates, the digestion of food lakes place both intracellularly as well as extracellularly. All other invertebrates exhibit extracellular digestion, which in higher invertebrates occurs within a well defined gut.

16. Circulatory System: Blood vascular system is well developed in higher invertebrates. Some, like arthropods and molluscs, possess open or lacunar circulatory system, while in others the blood flows in closed vessels, i.e., closed circulatory system. The heart is always located dorsal to the gut.

17. Respiratory System: Protozoans, sponges, coelenterates and many worms have a direct diffusion of gases between the general surface of the organism and the environment. In most annelids, the exchange of gases takes place through the moist skin. Gills are common in most higher invertebrates. Echinoderms possess branchiate and tube feet for this purpose. Sea cucumbers have respiratory trees which act as respiratory organs. In insects, the tracheal system is adapted for aerial respiration.

18. Excretory Mechanisms: In protozoans, sponges and coelenterates, excretion is performed by direct diffusion through cell membranes. Flatworms possess characteristic flame cells, while annelids and molluscs possess true nephridia. In insects, the excretory organs are Malpighian tubules. Echinoderms and some other invertebrates have amoeboid cells or phagocytes for storage and disposal of excretory products to outside.

19. Nervous System: In radially symmetrical invertebrates, e.g., coelenterates, the head is absent and the central nervous system is represented by a ring of nerve-tissue encircling the body. In bilaterally symmetrical invertebrates, the central nervous system comprises a pair of nerve cord running along the mid-ventral line of the body. The nerve ring and the nerve cords bear ganglia. In higher invertebrates, the head ganglia forms the brain. Invertebrate nervous system is characterised by solid nerves, these are not hollow within.

2.0. Sense Organs: In protozoans protoplasm acts as receptor, while in flagellates, the stigma or eyespot acts as a photoreceptor. Coelenterates possess long sensory cells, scattered throughout the body wall, while some also possess eyespots for the reception of light, statocysts for equilibrium and sensory pits for chemoreception. Eyespots and chemoreceptors are also found in flatworms. Annelids possess various sensory receptors including simple eyes, present in the epidermis. In arthropods, compound eyes are found in addition to simple eyes. Statocysts for equilibrium; tactile receptors and chemoreceptors are common in arthropods and molluscs.

21. Reproduction: Modes of reproduction vary from simple asexual binary fission to most complicated sexual reproduction. In certain cases, parthenogenesis has also been observed in which an unfertilized egg develops into a complete individual. Ex: rotifers, bees, some other insects and certain crustaceans. In sexually reproducing invertebrates, hermaphrodites or bisexual forms are found, particularly in coelenterates, platyhelminthes, annelids and crustaceans. Fertilization is either external or internal. Development is direct or indirect. In the indirect development, the development includes both larval stages and metamorphosis.

22. Cold-Blooded Animals: All invertebrates are cold-blooded, i.e., they cannot keep body temperature constant all the time

1.1 BODY CAVITY OF COELOM

All animals have cavities. These cavities perform different functions in different animals. Generally, body cavity means a large fluid filled space lying between the bodywall and the internal organs. The coelom is a perivisceral cavity between the body wall and alimentary canal. During embryonic development, coelom arises as a split in the mesoderm which becomes bifurcated into two layers, a **somatic layer** lying next to the epidermis and a**s planchnic layer** around the endoderm. Coelom becomes bounded on all sides by coelomic epithelium which secretes coelomic fluid. The excretory organs open into coelomaton end and to exterior at the other end. The wall of coelom gives rise to reproductive cells and to coelomo ducts. which carry sperms or eggs from the coelom to the exterior.

The greater part of the coelom forms the perivisceral cavity or splanchnocoel, which is a fluid-filled space inside which visceral organs are lodged. Certain portions of the perivisceral cavity are cut off from it to form restricted cavities; such as gonocoel and nephrocoel, whose coelomic nature can only be realized, if their developmental history is followed. The annelids are the first animals to have a **truecoelom**.

EVOLUTION OF COELOM

Coelom is a body cavity that is present in many animals, including humans. It is lined with mesodermally-derived tissue and contains the internal organs. ϖ There are different theories about the evolutionary origin of coelom, and some of these theories are discussed below: Schizocoelous Theory: This theory suggests that coelom evolved from a split in the mesoderm, resulting in two layers that enclose a cavity. This process is known as schizocoely, and it is seen in many protostomes, such as arthropods and mollusks. In these animals, the coelom is formed by the expansion of the blastocoel, which is the cavity that forms during gastrulation. Enterocoelous Theory: This theory proposes that coelom evolved from outpocketings of the gut, which eventually formed into the coelom. This process is known as enterocoely, and it is seen in deuterostomes, such as vertebrates and echinoderms. In these animals, the coelom is formed from the mesoderm that arises from the wall of the archenteron, which is the primitive gut. ϖ Coelom from Multiple Origins Theory: This theory suggests that coelom evolved independently in different lineages of animals. For example, the coelom in annelids may have evolved differently from the coelom in chordates. This theory is supported by the fact that the coelom has different characteristics in different groups of animals.

1.2 TYPES OF COELOMS

Thee volutionary sequence of coelom is from acoelomate to pseudocoelomate and then to coelomate. The difference between a pseudocoelomate and a coelomate animal is the absence or presence of epithelial lining or peritoneum. It is present in acoelomate animal and absent in a pseudocoelomate animal. The embryological origin of a true coelom varies. If it develops from a split in cells of the mesoderm, it is said to be **schizocoelous**. If it develops from outpocketing from the embryonic gut, it is said to be **enterocoelous**. Thus, on the basis of presence or lack of coelom and its nature, when present the metazoans are often divided into three large groups. When coelom or fluid-filled cavity is absent, the animals are said to be acoeloates andthe group is referred to as acelomata. The Platyhelminthese having no coelom, are termed acoelomates. The space between the gut and body wall is filled by a kind of densely packed connective tissue derived from both ectoderm and endomesoderm (entomesoderm), called parenchyma.

I. ACOELOMATA

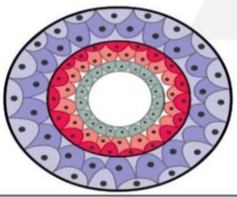
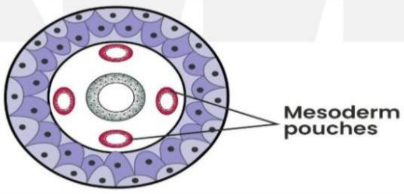
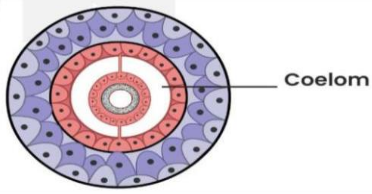
The Acoelomata are relatively simple triploblastic animals which have no perivisceral body cavity or coelom. Triploblasts that do not develop a coelom are called acoelomates. The space between the digestive tract and the body wall is filled with a tissue known as parenchyma derived from the mesoderm.

II. PSEUDOCOELOMATA

The body cavity which is lying between the gut and outer body wall musculature and is generally formed by persistence of **embryonic blastocoel**, called as pseudocoelom.
The term 'pseudocoelom' usually refers to the space which does not develop from embryonic mesoderm and it is lined by mesodermonly on the outer bodywall side and not around the gut.) The pseudocoelomi fluid acts as achydrostatic skeleton to maintain body shape and circulate nutrients. In **nematyhelminthes**, pseudocoel is founds other are termed as **pseudocoelomates**.

III. COELOMATA OR EUCOELOMATA

The coelom lying between the gut and outer body wall musculature and lined both on the inside of the body wall as well as around the gut by mesoderm is referred to as **truecoelom**. The true coelom is mesodermal in origin and opens to the exterior through the coelomo ducts like the oviducts and the excretory ducts. The coelomic fluid contains amoeboid cells or amoebocytes. The animals containing such a body cavity or coelom, are termed as **eucoelomates**.

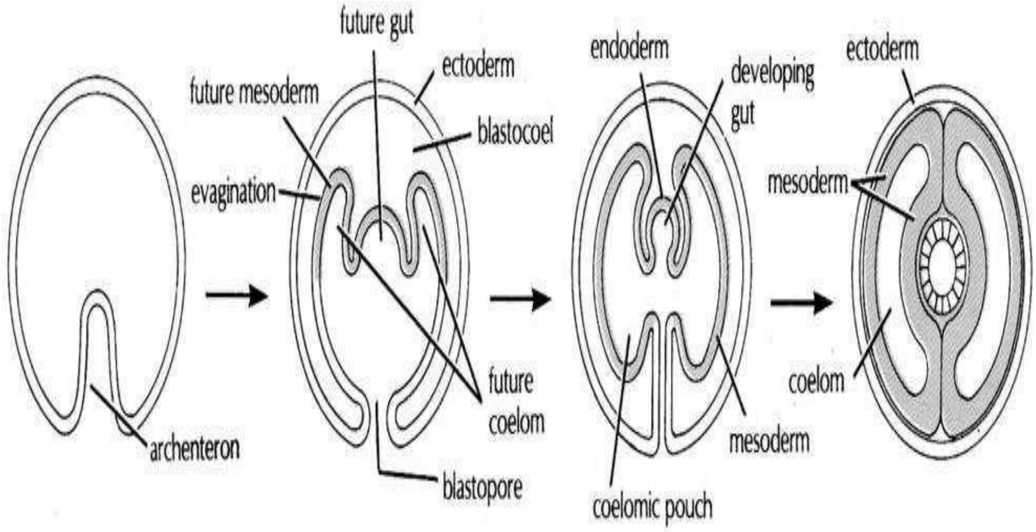
Acoelomate	Pseudo-coelomate (False coelomate)	Coelomate (True coelom)
Body cavity is absent. e.g, Porifera to Platyhelminthes	Body cavity is not lined by mesoderm, instead mesoderm is present as scattered pouches in between ectoderm and endoderm. e.g. Aschelminthes	Coelom is lined by mesoderm, and filled with coelomic fluid. e.g. Annelida to Chordata
		

MODES OF COELOM FORMATION

According to the mode of coelom formation, there are generally two types of animals.

I. SCHIZOCOELOMATE

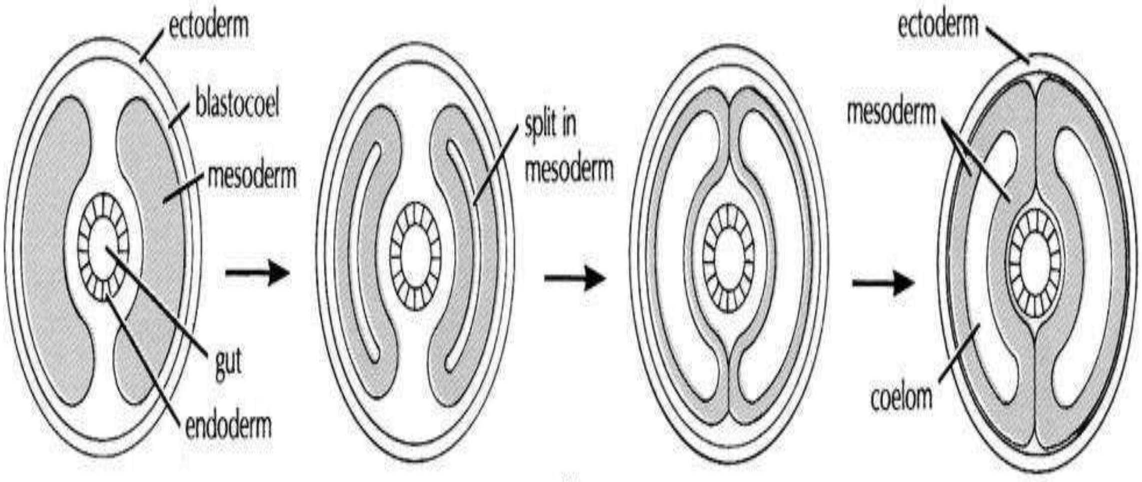
When coelomarises by the splitting of Mesodermal bands or masses during embryonic development, it is called as schizocoel and animals are called as schizocoelomates. The animals belonging to phylum Mollusca, Annelida, Arthropoda, and Onychophora are schizocoelomates.



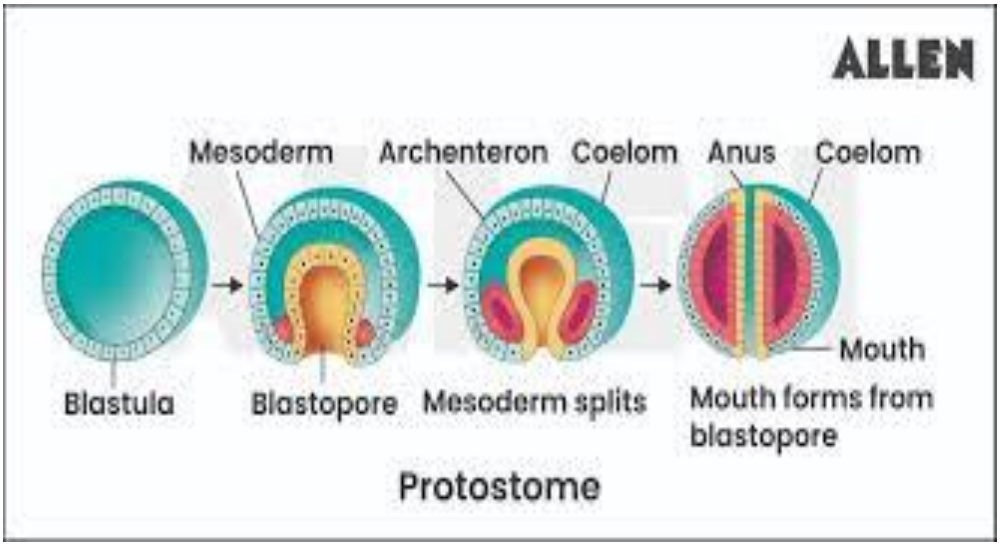
II. ENTEROCOELOMATE

When coelom is formed by the evagination from the embryonic archenteron and the pouch-like structures are detached from the archenteron and gradually occupy the whole body by enlargement, called as enterocoel. The animals having enterocoel are called enterocoelomate. The animals belonging to phylum Echinochordata, Hemichordata and Chordata are enterocoelomates.

Functions of Coelom



Coelom acts as a protective layer that absorbs shocks. It absorbs most of the mechanical shocks.



This cavity also provides flexibility to the organs to move. It also gives cushioning effects to the internal organs from damage on minor bends.

The coelomic fluid is a hydrostatic skeleton that helps in locomotion for soft-bodied animals. It also gives the body a definite shape. Contracting muscles can push against the coelomic fluid as a result of the fluid pressure.

The cells of the coelom called coelomocyte cells either float freely in the coelom or remain attached to the wall. The function of these cells is to support the immune system. They initiate the humoral immune response and phagocytosis.

Another function of the coelomic fluid is transporting gases, nutrients, and waste products.
Coelom provides extra space for the organs to develop properly and carry out their functions. Coelom makes the pumping of the heart possible, and also makes room for the baby in the womb.

1.3 DEVELOPMENTAL PATTERN OF INVERTEBRATES

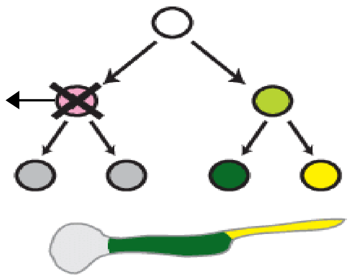
The bilateral metazoans can be differentiated into two main assemblages based on either the formation of mouth first or the anus. Metazoans in which blastopore forms the mouth of the animal and anus is formed secondarily are called ‘Protostomes’ and in which blastopore forms the anus of the animal and mouth is formed primarily are called “Deutrostomes”. You will study about these two groups in the following subsections.

1. PROTOSTOMIA

The metazoans in which mouth is derived from blastopore on the anterior end and anus appears latertal complete the alimentary canal are included in Protostomia. As the mouth forms first, there animals are included in‘ Protostomia”(Mouth first)division of animal kingdom. Nerve cord is ventral in protostomes.
The developmental characteristics of protostomes are as follows.

1. **Pattern of embryonic cleavage:** Cleavage is spiral in protostomes,i.e.,axis of cleavage plane is oblique and so that blastomeres have a spiral arrangement in Which onetier of cells alternates with the nexttier of cells. The spiral cleaage is masked at the 6th cleavages 64-cell stage.

2. **Fate of embryonic blastomeres:** Fate of blastomeres is determined very early during holoblastic cleavage. This is called determinate or mosaic cleavage, which Means blastomeres are destined to form a particular organ in very early stage of cleavage. Just after first cleavage ablation of one of the cells takes place which leads to the loss of head structure in embryo that drive from it. Such type of development is said to be mosaic.



Ablation of one blastomere

1. Fate of blastopore:

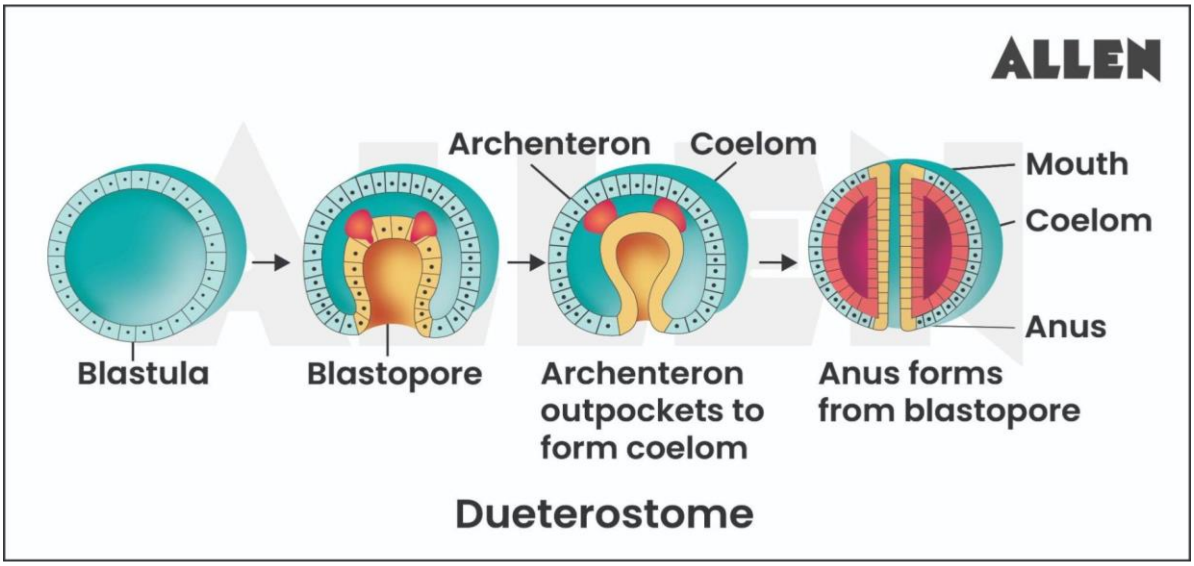
The blastopore either becomes mouth (e.g.Mollusca) or gives rise to both mouth and anus (e.g., some molluscs, polychaetes and onychophorans) in adult.

2. Formation of mesoderm:
Mesoderm originates from the fourth cell, named as mesentoblast (also called as'4d' cell) which increases in number by proliferation.

3. Formation of coelom:
Coelom originates by the splitting of them esodermal cell mass. This process of coelom Formation is known as **schizocoely** and coelom is called schizocoelom means('split').
Examples: Coelomate protostomes include Sipuncula, Echiura, Annelida, Pogonophora, Mollusca, Onychophora, Tardigrada, Pentastomida and some groups of arthropods.

4. DEUTEROSTOMIA

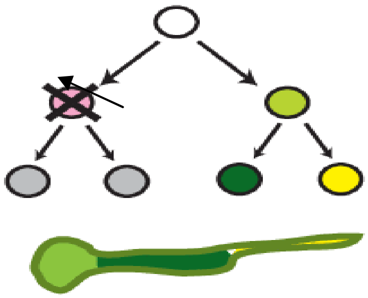
The metazoans in which anal opening are derived from blastopore during embryonic development and represents the posterior end of body and mouth is formed later are included in deuterostomia As the anus forms first and mouth is formed secondarily, these animals are grouped in Deuterostomia.



1. **Pattern of embryonic cleavage:** Radial pattern of embryonic cleavage occurs in which the cleavage plane is either parallel or at right angle to the polar axis. Blastomeres are arranged directly above or below one another.

2. **Fate of embryonic blastomeres:** Cleavage is indeterminate and if blastomeres are separated at 4 cell stages, each one will develop into a complete individual. Cleavage is regulative because each of the blastomeres, if separated can regulate its development. If ablation of one cell takes place, then the descendants of there maining cell cangiverise to the structure in embryo that would have developed from the lost cell. In this case green cell is able to regenerate head structure as well as trunk region. Such development is said to be regulative.

Ablation of one blastomere



Fate of blastopore:

Blastopore becomes the adult anus and then the formation of mouth takes place from a second opening on the dorsal surface of the embryo.

1. **Formation of mesoderm:** Mesodermal tissue is formed by the outgrowth of endodermal wall of the archenteron.
2. **Formation of coelom:** Coelom is formed by evagination of pouches from the wall of archenteron and each diverticulum becomes separated from the archenteron and develops independent coelomic pouch. This process of formation of coelom is called as **enterocoely** and coelom is called as enterocoelom.

Examples: Deuterostomes include echinoderms, chordates, pogonophores, hemichordates and some minor phyla.

Coelomate protostomes include Sipuncula, Echiura, Annelida, Pogonophora, Mollusca, Onychophora, Tardigrada, Pentastomida and some groups of arthropods.

Prof. V. Venkata Ratnamma

LESSON - 2

NUTRITION AND DIGESTION

The process of breakdown of complex food compounds into simpler one is known as digestion. A variety of chemical compounds can be utilized by the animals for energy. But for maintaining proper body function, animals require some compounds which they cannot synthesize-like vitamins, certain salts, some amino acids etc. The subject dealing with these supplies is called nutrition.

2.1 FEEDING IN INVERTEBRATES

There are various mechanical processes by which invertebrates capture food. The processes are developed in accordance to various kinds of food that a given animal can obtain and utilize.

i. Microphagy: These are mechanisms for dealing with small food particles. In this process pseudopodia, cilia, tentacles, mucus, setae and muscles are used for obtaining food.

ii. Macrophagy: These are mechanisms for dealing with large food particles or masses. This process involves swallowing of inactive food, scraping, boring, and seizing the prey. After seizing the prey, the animals chew, swallow and may digest it externally.

iii. Fluid or Soft Tissue Feeding: Thesetype of feeders generally suck fluid food. Some pierce and then suck the body fluid of the prey and some simply absorb the liquid food from the substrate through body surface.

a. Herbivores and Omnivores

These animals have digestive system meant for plant and animal food digestion.

b. Deposit Feeders

These animals pass large amount of substratum through their gut.

c. Carnivores

These animals depend upon animal proteins.

d. Filter Feeders

They continuously strain small particles from large volumes of water, trapping the particles in mucus films or screens of setae and utilizing elaborate devices for sorting and transporting them.

e. Fluid Feeders

They pierce and suck juices from animals and plants. There are several other animals which do not fit neatly into any of these classifications. They exploit whatever foods are available in their environment, viz., the brittle star Ophiocomina nigra is sometimes microphagous and sometimes macrophagous.

2.2 DIGESTION IN INVERTEBRATES

The word 'digestion' comes from two Latin words meaning "to carry" (gerere) and "apart" or "asunder" (dis). In all the members of the animal kingdom, the food are made up of organic materials, e.g., carbohydrate, protein, fats, etc. These compounds have a very large molecular configuration.

The large molecules of food are first broken down into simpler units, like monosaccharide's, amino acids, fatty acids and glycerol from polysaccharides, proteins and fats, respectively These are then absorbed and either incorporated into the body or metabolized to provide energy.

The process of digestion, thus involves the breaking of large and complex molecules of the food, after which, they become absorbable and available for use in the body. Digestion is an essential physiological activity in animals, whether they feed on minute food particles or on large plants and animals (exceptions, some internal body parasites and symbionts).

Digestive processes, particularly in macrophagous animals, are both mechanical and chemical. When large plant or animals are taken as food then mechanical digestion is essential. The final processes of digestion are always chemical, but there is frequently a pretreatment of the food, either before or after it is taken into the body.

i. Mechanical Digestion

This is achieved with the help of the different components of the mouth parts and different specialised parts of the digestive tracts. In this process large mass of the prey are crushed into smaller parts mechanically.

ii. Chemical Digestion

In this process smaller masses of prey are broken into simpler organic compounds with the help of different hydrolytic enzymes. The site of enzymatic action varies within the animal body.

According to the site of enzymatic action, chemical digestion is of two types:

(a) Intracellular Digestion

Here digestion takes place within the cell. The protoplasm of the unicellular animal captures the food, encircles it in a food vacuole, digests it, discharges the wastes and incorporates the digested simple organic components into the protoplasm.

(b) Extracellular Digestion

Here digestion takes place outside the cell and generally within the digestive tract of the higher animals. Digestion is wholly intracellular in Protozoa and Porifera. In other phyla extracellular digestion either supplements the intracellular mechanisms or completely replaces it. In the following discussion we shall describe the process of feeding and digestion in some invertebrates.

Prof. Venkata Ratnamma

LESSON - 3

PATTERNS OF FEEDING AND DIGESTION IN CNIDARIANS

Cnidarians, a diverse group of marine and freshwater animals that include jellyfish, corals, sea anemones, and hydra, exhibit unique patterns of feeding and digestion that reflect their relatively simple body plans. These animals are primarily carnivorous, capturing prey using specialized cells with stinging structures, and they rely on a gastrovascular cavity to digest and absorb nutrients. The structure and functioning of their digestive systems are adapted to their environments and lifestyles, ranging from solitary predators to colonial filter feeders. Understanding the feeding and digestion mechanisms of cnidarians provides insight into their survival strategies and ecological roles in marine ecosystems.

1. Feeding Structure and Mechanism

Most cnidarians have tentacles surrounding their mouth. These tentacles are equipped with specialized cells called **cnidocytes**, which contain stinging organelles called **nematocysts**. These nematocysts release toxins that can paralyze or kill prey (typically small fish, plankton, or other small organisms)Cnidarians capture prey by using their tentacles to sting and immobilize them. The tentacles thenbring the prey toward the mouth for ingestion.

2. Digestion Process

Once the prey reaches the mouth, it enters the gastrovascular cavity, a central digestive cavity with a single opening that serves as both the mouth and anus. This cavity acts as both the site of digestion and nutrient absorption.Digestion begins extracellularly in the gastrovascular cavity, where digestive enzymes break down food. The partially digested food is then engulfed by specialized cells, where intracellular digestion occurs (inside the cells).

3. Nutrient Distribution

After digestion, the nutrients are absorbed and distributed throughout the body by diffusion, as cnidarians lack a circulatory system. This process is aided by the relatively simple body plan and the direct contact between cells and the environment.

4. Symbiotic Relationships (in some species)

Many cnidarians, especially corals, engage in a symbiotic relationship with **zooxanthellae**, a type of algae. The algae live within the cells of the cnidarian's tissues, where they perform photosynthesis. The algae provide the cnidarians with nutrients, particularly sugars, while the cnidarians provide a protected environment and access to sunlight.

Most cnidarians are carnivores, capturing small animals like plankton, small fish, and other invertebrates. They rely on their stinging cells to immobilize and capture prey.

5. Excretion and Waste Removal

Because cnidarians have a single opening to their gastrovascular cavity, undigested food particles and waste products are expelled through the same mouth/anus opening.

FILTER FEEDING IN POLYCHAETA

Filter feeding, also known as suspension feeding, is a feeding strategy that involves extracting small food particles, such as phytoplankton, detritus, and zooplankton, from the surrounding water column. Polychaetes that employ filter feeding have evolved specialized structures and behaviors to facilitate efficient food capture and ingestion.

Mechanism of filter feeding

Polychaetes employ different mechanisms to filter-feed, depending on their specific adaptations and habitats. Here are some common mechanisms employed by filter-feeding polychaetes:

Many filter-feeding polychaetes possess specialized appendages called branchiae or gills, which are responsible for both respiration and food capture. These structures are covered with cilia that create water currents, directing the flow of water and suspended particles toward the mouth. Examples of polychaetes that use branchial filter feeding include fanworms (Sabella spp.) and feather duster worms (Sabellidae).

Some polychaetes employ a unique strategy known as mucous net feeding. These worms secrete a sticky mucus from specialized structures, such as palps or tentacles, which form a net-like structure in the water. Suspended particles adhere to the mucus, and the polychaete subsequently collects and ingests the trapped food. The Christmas tree worm (Spirobranchus giganteus) is an example of a polychaete that utilizes mucous net feeding.

Certain filter-feeding polychaetes are selective in their feeding habits. They possess specialized structures, such as modified appendages or jaws, that allow them to selectively capture specific types or sizes of particles from the water column. This strategy enables them to optimize their nutrient intake. The sandworm (Alitta virens) is known to employ particle selection feeding
Adaptations of filter feeding:

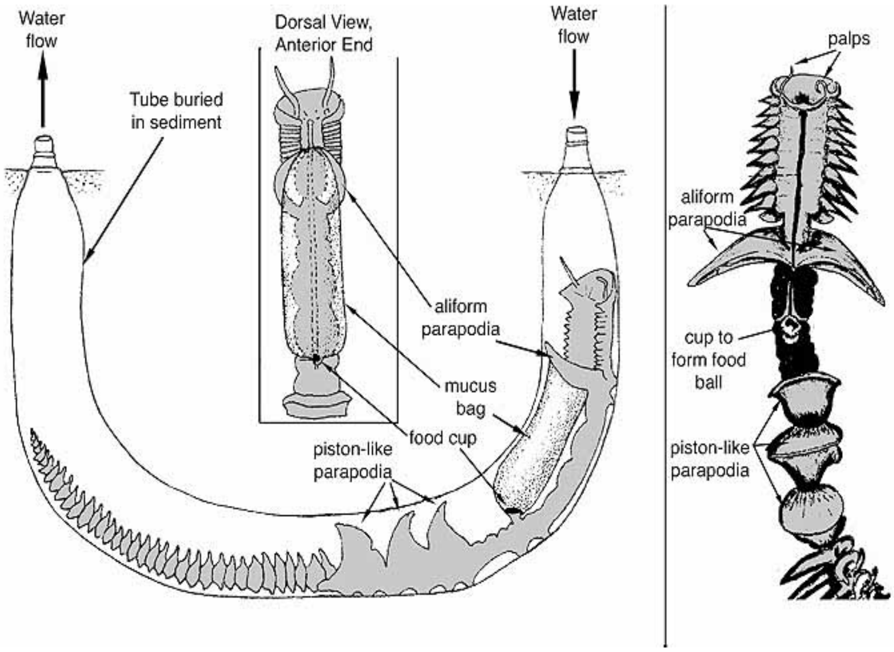
Filter-feeding polychaetes have evolved various adaptations to enhance their efficiency in capturing and processing food particles. These adaptations include:

Many filter-feeding polychaetes possess well-developed ciliary tracts and tentacles that aid in creating water currents and capturing suspended particles. The cilia generate water flow, directing particles towards the mouth region, while the tentacles act as filters or collectors.

1. Polychaetes that use mucous net feeding produce copious amounts of mucus to form nets or traps for capturing food particles. The mucus is sticky, allowing for effective particle entrapment and subsequent ingestion.
2. Certain filter-feeding polychaetes possess specialized structures, such as specialized chaetae (bristles) or filters, which aid in the filtration process. These structures help in trapping and retaining food particles while allowing water to pass through.

3. Some filter-feeding polychaetes construct intricate tubes made of mucus, sand, or secreted materials. These tubes serve as both protective shelters and filtering apparatus. The worms extend their feeding structures, such as tentacles or branchiae, out of the tube to capture food particles while remaining safely enclosed within their tube homes.

Filter-feeding polychaetes play significant roles in marine ecosystems. By consuming suspended particles, they contribute to the transfer of energy and nutrients from the water column to the benthic environment. They also help in controlling phytoplankton populations and recycling organic matter. Moreover, filter feeders serve as a vital food source for other organisms, such as fish and crustaceans, forming the basis of intricate food webs.



PATTERNS OF FEEDING AND DIGESTION IN MOLLUSCA

Mollusca is a diverse phylum of invertebrates that includes animals such as snails, clams, and octopuses. These animals have a variety of feeding mechanisms that allow them to obtain food in different ways.

Feeding

Food is taken into the buccal cavity by the chain saw movements of radula, which are limited in pila in comparison to other molluscs. By the action of sphincter and protractor muscles of the buccal mass, the two jaws move upto mouth opening and cut up leave of aquatic plants. Meanwhile the radula is also brought forward, the pieces of leaves caught by its teeth and thrown backward into the buccal cavity. Thus the food is cut and masticated inside the buccal cavity.

FEEDING MECHANISMS OF MOLLUSCA

1. Radula Feeding (Scraping)

The radula is a specialized feeding organ, resembling a rasp or tongue covered in tiny, backward-facing teeth.

Mechanism: Molluscs like snails and chitons use the radula to scrape algae or plant material from surfaces, enabling them to consume nutrients.
Examples: Found mainly in gastropods (snails and slugs) and polyplacophorans (chitons).

2. Filter Feeding

A process where molluscs filter small food particles from the surrounding water.
Mechanism: Bivalves like clams and oysters use cilia on their gills to draw in water, trapping plankton and other particles which are then transported to the mouth.Adaptation: Bivalves' gills are modified for efficient filter feeding, allowing them to thrive in aquatic environments with abundant plankton.

3. Suspension Feeding

Similar to filter feeding but involves trapping suspended organic particles.
Mechanism: Sessile mollusks like mussels use gill cilia to capture particles floating in the water, suitable for stationary organisms.Ecological Role: Helps in nutrient recycling by capturing organic debris.

4. Deposit Feeding

A feeding method where mollusks ingest organic matter settled on the substrate.Mechanism: Some gastropods and bivalves consume detritus, or organic particles, from the seafloor or mud, processing nutrients from decomposing material.
Example: Common deep-sea and soft-substrate environments where organic matter accumulates.

5. Predatory Feeding

Carnivorous feeding behaviour where mollusks actively hunt or capture other organisms.Mechanism: Predatory gastropods, like cone snails and some cephalopods, use toxins or specialized appendages (e.g., beaks, tentacles) to immobilize prey.
Examples: Octopuses and squids use a beak-like structure to tear food, while cone snails have harpoon-like radulas with venom for hunting fish.

6. Grazing

Feeding on vegetation, typically algae, found on rocks or other substrates.
Mechanism: Mollusks, such as limpets, use their radula to graze on biofilm and algae growing on hard surfaces, playing a role in regulating algae growth.

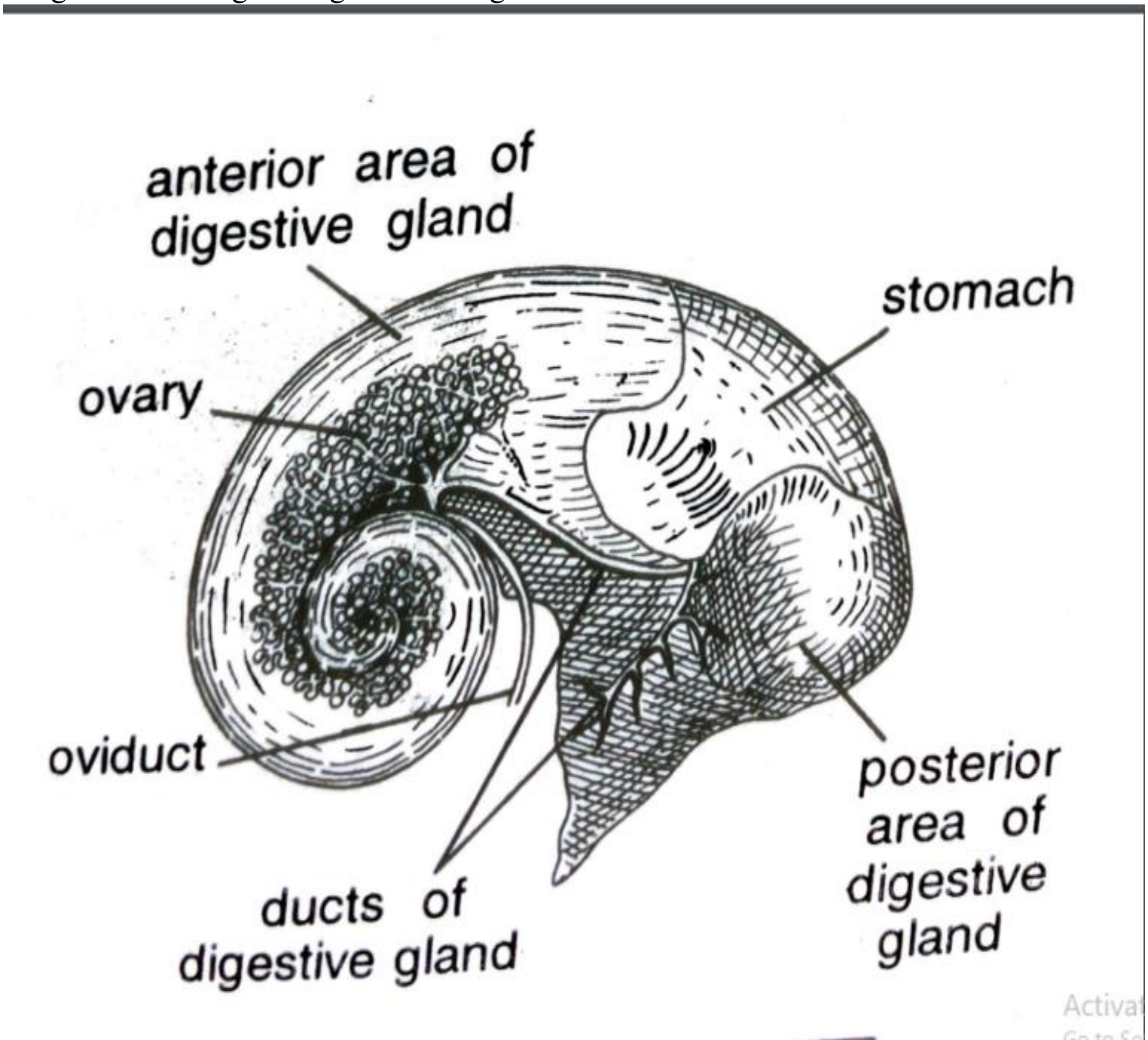
DIGESTION

Salivary glands pour their secretion, by the mean of their ducts, into the buccal cavity where it mixes with food.

It contains carbohydrate enzymes which converts starch into sugar. In the stomach the food is digested by the secretion of digestive glands, containing enzymes comparable to those of the pancreases in vertebrate animals. Thus, extracellular digestion takes place in the stomach.

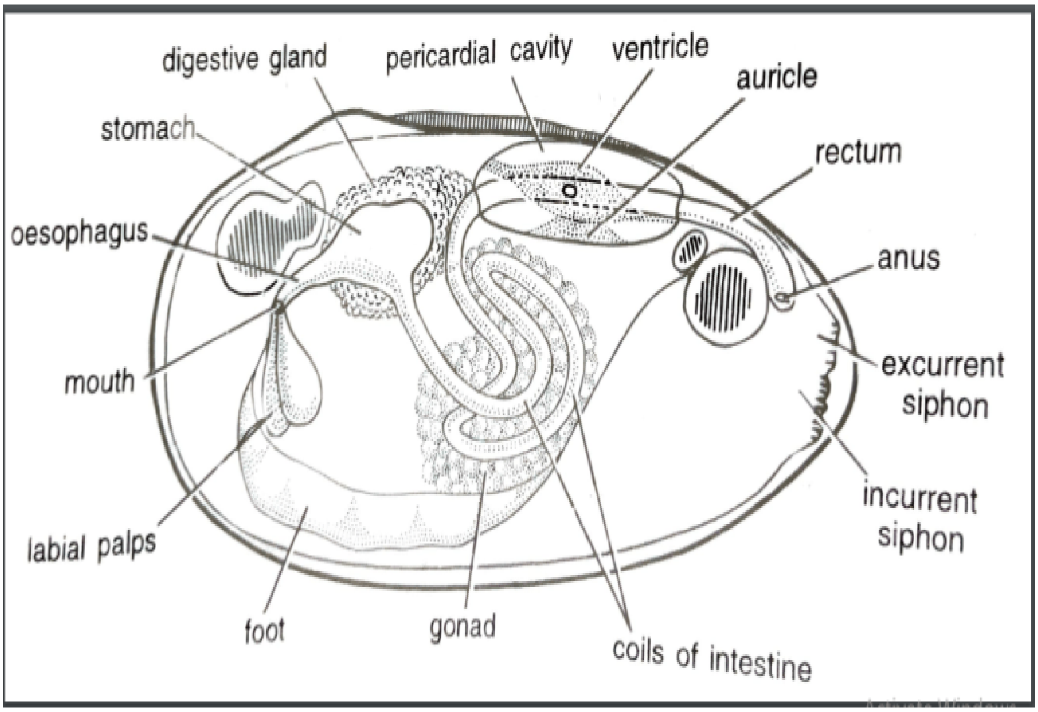
Digestion also occurs intracellularly inside the digestive gland, undigested food from the rectum passes out through the anus into the branchial chamber and finally to the exterior along with the outgoing current of water through the right nuchal lobe or pseudopipodium.
Within the stomach the food particles are subjected to sorting, maceration, digestion and partial absorption. The crystalline style performs the function of stirring rod and a windlass. Its rotation by the style sac cilia causes the detachment of the food particles from the string like mucous sheet entering the stomach. The detachment of food particles from the mucous sheet is faciliated by lower pH of the stomach with decrease in the viscosity of mucus. The styles frees in amlylase enzymes into the stomach fluid where it hydrolyses the carbohydrates extracellularly.

The sorting region of the dorsal portion of stomach directs the finer particles of food towards the opening of duct of digestive gland.The digestive nutrients are absorbed into the blood and



undigestable residue are sent back into the stomach. From here undigested food particles passes into the lumen of intestine. In intestine the food content are moulded as faeces pallet that are sent into the rectum and finally to the anus and then to cloaca.

Digestive gland of Pila



Unio alimentary canal and digestive glands

FILTER FEEDING IN ECHINODERMS

All echinoderm species are found in the sea. Filter feeders that collect food particles filtered from seawater, deposit feeders that sift through sediments at the ocean's bottom to acquire food particles, predators, and scavengers are all examples of echinoderm eating.

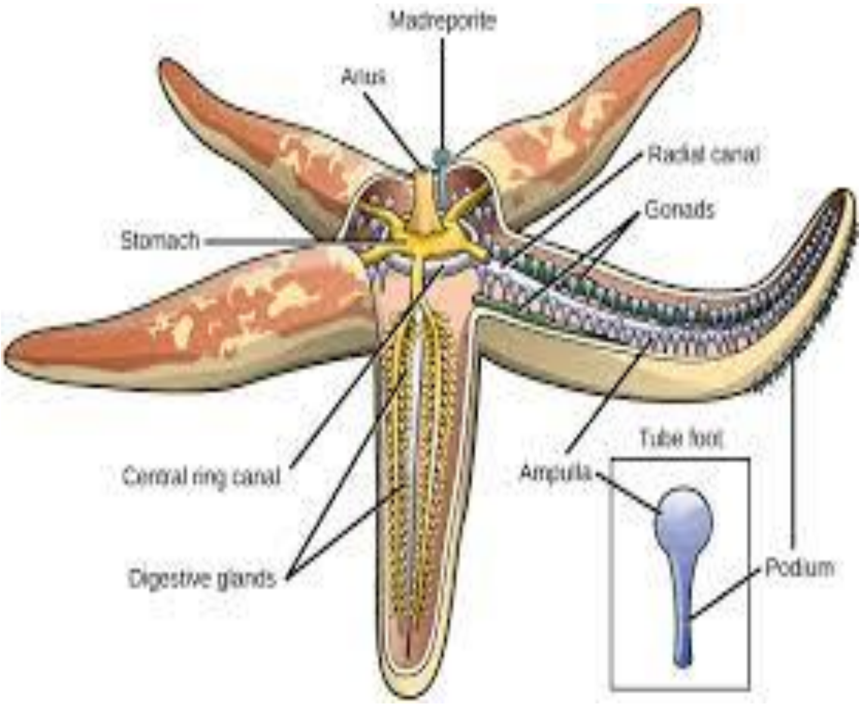
1. Crinoidea (Feather Stars & Sea Lilies)
Feather-like arms are covered with numerous tube feet and cilia.
The pinnules (small branches on the arms) have sticky mucus that traps food particles.
Cilia move the captured particles down toward the ambulacral grooves.
The food is then transported to the mouth via ciliary action.

2. Holothuroidea (Sea Cucumbers)
Some sea cucumbers use branched tentacles (modified tube feet) to trap suspended organic material.

These tentacles are covered in mucus to catch plankton and detritus.
The tentacles are periodically placed in the mouth, where the food is scraped off.
Ciliary action within the digestive tract helps further process the food.

1. **Deposit feeding**
   Involves sifting through sediments at the ocean's bottom to acquire food particles. Sea cucumbers are deposit feeders.

2. **Hunting**
   Involves actively pursuing and capturing prey. Sea stars are hunters that bend their arms to push food into their mouths.
3. **Grazing**
   Involves scraping algae off rocks and other surfaces. Sea urchins are grazers that use their Aristotle's lantern mouthparts to scrape algae.



Prof. Venkata Ratnamma

LESSON - 4
STRCTURE AND FUNCTIONS OF RESPIRATORY ORGANS

Invertebrates exhibit a variety of respiratory structures depending on their habitat and oxygen requirements. These organs facilitate gas exchange by allowing oxygen intake and carbon dioxide release. The main types of respiratory structures in invertebrates include **body surface, gills, tracheae, and book lungs.**

OBJECTIVES

4.1	**RESPIRATORY ORGANS IN ANNELIDA**
4.2	**RESPIRATORY ORGANS IN ARTHROPODA**
4.3	**RESPIRATORY ORGAN IN MOLLUSCA**
4.4	**SUMMARY**
4.5	**KEY WORDS**
4.6	**QUESTION AND ANSWERS**
4.7	**REFERENCE**

4.1 RESPIRATORY ORGANS IN ANNELIDA

Earthworms don't have lungs, hence they can't breathe. They inhale and exhale via their skin. Diffusion allows oxygen and carbon dioxide to travel through the earthworm's epidermis. The earthworm's skin must be maintained wet in order for dispersion to take place. To keep its skin wet, body fluid and mucus are secreted. Earthworms, on the other hand, require wet or moist soil. This is one of the reasons they prefer to come out at night, when the temperature is likely to be colder and the "evaporating potential of the air" is lower. Even though they can't sight, earthworms have gained the capacity to detect light.

1. Cutaneous Respiration (Through the Skin)

Structure: Present in earthworms (e.g., *Lumbricus terrestris*) and other terrestrial annelids. The moist, thin, vascularized skin allows efficient gas exchange. Capillaries in the dermis transport oxygen to the circulatory system.

Function: Oxygen diffuses into the blood, and carbon dioxide diffuses out. Requires a moist environment for efficient diffusion. The blood contains hemoglobin, which aids in oxygen transport.

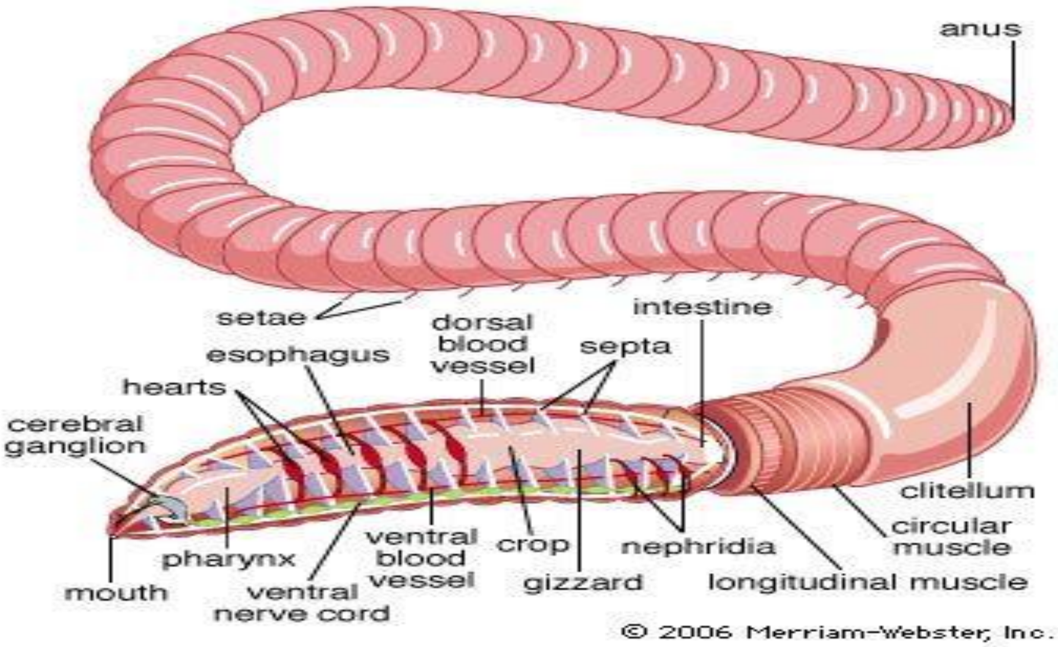
2. Branchial Respiration (Through Gills)

Structure:Found in aquatic annelids like polychaetes (e.g., *Nereis*).Gills are filamentous or branched structures located on parapodia or body segments.Richly supplied with blood vessels for efficient gas exchange.

Function:Water flows over the gills, and oxygen diffuses into the blood while CO_2 diffuses out. The circulatory system transports oxygen throughout the body**.**

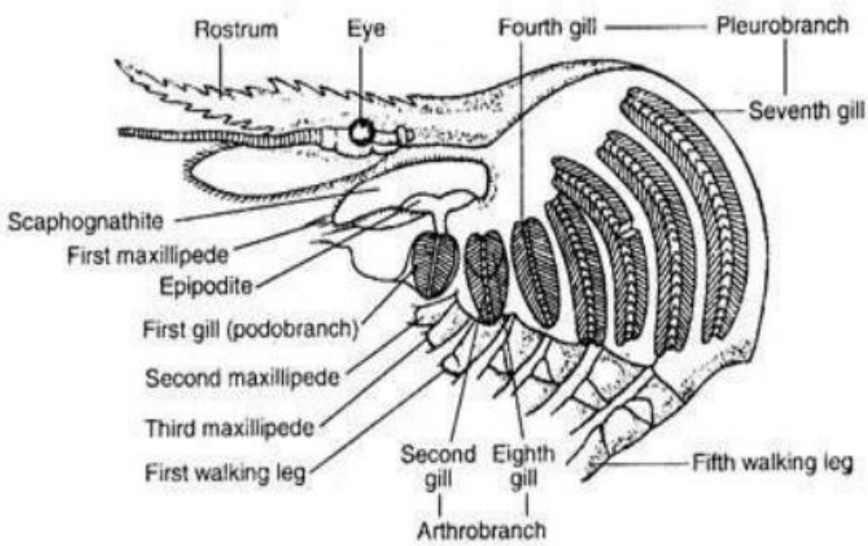
3. Parapodial Respiration (Through Parapodia)

Structure:Present in polychaetes like *Nereis*.Parapodia are fleshy, lateral extensions of the body.Contain capillary networks for gas exchange.
Function:Assist in both locomotion and respiration.Work similarly to gills by increasingsurface area for oxygen absorption.



4.2 RESPIRATORY ORGANS IN ARTHROPODA

Arthropods occupy varied habitats both terrestrial and aquatic. Depending on their habitat or way of living, arthropods have any one or more of the respiratory organs given below. Body Surface Respiration through the body surface is generally found in small arthropods which are aquatic. Crustaceans which are smaller in size such as Copepods and Ostracods (subclasses of Class Crustacea) allow gas exchange, particularly the intake of Oxygen through their body surface since these animals have a larger surface area to body mass ratio. B. Gills They are the principal organs of respiration in aquatic arthropods. They are best developed in class Crustacea while some other arthropods may have modified or special types of gills. Gills are present enclosed in a gill chamber which is situated on each lateral side of the cephalothorax and covered by the gill cover (Also known as the Branchiostegite) or the carapace. The Branchiostegite is actually the inner side of the carapace which covers the cephalothorax and it has a vascularised respiratory epithelium. The gills most commonly originate as out-pushings or evaginations of the body wall. Structure of gill A typical gill is crescent shaped or half-moon shaped. It consists of a central axis on each side of which are arranged blade-like gill filaments or gill lamellae, One end of each gill filament is connected to the axis while the other end is blind or free. Each gill filament is supplied by the branches of an afferent and efferent branchial channel which runs through the axis.



Gills of *Palaemon* with exposed gill chamber

Book Lungs They are best seen respiratory organs of Arachnids, namely scorpions and spiders.

Book lungs are blind sac-like structures originating from the evaginations of opisthosoma within which there are delicate folds of the inner lining arranged like the leaves of a book. These folds are richly vascularised and thus respiration is circulation dependent. Each book lung communicates to the exterior by a stigma. They are regarded as modified abdominal appendages. Each book lung consists of an air cavity or atrial chamber on the ventral side which opens to the outer side by a slit-like spiracle or stigmata that opens on the ventro-lateral side of the sternum. Dorsal part of book lung consists of nearly 150 vertical folds or lamellae arranged like leaves of a book. Each lamella is a hollow structure, made of two thin layers of respiratory epithelium. The air breathing in the book-lungs is effected by the action of the dorso-ventral and atrial muscles.

Contraction of the dorso-ventral muscles compresses the pulmonary chamber so that the air from the chamber is forced out through the stigmata. When the atrial muscles contract the book-lungs expand creating vacuum and sucking fresh air in through the stigmata

Tracheal System: This is the most important organ for aerial respiration. This chitin-lined tube is seen in almost all land arthropods, such as insects, centipedes, millipedes and also in many arachnids. The tracheae originate as invagination of the body wall as opposed to gills which are evaginations. Two types of tracheae are seen: Ventilation trachea—oval in section and collapses after the exhalation of air and Diffused trachea—rigid and does not collapse after the exhalation. Structures of trachea Each trachea is a tube with walls made up of polygonal cells. The wall of trachea is composed of three layers—these are the internal layer, called intima, a middle layer of epithelium and an outer layer of basement membrane. The intima is lined by spiral cuticular ridges, called taenidea, that prevent collapse. The tracheae open externally by small openings, called spiracles or stigmata. These spiracles are located along the sides of the body. Each spiracle opens into a chamber, called atrium and the spiracle is placed on a plate, called penetrene.

Each spiracle has two lids for opening and closing. Within the chamber foreign particles are eliminated by a filtering apparatus, containing either special bundles of setae or a kind of sieve-like membrane. Some parts of tracheae are dilated to form air-sacs. They help as reservoirs of air. The finer branches of tracheae are called tracheoles which are without inner taenidial ridges. A tracheole may be 1μ in diameter and reaches every cell of the body. Instead they are lined by a protein called trachein and are usually filled with a fluid in which oxygen dissolves and diffuses to the tissues. The tracheal system carries oxygen directly to the body cells and does not require blood to transport it. Generally there are 10 pairs of spiracles in insects, two pairs are thoracic and eight pairs are abdominal. Breathing is affected by the paired tergo-sternal muscles which connect dorsal side of body with the ventral side and hence their contraction compresses the abdominal cavity forcing air to move out. Relaxation of these muscles brings the abdominal cavity into its original shape, sucking the air into the tracheal tubes.

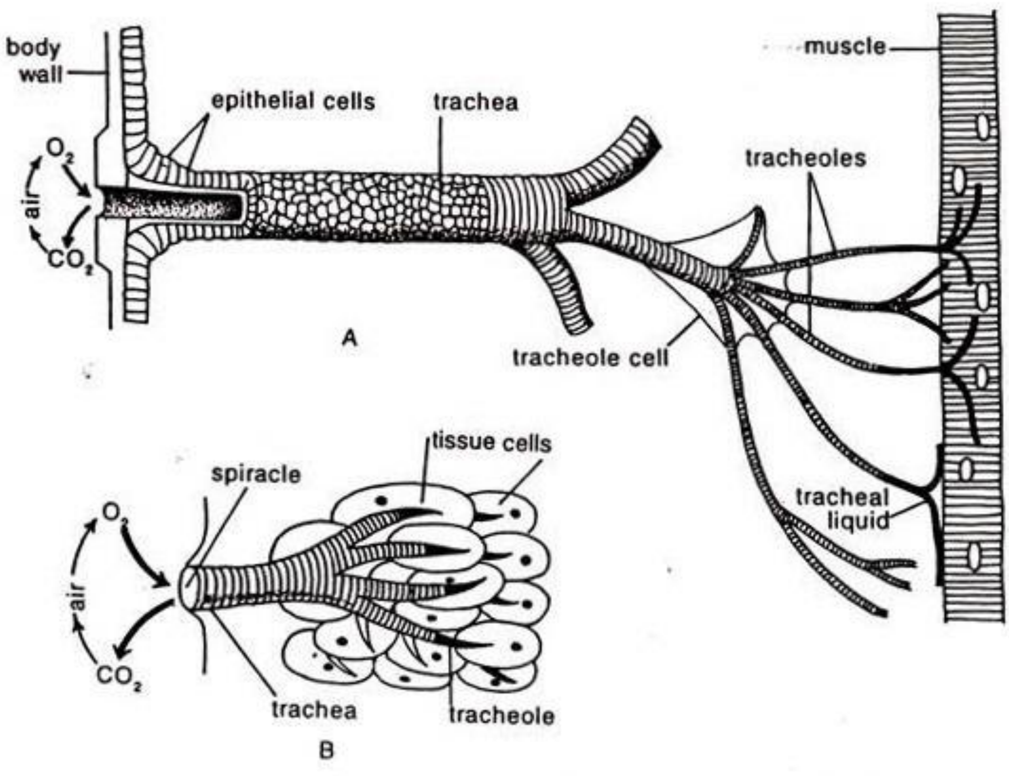


Fig. 9.7. Diffusion of gases in insects : A. The tracheal system, B. Trachea and tracheoles

4.3 RESPIRATORY ORGAN IN MOLLUSCA

Most molluscs breathe using gills known as ctenidia or comb-like gills. In terrestrial molluscs, this respiratory apparatus is smaller, but pallial cavity respiration still occurs. Thus, the three types of respiration seen in molluscs are:

1. Cutaneous respiration
2. Branchial respiration
3. Pulmonary respiration

1. Cutaneous Respiration

The simplest sort of respiratory system found in molluscs is cutaneous respiration. When there is no specific respiratory device present, it functions as a respiratory organ in some forms. Such respiratory organs are present in parasitic *Entoconcha, Cenia* and *Limapontids*. The dorsal surface of the body is covered in papillae in the majority of the Aeolididae species. The papillae differ in size and are connected to the heart by veins. The majority of Nudibranchia breathe through their skin.

The mantle is employed for respiration in some forms of Nudibranchs such as *Aplysia, Neomenia* and *Chaetoderma*.Branchial or Ctenidial RespirationMolluscs living in water breathe through ctenidia. These are the mantle's comb-like protrusions that are found inside the mantle space.The cilia's beating causes the water to travel through the mantle cavity.Afferent and efferent blood arteries can be seen in each ctenidium, and they pass through the ctenidial axis. Through the afferent blood artery, the ctenidium's body receives deoxygenated blood from the animal, and through the efferent blood vessel, oxygenated blood is returned to the heart after being oxygenated in the gill filaments.

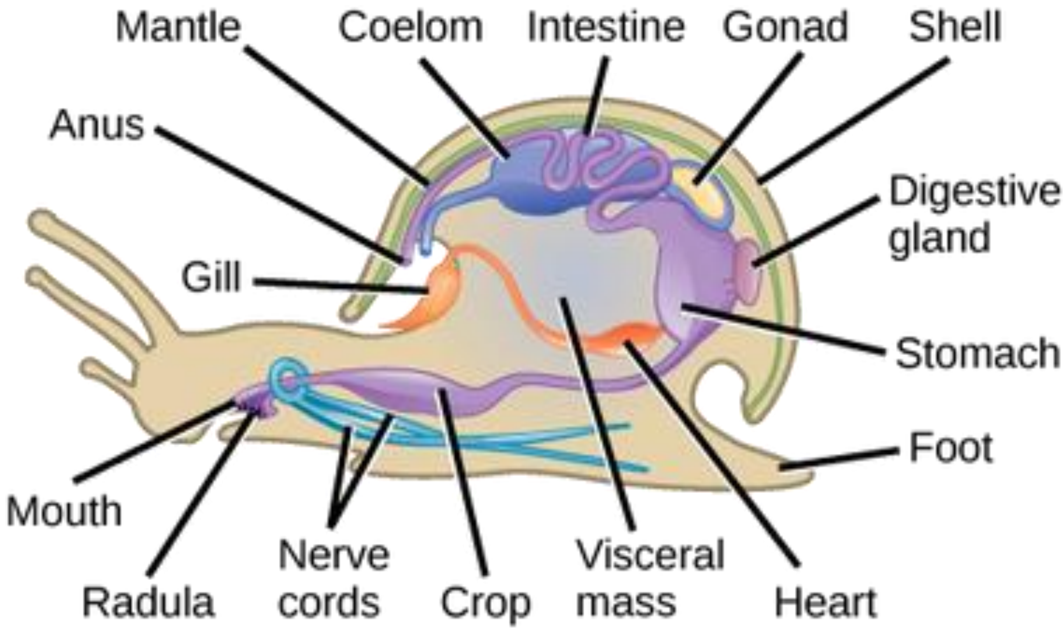
2. Modifications of Ctenidia

Anal gills are the little, fragile leaflet-like structures that develop in a rosette around the anus in the *Doris* species.On the dorsal surface of the body, *Aeolis* (sea slug) has a large number of highly vascular secondary gills called the cerata, which are used for gas exchange.
Pallial gills are seen in *Patella*. Their pallial grove houses a row of modified gills on each side.Pleural gills are seen in *Pleurophyllida* which has many rows of branchial leaflets beneath the mantle.

3. Pulmonary Respiration

A real ctenidium is absent in terrestrial pulmonates, and the mantle cavity develops into a pulmonary sac or lung for aerial respiration. The pulmonary sac's ceiling is well-supplied with blood vessels. Air rushes in and out of the mantle cavity as a result of the alternate muscular contraction and relaxation of the mantle floor.

A small, circular pulmonary opening or pneumostome is present on the right side of the sac with a valve. It allows air to enter or exit. The mantle cavity's compression increases the partial pressure of oxygen and makes it easier for it to be absorbed.The mantle cavity of lower pulmonates like *Lymnaea* serves both for aquatic and aerial respiration.



Respiratory organ in Mollusca

4.4 SUMMARY

In this unit we will studied about the general characters of invertebrates and their functions., the coelom and evolution of coelom in invertebrates. Under this unit, we focused on the body cavity, acoelomates, eucoelomates, protostomes, deuterostomes, schizocoelom, myocoelom, evolution of coelom theories, such as enterocoel theory, gonocoel theory, nephrocoel theory and schizocoel theory, significance of coelom, coelomic fluid definition and significance of coelomic fluid.we have studied about the filter feeding in invertebrates. Here, we will focus on the filter feeding mechanism in Polychaetes, molluscs and Echinodermata.In this unit, we studied about the respiration and respiratory organs in invertebrates. Under this unit, we focused on the structure and functions of gills, aquatic respiration by gills, gills in Mollusca, adaptive or secondary gills and integument, types of ctenidia, ctenidia in different groups of mollusc, gill respiration in Arthropoda, modification of gills in Arthropoda.

4.5 KEY WORDS

Symmetry: Arrangement of body parts in relation to the central axis.
Coelom: Fluid-filled cavity that accommodates organs.
Metamerism: Similar body segments that are serially repeated.
Filter feeding; It is a form of food procurement in which food particles or small organisms are randomly strained from water**.**

4.6 QUESTION AND ANSWERS

1. Write the general classifications of invertebrates?
2. Write about filter feeding in Mollusca
3. Explain the structure and functions of respiratory organs in Arthropoda
4. Explain the types of coeloms?

4.7 REFERENCE

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Prof. Venkata Ratnamma (Prof. VVR)

LESSON - 5
LARVAL FORMS OF FREE-LIVING INVERTEBRATES

INVERTEBRATE LARVAE INTRODUCTION

The different stage larva, plural larvae in the development of many animals, occurring after birth and before the adult form are reached. These immature, active forms are structurally different from the adults and are adapted to a different environment. Larvae appear in a variety of forms. Many invertebrates have a simple ciliated larva called a planula. Flukes have several larval stages, and annelids, mollusks and crustaceans have various larval forms. In crustaceans both direct and indirect development. The direct development, adult is attained by progressive growth and differentiation, whereas in the indirect development, there is a larval stage which differs from the adult in many features and acquires adulthood through metamorphosis. Many of the crustaceans undergo indirect development, involving a wide variety of larval forms. The larval forms of the various insects are called caterpillars, grubs, maggots and nymphs. In some species the larva is free living and adult is an attached or non mobile form, in other the larva is aquatic and the adults lives on land.

Definition of larvae

Larva, plural larvae, or larvaes, stage in the development of many animals, occurring after birth or hatching and before the adult form is reached. These immature, active forms are structurally different from the adults and are adapted to a different environment.

5.1 INTRODUCTION

In some species the larva is free-living and the adult is an attached or nonmobile form; in others the larva is aquatic and the adult lives on land. The mobile larva increases the geographic distribution of the species.

A larva sometimes functions as a food gatherer in many species the larval stage occurs at a time when food is abundant and has a well-developed alimentary system. It stores food so that the transformation to the adult stage can occur. Some larvae function in both dispersion and nutrition.

The larval stage the life cycle varies among species. Some have long larval periods, either hatching early, metamorphosing into adults late, or both. Some organisms have a short-lived larval phase or no larvae at all. Many invertebrates have a simple ciliated larva called a planula. The larval forms of the various insects are called caterpillars, grubs, maggots, and nymphs. Phylum PORIFERA has two larval forms.

1. Parenchyma larva
2. Amphiblastula larva

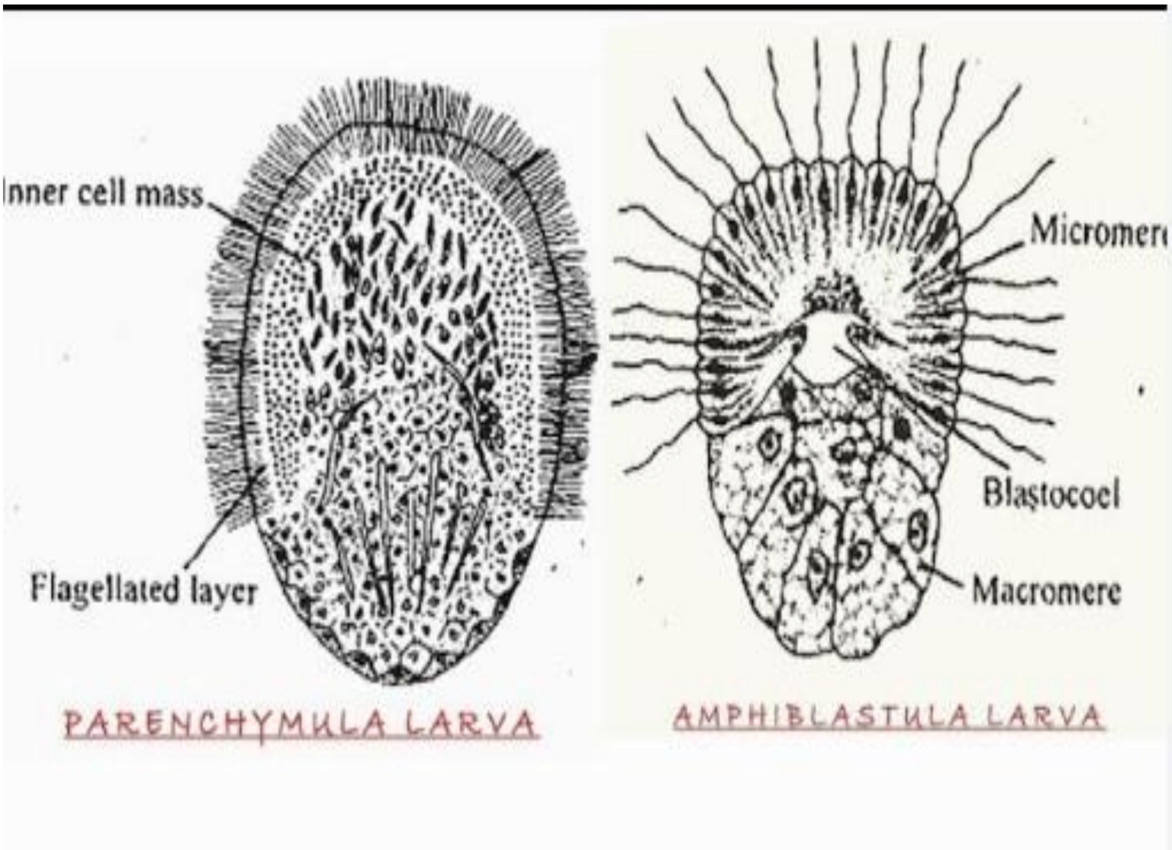
1. **Parenchyma larva**

Parenchyma Larva is seen in the life history of Leucosolenia and fertilisation is internal. Zygote undergoes holoblastic cleavage and develops into coeloblastula. a hollow cavity covered by a

single layer of cells. Many amoeboid cells enter the central cavity and it becomes parenchymuia larva (or) stereogastrula.
This larva shows an outer layer of flagellated cells and a mass of internal amoeboid cells. At the posterior and non-flagellated cells are present called archaeocytes. This larva swims in the water for sometimes. Then attaches to a suitable substratum.

2. **Amphiblastula larva**

Amphiblastula larva is a typical free swimming larva formed in Sycon sponge reproduction. ova! in shape, small micromeres with flagella on one side. The other half of the larva shows large macromeres. The larva comes out of the sponge through osculum and swims in the water with the help of flagella.

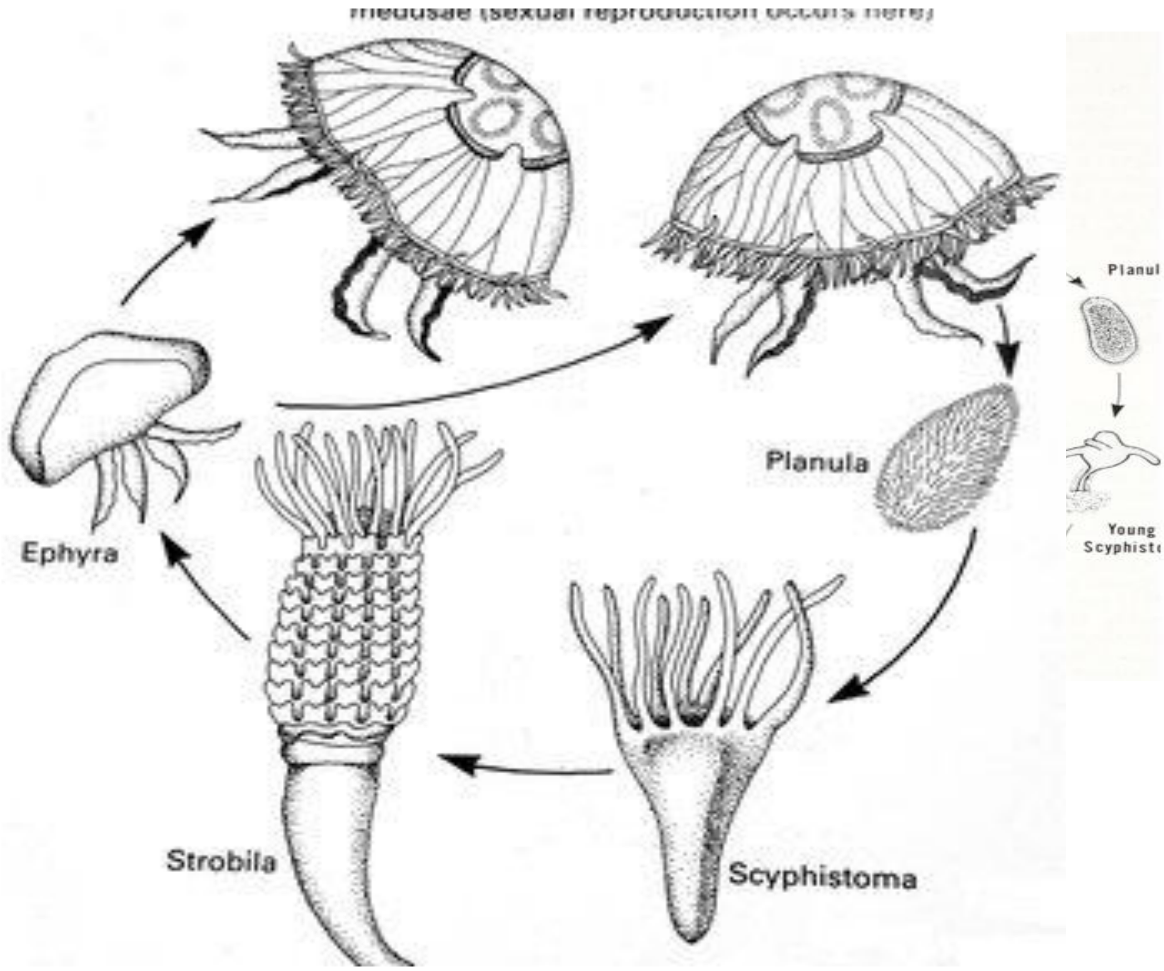


Scyphistoma Larva

Scyphistoma is the larva of Aurelia. Planula larva metamorphoses in to a small scyphistoma larva. It attaches to rocks by aboral end. The cilia are lost and body becomes elongated. Scyphistoma larva is also known as hydratuba. An oral cone or manubrium is formed, the blastopore opened to become the mouth. Four hollow buds arise become tentacles. Subsequently four inter-radial and eight adradial tentacles are formed. The endoderm of colenteron forms four inter-radial longitudinal ridges called gastric ridges or mesenteries. The mouth becomes square and the manubrium sinks down to form funnel- like depressions called septal funnelsorinfundibuls. A root- like 149 stolon arises at the base of hydratuba larva, which feeds and buds new hydratubae from its stolon throughout the summer. After summer the hydratuba cease to bud, it continues feeding and storing food. The hydratuba generally winters over the first year and may bud other hydratubae, but next winter it undergoes a process of transverse fission and called strobilation, the dividing hydratubae is called a scyphistoma or strobila. The transverse discs of the scyphistoma which have been produced by strobilation looks like a serial pile or saucers and each disc is an ephyra larva. About dozen ephyrae are formed in a single strobiltion.

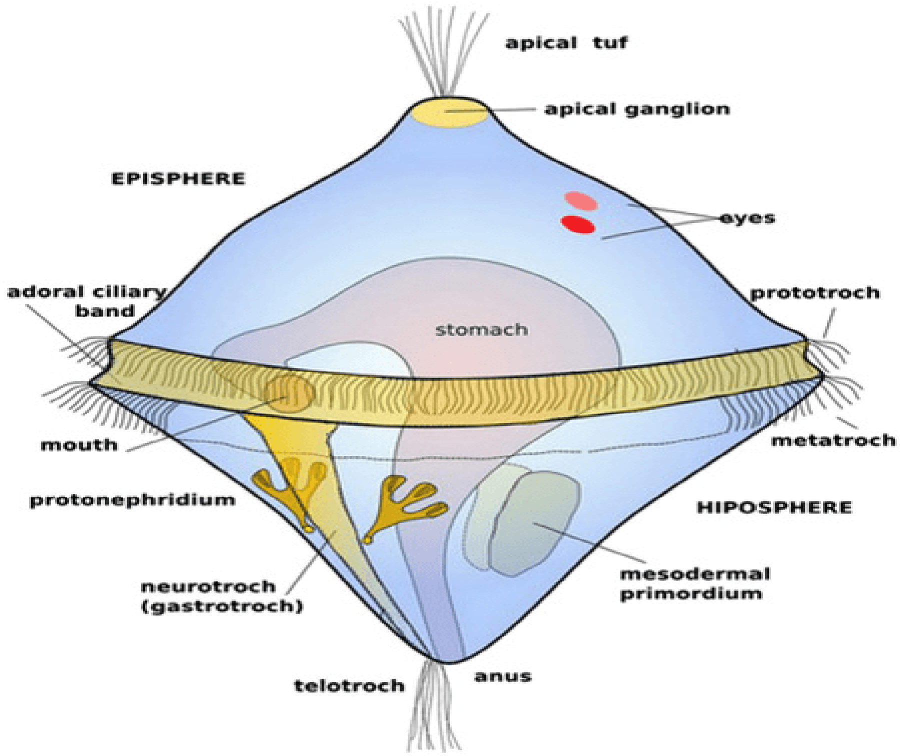
Ephyra Larva

Ephyra larva is the larva of Aurelia. It is a small medusoid form which develops from the scyphistoma larva as a result of transverse fission body is umbrella like and having tetramerous symmetry. The umbrella is divided into eight long forked arms. The distal ends of arms are deeply notched and form marginal lappets. Eight prominent tentaculocysts are present in the notches between the marginal lappets. Manubriummmm with the mouth is present in the middle on the sub- umbrella surface. Gastric filaments, 150 pre- radial and inter-radial canals are also seen. Ephyra larva swims actively in the water and metamorphoses into adult Aurelia



Trochophore

It is also called trochosphere, small, translucent, free-swimming larva characteristic of marine annelids and most of mollusks. Trochophores are spherical or pear-shaped and are girdled by a ring of cilia (minute hairlike structures), the prototroch, that enables them to swim. Above the prototroch is a sensory plate, an apical tuft of cilia, and an ocellus (simple eye).



Trochophore diagram

Below the prototroch are the mouth, stomach, anus, and other structures including the solenocyte, and its function is to maintain proper internal salt-water balance, and, in some species, one or two additional ciliary rings. In some mollusks (such as gastropods and bivalves), the trochophore develops into a second stage, the veliger (q.v.), before metamorphosing to adult form. Rotifers and the larvae (sometimes considered trochophores) of such invertebrates as phoronids and bryozoans are trochophore-like in appearance

The nine important larval forms found in Crustacea are:

1. Nauplius Larva
2. Metanauplius Larva
3. Protozoaea Larva
4. Zoaea Larva
5. Cypris Larva
6. Mysis or Schizopod Larva
7. Megalopa Larva
8. Phyllosoma Larva
9. Alima Larva.

1. Nauplius Larva: Nauplius larva is egg-shaped and un-segmented. It has a broad anterior end with a median eye, large labrum and three paired appendages. The median eye is characteristic of the nauplius larva and is referred to as the nauplius eye, it is made usually of three but at times four ocelli which are pigmented cups with no lens, and are innervated by the protocerebrum.

The median eye may degenerate or persist in the adult crustacean. The appendages are uniramous antennules having two groups of sensory cells forming frontal organs, a pair of biramous antennae, and a pair of biramous mandibles for swimming. A stomodaeum with mouth, proctodaeum with anus, and a midgut are also present. A typical crustacean hatches as a free-swimming nauplius, but in Malacostraca the nauplius is passed over as a stage within the egg membrane. In certain crustaceans like Branchiopoda the nauplius metamorphoses directly into the adult but in majority of crustaceans it metamorphoses to adult through various intermediate larval stages like metanauplius, protozoaea, zoaea, cypris, mysis, megalopa, phyllosoma, alima, etc.

2. Metanauplius Larva: Metanauplius larva is like a nauplius, except that it shows some segmentation of the body, and there are four pairs of additional appendages of the thorax which shows some segmentation; these appendages are two pairs of maxillae and two pairs of maxillipedes. Some Notostraca, such as Apus, hatch as a metanauplius larva.

3. Protozoaea Larva:In marine prawns like Penaeus and some other decapods, the nauplius directly develops into protozoaea larva. The body of protozoaea is divisible into cephalothorax and abdomen. The cephalothorax is broad, segmented and covered with carapace.
The appendages that appeared in metanauplius become well developed and functional. The rudiments of other thoracic appendages also appear. The abdomen is unsegmented, without any appendage and has a forked telson.

4. Zoaea Larva: Zoaea larva has a well formed head with a long, median dorsal spine, two stalked compound eyes and one simple eye, all appendages from antennules to the last pair of maxillipedes are present, carapace is well formed and produced in front into a rostrum.
Thorax is un-segmented and rudimentary at its hinder end. Abdomen is well formed and six segmented, but it has no appendages except a forked telson. It swims by its biramous maxillipedes.

In Penaeus, protozoaea develops into zoaea. In some Anomura the egg hatches as a zoaea which passes through a metazoaea stage to become the adult. Metazoaea is an advanced stage of zoaea but differs from it in having uniramous rudiments of thoracic appendages behind the maxillipede. However, the third maxillipedes are biramous in hermit crab’s (Anomura) metazoaea and uniramous in that of crab (Brachyura). The abdominal appendages, i.e., pleopods also develop as buds. In some decapods, e.g., crabs, the life history starts from zoaea stage.

5. Cypris Larva: It is covered by a bivalved shell having adductor muscle. Head has compound eyes, antennules with discs on which cement glands open, antennae are lost but remaining cephalic appendages are present, thorax has six pairs of biramous limbs, there is an abdomen of four segments. In Cirripedia, e.g., Lepas, the egg hatches as a nauplius, it changes into a cypris which gets fixed by discs of antennules with the secretion of cement glands, then it becomes a pupa which forms shell plates and rotates to assume the adult form.

6. Mysis or Schizopod Larva: Mysis or schizopod larva resembles an adult Mysis. Head and thorax have a carapace, all cephalic and thoracic appendages are present, but all thoracic appendages are alike and biramous with exopodites, abdomen has five pairs of pleopods and the sixth form uropods.In some Decapoda, e.g., in Penaeus, a marine prawn, the egg hatches as nauplius, it passes by successive moults through zoaea stage, protozoaea stage and mysis stage which changes into an adult. In some lobsters, e.g., Homarus both nauplius and zoaea are passed within the egg, it hatches as a mysis larva which changes into an adult.

7. Megalopa Larva:Megalopa larva has a large un-segmented cephalothorax with all 13 pairs of appendages like those of a crab, abdomen is straight and in line with cephalothorax, it is like the abdomen of prawn with 6 pairs of wellformed pleopods. In crabs the nauplius is passed in the egg, it hatches as a zoaea which by moulting forms the megalopa stage, the megalopa by moulting forms the adult.

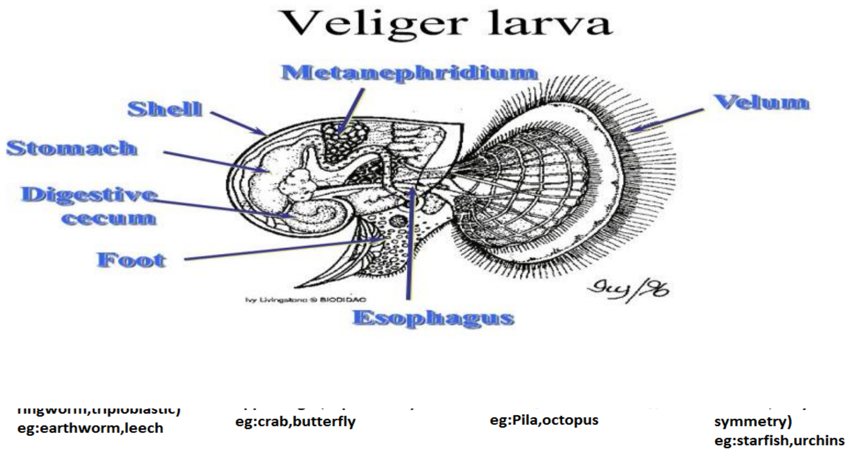
8. Phyllosoma Larva: In Palinurus (the rock lobster), the egg hatches directly into a transparent, extremely flattened leaf-like larva called phyllosoma or glass crab. This is large sized larva having three distinct regions in the body, the head, thorax and abdomen. Thorax bears six pairs of appendages; the first thoracic or maxillipedes are rudimentary, second are uniramous, third formed biramous, and remaining three (4th, 5th, and 6th) pairs are biramous legs which are enlarged. Abdomen shows segmentation but appendages are absent. Larva undergoes several moultings and transforms into the adult. Phyllosoma is, considered as modified mysis larva.

9. Alima Larva: In Squilla, the egg directly hatches out in a young stage called alima larva. It is a pelagic form having slender body with a short and broad carapace. Its body is glassy and transparent. only first two thoracic appendages are found. The abdomen has distinct six segments with four or five pairs of pleopods. The alima larva is supposed to be modified zoaea stage but it differs strikingly from zoaea in having the armature of the telson and well developed large second maxillipedes.

In molluscs, the development may be direct or indirect. In the direct development, there will be no larval stage and the young ones will hatch out from the eggs which resemble their parents except the size. Ex cephalopods. Paludina is a viviparous form.

Three main larval forms are observed in molluscans.
They are:

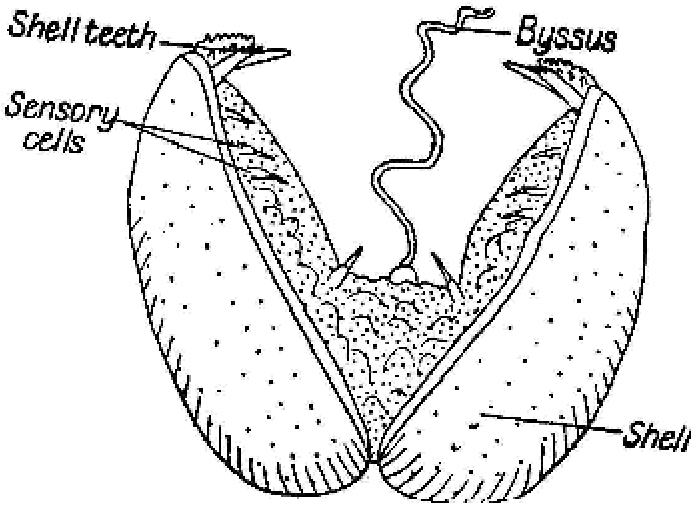
1. Trochophore
2. 2. Veliger
3. **3.** Glochidium



Veliger, larva typical of certain mollusks such as marine snails and bivalves and a few freshwater bivalves. The veliger develops from the trochophore (q.v.) larva and has large, ciliated lobes (velum). The velum forms from the ciliary ring (prototroch), a characteristic of the trochophore stage. The velum is used for swimming, feeding, and gas exchange, and it is resorbed or lost asthe mollusk metamorphoses into adult stage and begins to develop a foot and shell during the veliger stage.

Glochidium larva: Glochidium larva enclosed by two valves. Each edge of which bears a hook.Shell valves cover a larval mantle.Bears four groups of sensory bristles. Rudimentary foot is attached a long adhesive thread
Byssal thread Neither mouth nor anus.Measures from 0.1 mm to 0.5mm

Glochidium larva



Larvae of echinodermata: Development may be direct or indirect. In direct one, the larval stages are missing while in indirect one, various types of free-swimming larvae are formed.

1. Larvae of asteroidea: Three larval stages in Asteroidea in their development to adult stage. Earlybipinnaria appears like hypothetical dipleurula. It has oval body without arms and ciliary bands for locomotion and well developed alimentary canal for feeding and grows to become bipinnaria.Bipinnaria larva possesses 5 pairs of ciliated arms which do not have any skeletal support inside. These arms are used for swimming in water while feeding on planktons. Preoral and postoral ciliary bands are also present. This larva resembles auricularia larva of Holothuroidea in general appearance.

Brachiolaria larva is formed after 6-7 weeks of life and growth of bipinnaria. This larva is sedentary and remains attached to a hard substratum for which it possesses three brachiolarian arms having adhesive discs at the tip. Ciliated arms get reduced and become thin and functionless, while mouth, anus and gut are well developed. It has axocoel, hydocoel and somatocoel that later on give rise to water vascular system.

2. Larvae of holothuroidea: Class Holothuroidea demonstrate two larval stages, namely, auricularia and doliolaria larvaeAuricularia larva has striking resemblance with bipinnaria of Asteroidea as it also possesses 4 or 5 pairs of ciliated arms for swimming and has a well developed mouth, gut and anus.

Doliolaria larva is the next stage after auricularia. It has barrel like body with 5 ciliated bands surrounding it. Mouth or vestibule is on the ventral side for feeding. There is neural sensory plate on the anterior side and an apical tuft of cilia for balancing while swimming. Doliolaria transforms into adult but in some holothurians doliolaria stage may be absent.

3. Larvae of echinoidea: There is a single larval stage in echinoidea called Echinopluteus which is bilaterally symmetrical. The larva has oval body and long paired ciliated arms that are supported by calcareous skeletal rods. Preoralarm is present but posterolateral arm is absent. The other three arms are anterolateral, postoral and posterodorsal arms. Mouth, anus and gut are well developed.

4. Larvae of ophiuroidea: Ophiopluteus is the only larva of Ophiuroidea that resembles echinopluteus larva of Echinoidea in general features. Anterolateral, postoral and posterodorsal arms are present but preoral arm is absent. Instead, it has very long posterolateral arms. All arms are supported by calcareous skeletal rods. This larva metamorphoses to become adult.

5**. Larvae of crinoidea:**Pentactula is the basic larval stage of Crinoidea but it passes inside the egg. There is one or two larval stages in sea lilies. Doliolaria larva, which is also called Vitellaria larva, is found in some sea lilies. It resembles doliolaria of holothuroids but has an adhesivepit on the ventral side with which it attaches to substratum and becomes sedentary. This larval resemblance demonstrates close evolutionary relationship between crinoidea and Holothuroidea.

Pentacrinoid larva is sedentary and attaches to substratum with an attachment plate. Body is supported by a stalk. There are 10 cilia bearing tentacles which are used for capturing food. Both mouth and anus are on the same side of the disc.

Importance of Larval Stages: They help in wide dispersal of the species and help in establishing relationships between various groups. Occurrence of nauplius stage in all crustaceans connects the different representatives of this class together. the nauplius establishes relationship of some obscure animals like Sacculina where adult has lost the characters of the class and even the phylum.In nauplius stage that connects Sacculina to class Crustacea and further the presence of cypris stage relates it to subclass Cirripedia.

If Haeckel's law of recapitulation (which states that every organism during its development, i.e., ontogeny, repeats its evolutionary history, i.e., phylogeny) is considered true then it can be said that the nauplius stage represents the ancestral form of crustaceans because all crustaceans invariably pass through nauplius stage during their development.

Prof. P. Padmavathi

LESSON - 6
LARVAL FORMS OF PARASITES

Parasites often undergo complex life cycles involving various larval stages, each adapted to specific hosts or environmental conditions. Understanding these larval forms is crucial for comprehending how parasites develop, transmit, and cause diseases.

INTRODUCTION

- Helminthes constitute a large assemblage of 'worms' of comparatively simple and varied organization .
- Platyhelminthes includes flatworms (platy-flat ,helminthe-worm) . they are bilaterally symmetrical ,acoelomate , triploblastic invertebrates without an anus . the flatworms are both free living as well as parasitic.
- They are dorso ventrally flattened like a leaf. The digestive system is completely absent from cestoda and acoela .
- They are hermaphrodite i.e., both male and female reproductive organs are present in the same animal . fertilization is internal in them. Self or cross fertilization takes place in them.
- Their development is direct or indirect . Endoparasites show usually indirect development with may larval stages. Their life cycle is completed in one or two hosts.

Platyhelminthes is divided in to three classes :

1. **Tubullaria**
2. **Trematoda**
3. **Cestoda**

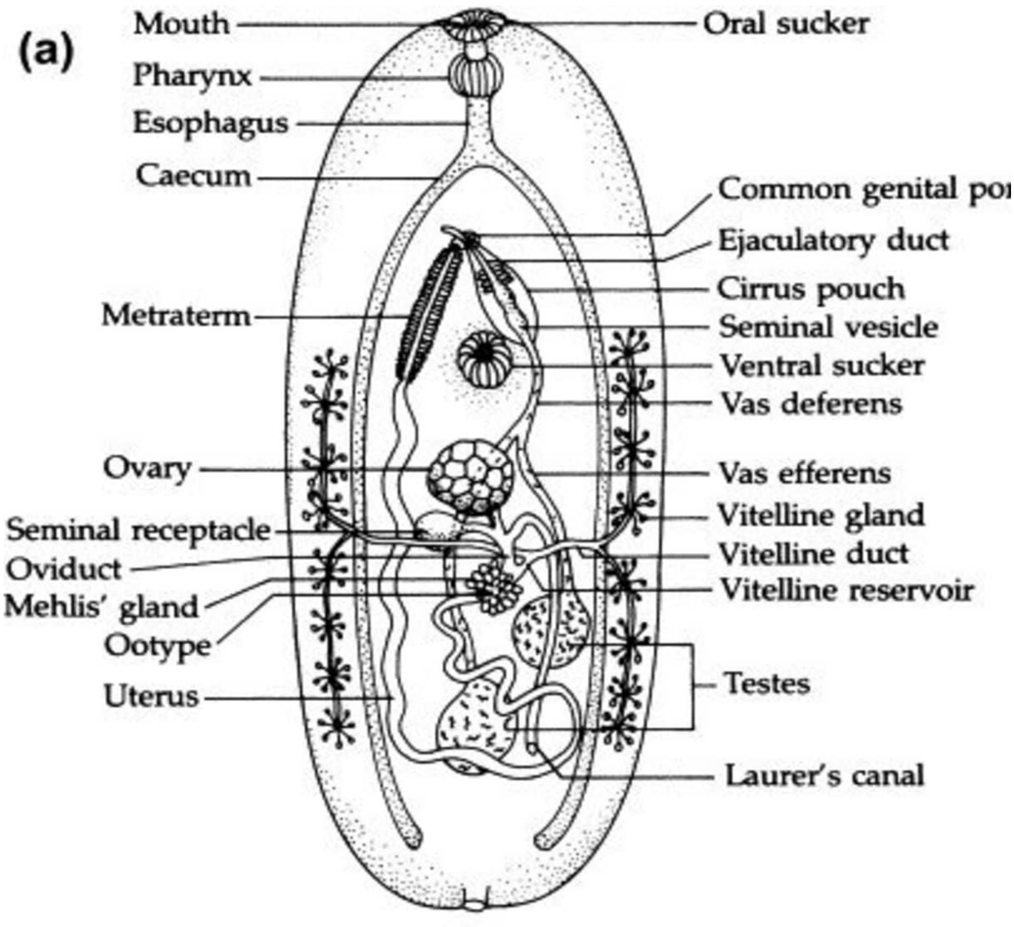
Larval forms of class trematoda

General characters of trematoda :-

- They are generally ecto or endoparasite.
- Body is leaf shaped or cylindrical and covered with cuticle.
- Epidermis ,rhabdites and cilia (except in larval stages) are absent.
- Suckers and sometimes hooks are present.
- Digestive tract with an anterior suctorial mouth , simple pharynx and two forked many branched intestine.
- Life cycle is simple or complicated.
- They generally includes flukes.

Trematodes (Flukes)

Trematodes, commonly known as flukes, are flatworms that typically require multiple hosts to complete their life cycles. Adult flukes are leaf-shaped flatworms. Prominent oral and ventral suckers help maintain position in situ. Flukes are hermaphroditic except for blood flukes, which are bisexual. The life-cycle includes a snail intermediate host. Their larval stages include:



The structure of flukes is summarized. A dorsoventrally flattened body, bilateral symmetry, and a definite anterior end are features of platyhelminths in general and of trematodes specifically. Flukes are leaf-shaped, ranging in length from a few millimeters to 7 to 8 cm. The tegument is morphologically and physiologically complex. Flukes possess an oral sucker around the mouth and a ventral sucker or acetabulum that can be used to adhere to host tissues. A body cavity is lacking. Organs are embedded in specialized connective tissue or parenchyma. Layers of somatic muscle permeate the parenchyma and attach to the tegument.

Flukes have a well-developed alimentary canal with a muscular pharynx and esophagus. The intestine is usually a branched tube (secondary and tertiary branches may be present) consisting of a single layer of epithelial cells. The main branches may end blindly or open into an excretory vesicle. The excretory vesicle also accepts the two main lateral collecting ducts of the excretory system, which is of a protonephridial type with flame cells. A flame cell is a hollow, terminal excretory cell that contains a beating (flamelike) group of cilia. These cells, anchored in the parenchyma, direct tissue filtrate through canals into the two main collecting ducts.

Except for the blood flukes, trematodes are hermaphroditic, having both male and female reproductive organs in the same individual. The male organ consists usually of two testes with accessory glands and ducts leading to a cirrus, or penis equivalent, that extends into the common genital atrium. The female gonad consists of a single ovary with a seminal receptacle and vitellaria, or yolk glands, that connect with the oviduct as it expands into an ootype. The tubular uterus extends from the ootype and opens into the genital atrium. Both self- and cross-fertilization occur. The components of the egg are assembled in the ootype. Eggs pass through the uterus into the genital atrium and exit ventrally through the genital pore. Fluke eggs, except for those of schistosomes, are operculated (have a lid).

The blood flukes or schistosomes are the only bisexual flukes that infect humans. Although the sexes are separate, the general body structure is the same as that of hermaphroditic flukes. Within the definitive host, the male and female worms inhabit the lumen of blood vessels and are found in close physical association. The female lies within a tegumental fold, the gynecophoral canal, on the ventral surface of the male. The medically important flukes belong to the taxonomic category Digenea. This group of flukes has a developmental cycle requiring at least two hosts, one being a snail intermediate host. Depending on the species, other intermediate hosts may be involved to perpetuate the larval form that infects the definitive human host.

Flukes go through several larval stages, each with a specific name, before reaching adulthood. Taking into account variations among species,a generalized life cycle of digenetic flukes runs the following course. Eggs are passed in the feces, urine, or sputum of humans and reach an aquatic environment. The eggs hatch, releasing ciliated larvae, or miracidia, which either penetrate or are eaten by a snail intermediate host. In rare instances land snails may serve as intermediate hosts. A saclike sporocyst or redia stage develops from a miracidium within the tissues of the snail.

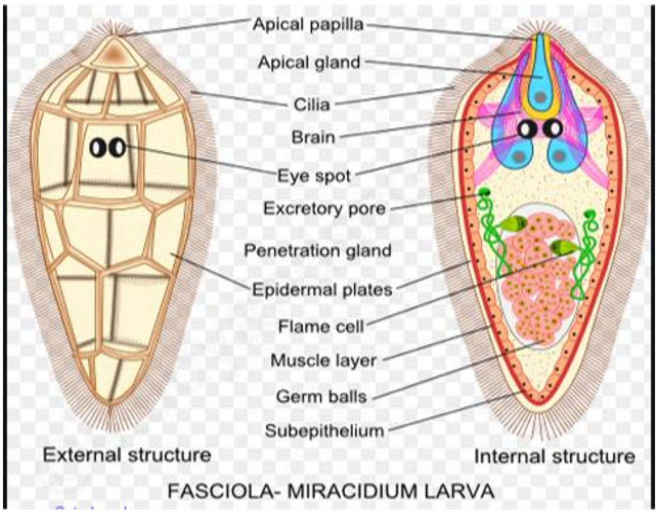
The sporocyst gives rise either to rediae or to a daughter sporocyst stage. In turn, from the redia or daughter sporocyst, cercariae develop asexually and migrate out of the snail tissues to the external environment, which is usually aquatic.

The cercariae, which may possess a tail for swimming, develop further in one of three ways. They either penetrate the definitive host and transform directly into adults, or penetrate a second intermediate host and develop as encysted metacercariae, or they encyst on a substrate, such as vegetation, and develop there as metacercariae. When a metacercarial cyst is ingested, digestion of the cyst liberates an immature fluke that migrates to a specific organ site and develops into an adult worm.

Miracidium larva

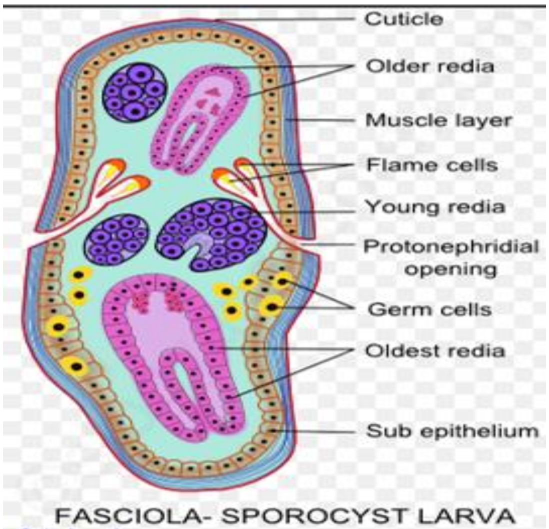
- The first larval stage develops in 9 to 15 days under optimum temperature of 22 – 25 degree C , until it is ready to hatch . this is known as the miracidium larva
- When the larvated egg capsule comes in contact with water , the lid or operculum is dissolved and the miracidium is hatched by the capsules . it is a free swimming larva living in ponds .
- Which is conical in shape . the anterior end is broad and the posterior end is narrow.
- At the anterior end inside the body , there is a sac like gland called apical gland . it opens at the apical papilla by a duct .
- Two sac like glands are located on the sides of the apical glands. They are called penetration gland.
- A large brain is present . The interior of the larva is filled with groups of specialized cells called as germ cells.

(when it comes in contact with the snail limnaertruncatula. The miracidium penetrates in to the body of the snail . it reaches the digestive gland of the snail and gets transformed in to another larva called as sporocyst).



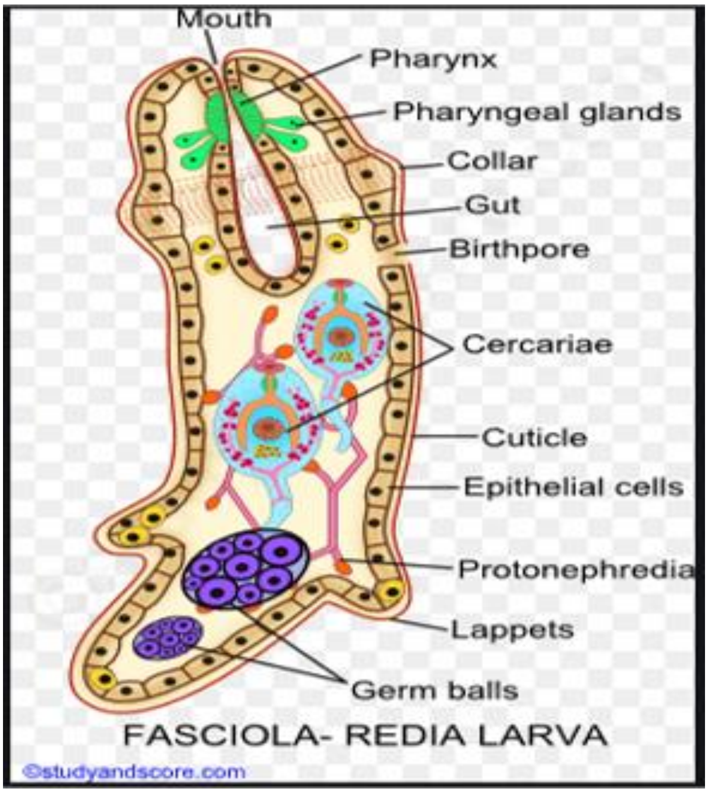
Sporocyst larva

- Sporocyst develops from miracidium .
- It is the 2nd larva of liver fluke. It lives in digestive gland of snail.
- The epidermal cells along with the cilia are shed primitive gut, cephalic glands , brain, and eye spots are degenerated and larva becomes like an elongated sac.
- About 0.07 mm long covered with a thin cuticle.
- The sub-epithelial cells , muscles and mesenchyme remain as in the previous stage.
- The protonephridium of each side divides in to two flame cells but they are open to outside by a common excretory duct. Besides, the sporocyst may be called as germ balls.
- The sporocyst may be called as a living cyst moving about in the tissue of the host absorbing nourishment from it.
- This germ cells divide and redivide to form the next larva called as redialarva . each sporocyst can produce 5-8 larvae.



Redia larva

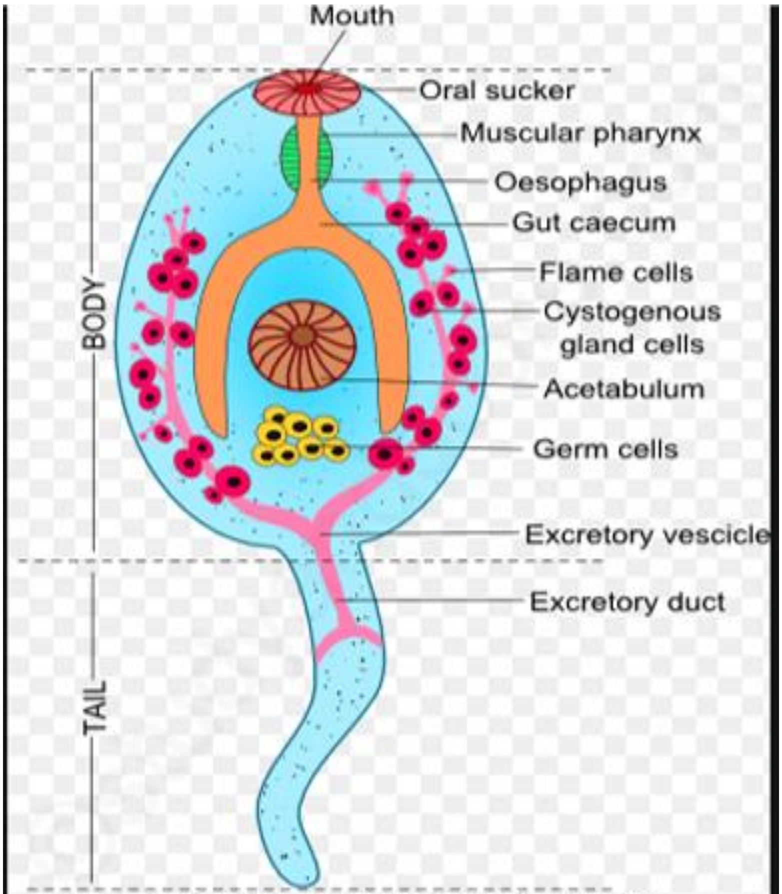
- Redia larva develops from the germ cells of sporocyst.
- It lives in the digestive glands of snail and cylindrical in shape. The body is covered by cuticle.
- The anterior end has a mouth ,behind the mouth there is a muscular ring called as collar or opening called birth pore is located.
- Near the posterior end a pair of projection is found ..They are called as lappets. They are used for locomotion.
- The mouth leads into a pharynx which ends in a sack like intestine.
- To protonephridia are located inside the body and each protonephridia formed of many flame cells.
- The cavity of redia larva is filled with germ cells . The germ cells of daughter rediadevelop into the next larva called as cercaria . They come out trough birth pore.



Cercaria larva

- Each redia produces about 20 cercaria . They lives in the digestive gland of snail.
- Its body is tadpole like rounded or oval with a long simple tale. Its length about 0.25 mm to 0.35mm.
- Its body surface is covered with cuticle.
- Digestive system consist in this larva . Numerous flame cells are located inside the body .

- The cercaria lives for 3 days and it is transformed into another larva called as metacercatria.



FASCIOLA- CERCARIA LARVA

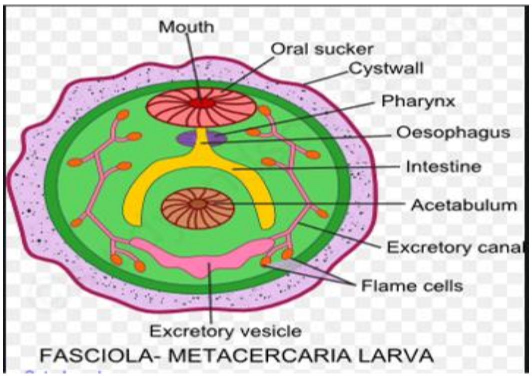
Metacercaria larva

- The cercaria looses its tail and the cystogenous gland secretes a cyst around larva. The encysted cercaria is called metacercaria.
- It is found attached to the grasses or near to water .
- shape- round , germ cells are present .
- In this larva tail and cystogenous gland have degenerated and a thick hard cyst wall is present .
- Flame cells have increased and the germ balls are present.
- The metacercariae are in fact the juvenile flukes. They develop further only when swallowed by sheep.
- Metacercariae survive only for a few weeks

Larval forms of class cestode

General characters of cestoda :-

1. Cestodes are the most specialized of all the flatworms they are all endo parasites of vertebrates from fishes to mammal.
2. They are commonly called as tapeworms.
3. They are long ,flat , ribbon like in shape.
4. They are depressed , headless and limbless worms with no coelome , no circulating mechanism , no skeleton , no distinct excretory system and no food canal.
5. The body contains an osmo- regulatory or water- expulsion system



2. Cestodes (Tapeworms)

Tapeworms are segmented flatworms that inhabit the intestines of their definitive hosts. Adult tapeworms are elongated, segmented, hermaphroditic flatworms that inhabit the intestinal lumen. Larval forms, which are cystic or solid, inhabit extraintestinal tissues.

Whereas flukes are flattened and generally leaf-shaped, adult tapeworms are flattened, elongated, and consist of segments called proglottids. Tapeworms vary in length from 2 to 3 mm to 10 m, and may have three to several thousand segments.

Anatomically, cestodes are divided into a scolex, or head, which bears the organs of attachment, a neck that is the region of segment proliferation, and a chain of proglottids called the strobila. The strobila elongates as new proglottids form in the neck region. The segments nearest the neck are immature (sex organs not fully developed) and those more posterior are mature. The terminal segments are gravid, with the egg-filled uterus as the most prominent feature.

The scolex contains the cephalic ganglion, or “brain,” of the tapeworm nervous system. Externally, the scolex is characterized by holdfast organs. Depending on the species, these organs consist of a rostellum, bothria, or acetabula. A rostellum is a retractable, conelike structure that is located on the anterior end of the scolex, and in some species is armed with hooks. Bothria are long, narrow, weakly muscular grooves that are characteristic of the pseudophyllidean tapeworms. Acetabula (suckers like those of digenetic trematodes) are characteristic of cyclophyllidean tapeworms. Differential features of pseudophyllidean and cyclophyllidean tapeworms. Most human tapeworms are cyclophyllideans.

A characteristic feature of adult tapeworm is the absence of an alimentary canal, which is intriguing since all of these adult worms inhabit the small intestine. The lack of an alimentary tract means that substances enter the tapeworm across the tegument. This structure is well adapted for transport functions, since it is covered with numerous microvilli resembling those lining the lumen of the mammalian intestine. The excretory system is of the flame cell type.

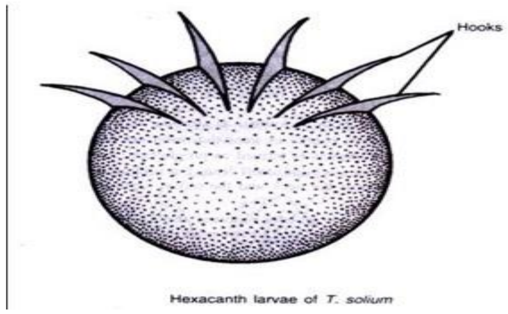
Cestodes are hermaphroditic, each proglottid possessing male and female reproductive systems similar to those of digenetic flukes. However, tapeworms differ from flukes in the mechanism of egg deposition. Eggs of pseudophyllidean tapeworms exit through a uterine pore in the center of the ventral surface rather than through a genital atrium, as in flukes. In cyclophyllidean tapeworms, the female system includes a uterus without a uterine pore. Thus, the cyclophyllidean eggs are released only when the tapeworms shed gravid proglottids into the intestine. Some proglottids disintegrate, releasing eggs that are voided in the feces, whereas other proglottids are passed intact.

The eggs of pseudophyllidean tapeworms are operculated, but those of cyclophyllidean species are not. Eggs of all tapeworms, however, contain at some stage of development an embryo or oncosphere. The oncosphere of pseudophyllidean tapeworms is ciliated externally and is called a coracidium. The coracidium develops into a procercoid stage in its micro-crustacean first immediate host and then into a plerocercoid larva in its next intermediate host which is a vertebrate. The plerocercoid larva develops into an adult worm in the definitive (final) host. The oncosphere of cyclophyllidean tapeworms, depending on the species, develops into a cysticercus larva, cysticercoid larva, coenurus larva, or hydatid larva (cyst) in specific intermediate hosts. These larvae, in turn, become adults in the definitive host. illustrates these larval forms and representative life cycles.

Hermaphorditism is of universal occurance among tapeworms, except in dioecoesisa, a taenioid genus which is not only dioecious but sexually dimorphic. The gonads are arise from the mesenchyme cells.It is a digenic parasite. The egg develops in to a larva called hexacanth or onchosphere larva.

Onchosphere (hexacanth larva)

- It is the larva developed from the capsule. It remains in capsule it is spherical in shape.
- It is covered by two cover rings namely an outer shell and an inner embryonic membrane.
- The interior is filled with a mass of cells.
- The embryo has 6 pairs of hooks hence it is also called as hexacanth larva(hexa-6,canth-hook).
- The oncho sphere remains inside the gravid proglottid.
- It is passed out along with faeces further development takes place only inside the pig.



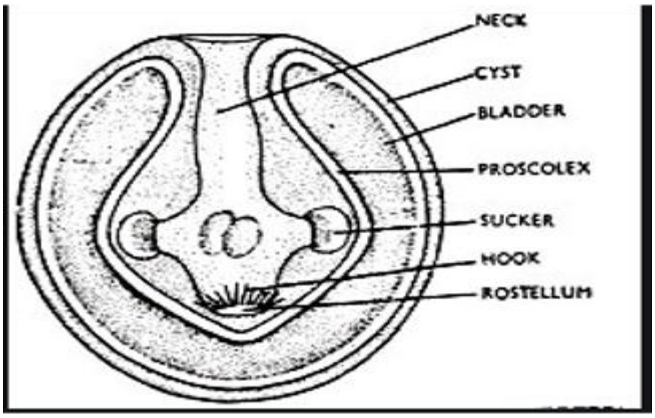
Hexacanth larvae of *T. solium*

Infection to pig

- When a pig eats the faeces, the onchosphere inters the intestine of the pig. Where the embryonic membrane dissolves.
- The larva penetrates the intestine wall with the help of hooks then reaches the muscles it looses the hooks and develops into the next larva called as cysticercus or bladder worm.

Cysticercus larva or bladder worm

- Cysticercusdevelopes from the onchosphere. It has following salient features:-
- It lives in the muscles of the pig.
- it is formed of a fluid filled vesicle called bladder.
- The bladder is covered by two coverings namely an outer cuticle and an inner dermal layer.
- The flesh of pig containing the cysticercus is called measly pork.
- Further development of cysticercus occurs inside the man.



Larval forms of annelida

General characters of annelida

1. Mostly aquatic, some terrestrial burrowing or tubicolous. Some commensol and parasitic.
2. Body elongated bilaterally symmetical ,triploblastic ,truly coelomate and metamericallysequented into similar metamerces.
3. Locomotory organs are segmentally repeated chitinous bristles called setae or chaetae embedded in skin. May be borne by lateral fleshy appendages or parapodia.
4. True coelom, schizocoelous . Mostly well developed except in leeches.
5. Ventrally divided into compartments by transverse septa coelomic fluid with cells or corpuscles.
6. Sexes are separate cleavage spiral and determinate larva when present is a trocophore
7. Regeneration common .
8. Respiration by moist skin or gills of parapodia and head.
9. Digestive system straight and complete digestion entirely

Example :- Neries – nereis is hermaphroditic or sexes are separate cleavage spiral and determinate larva, when present is a trocophore.

Nematodes (Roundworms)

Nematodes are cylindrical worms with diverse life cycles.Adult and larval roundworms are bisexual, cylindrical worms. They inhabit intestinal and extraintestinal sites.

In contrast to platyhelminths, nematodes are cylindrical rather than flattened; hence the common name roundworm. The body wall is composed of an outer cuticle that has a noncellular, chemically complex structure, a thin hypodermis, and musculature. The cuticle in some species has longitudinal ridges called alae. The bursa, a flaplike extension of the cuticle on the posterior end of some species of male nematodes, is used to grasp the female during copulation.

The cellular hypodermis bulges into the body cavity or pseudocoelom to form four longitudinal cordsa dorsal, a ventral, and two lateral cords—which may be seen on the surface as lateral lines. Nuclei of the hypodermis are located in the region of the cords. The somatic musculature lying beneath the hypodermis is a single layer of smooth muscle cells. When viewed in cross-section, this layer can be seen to be separated into four zones by the hypodermal cords. The musculature is innervated by extensions of muscle cells to nerve trunks running anteriorly and posteriorly from ganglion cells that ring the midportion of the esophagus.

The space between the muscle layer and viscera is the pseudocoelom, which lacks a mesothelium lining. This cavity contains fluid and two to six fixed cells (celomocytes) which are usually associated with the longitudinal cords. The function of these cells is unknown.

The alimentary canal of roundworms is complete, with both mouth and anus. The mouth is surrounded by lips bearing sensory papillae (bristles). The esophagus, a conspicuous feature of nematodes, is a muscular structure that pumps food into the intestine; it differs in shape in different species.

The intestine is a tubular structure composed of a single layer of columnar cells possessing prominent microvilli on their luminal surface.

The excretory system of some nematodes consists of an excretory gland and a pore located ventrally in the mid-esophageal region. In other nematodes this structure is drawn into extensions that give rise to the more complex tubular excretory system, which is usually H-shaped, with two anterior limbs and two posterior limbs located in the lateral cords. The gland cells and tubes are thought to serve as absorptive bodies, collecting wastes from the pseudocoelom, and to function in osmoregulation.

Nematodes are usually bisexual. Males are usually smaller than females, have a curved posterior end, and possess (in some species) copulatory structures, such as spicules (usually two), a bursa, or both. The males have one or (in a few cases) two testes, which lie at the free end of a convoluted or recurved tube leading into a seminal vesicle and eventually into the cloaca.

The female system is tubular also, and usually is made up of reflexed ovaries. Each ovary is continuous, with an oviduct and tubular uterus. The uteri join to form the vagina, which in turn opens to the exterior through the vulva.

Copulation between a female and a male nematode is necessary for fertilization except in the genus *Strongyloides,* in which parthenogenetic development occurs (i.e., the development of an unfertilized egg into a new individual). Some evidence indicates that sex attractants (pheromones) play a role in heterosexual mating. During copulation, sperm is transferred into the vulva of the female. The sperm enters the ovum and a fertilization membrane is secreted by the zygote. This membrane gradually thickens to form the chitinous shell. A second membrane, below the shell, makes the egg impervious to essentially all substances except carbon dioxide and oxygen. In some species, a third proteinaceous membrane is secreted as the egg passes down the uterus by the uterine wall and is deposited outside the shell. Most nematodes that are parasitic in humans lay eggs that, when voided, contain either an uncleaved zygote, a group of blastomeres, or a completely formed larva. Some nematodes, such as the filariae and *Trichinella spiralis*, produce larvae that are deposited in host tissues.

The developmental process in nematodes involves egg, larval, and adult stages. Each of four larval stages is followed by a molt in which the cuticle is shed. The larvae are called second-stage larvae after the first molt, and so on. The nematode formed at the fifth stage is the adult. summarizes the life cycles of several intestinal nematodes.

Prof. P. Padmavathi

LESSON - 7
MINOR PHYLA

OBJECTIVES

7.1 INTRODUCTION

7.2 CONCEPT OF MAJOR AND MINOR PHYLA

7.3 GENERAL CHARACTERS OF MINOR PHYLA

7.1 INTRODUCTION

The invertebrates include those which are without backbone. The invertebrates constitute about 90 per cent of the known animals which number over a million. Vast and heterogeneous groups have been placed in the invertebrates. The differences between the groups are very large, each group of invertebrates has certain structural peculiarities, a special terminology, and a distinct classification. However, the life of invertebrates is as fascinating, revealing and complicated. Presently there are 30 invertebrate phyla, which are characterized by a unity of basic structural pattern in each of them. This means that in each phylum, though the members may differ in external features, the anatomical features are constructed on the same ground plan in many respects. The common anatomical ground plan exhibits a unique relationship among the groups of structural units which compose it. Other significant features of inter-relationships among the members of same phylum are functional. Another important feature, by which the members of the individual phylum are related with one another, is the common ancestry. Evolutionary studies have confirmed that all the members of an individual phylum have been derived directly or indirectly from a common primitive ancestral type.

The invertebrate phyla are usually referred to as lower and higher invertebrates. The lower invertebrates are simple in body organisation and generally smaller in size. These are thought to have originated in the main lines of evolution, near the base of the phylogenetic tree of the Animal Kingdom. The lower invertebrates include various phyla such as Protozoa, Porifera, Coelenterata (Cnidaria), Platyhelminthes and Nematoda. On the other hand, the higher invertebrates are generally larger in size and possess a complex body organisation. These occupy higher position inthe phylogenetic tree of the Animal Kingdom. The higher invertebrates also include various phyla such as Mollusca, Annelida, Arthropoda and Echinodermata.

7.2 CONCEPT OF MAJOR AND MINOR PHYLA

The invertebrate phyla have been divided into major and minor phyla. If the phyla are represented in great majority of ecological communities, they would be regarded as major phyla whereas, the minor phyla form only a fraction of animal communities. The concept of major and minor phyla is based on two factors:

(i) The number of species and individuals; (ii) Their participation in ecological communities. On the basis of the first factor, 11 phyla appear to be clearly major phyla, these are Protozoa, Porifera, Coelenterata, Platyhelminthes, Rotifera, Nematoda, Mollusca, Annelida, Arthropoda, Ectoprocta and Echinodermata. On this basis, the two phyla, Rotifera and Ectoprocta, cannot be considered as major phyla. They are included in minor phyla due to their limited participation in animal communities. Thus, keeping in view the utility of the above two factors, we can regard only nine as major phyla and the rest as minor phyla.

7.3 GENERAL CHARACTERS OF MINOR PHYLA

1. The body is not metamerically segmented at least in the adult, but may be annulated. 242
2. There is no distinct head, although a prostomium or proboscis may be present. The body is often worm-like
3. The gut is straight, coiled or U-shaped.
4. The nervous system is simple: a cerebral ganglion may be present or absent; a circum-oesophageal ring connects with a single ventral nerve cord which mayor may not be ganglionated. 5. Organs of special sense are usually lacking.
6. The epidermis may be covered with a thin cuticle or it may secrete a shell or tube around the body.
7. Appendages are generally lacking, although tentacles or spines are sometimes present anteriorly.
8. The body usually contains circular and longitudinal muscles, but these may be lacking in certain Bryozoa. Circular muscles are lacking in the Chaetognatha.
9. A coelom is present and is often subdivided into distinct regions.
10. Excretory organs may be present or absent. They are of the nephridial type.
11. Blood vascular system is often reduced or lacking and closed type.
12. The products of the gonads are passed to the exterior through nephridia or via the coelom through gonoducts.
13. The sex’s mayor may not be separate.
14. Larval forms of various kinds occur, some of which resemble trochophores.

Prof. P. Padmavathi

LESSON - 8
GENERAL CHARACTERS OF ROTIFERA

OBJECTIVES

8.1 GENERAL CHARACTERS OF ROTIFERA

Shape and Size of Rotifers: Rotifer, also called wheel animalcule, approximately 2,000 species of microscopic, aquatic invertebrates that constitute the phylum Rotifera. Rotifers are so named because the circular arrangement of moving cilia (tiny hairlike structures) at the front end resembles a rotating wheel.

common in freshwater on all continents, some species occur in salt water or brackish water, whereas others live in damp moss or lichens. Most are free-living; some are parasitic. Most live as individuals, but a few species form colonies. Most rotifers are only 0.1 to 0.5 mm (0.004 to 0.02 inch) long. The body may be spherical, flattened, bag-like, or wormlike. The body wall consists of a thin cuticle.

Tufts of cilia at the anterior end make up the corona, which is used for feeding and locomotion. Small organisms are extracted as food from water currents created by the ciliated corona. Larger organisms, such as other rotifers, crustaceans, and algae, are also eaten.

In addition to the swimming rotifers, some (subclass Bdelloidea) loop along the bottom of ponds, alternately attaching the head and tail ends; others remain anchored by means of tubes or cases of jelly attached to the bottom.

Shape: Extremely variable, slender and worm like, broad, flattened sacciform or even spherical.
Size: Minute, usually microscopic, normal range between 100 to 500 u in length.
Symmetry: Bilaterally symmetrical.

Colour: Usually they are transparent and colourless, some may show brown, red, and orange colours in their digestive tract.

Structure of Rotifers:The rotifer body is divided into an anterior head, a middle trunk and a posterior tail or foot. A neck may separate head and trunk.

1. Head: Central part of head is without cilia. This is known as the apical field and the ciliated corona or trochal disc encircles the apical field. In some times the corona is surrounded by a double ciliated ring, the outer ciliary band cingulum and inner ciliary band or trochus. Ciliary movement helps in feeding and respiration.

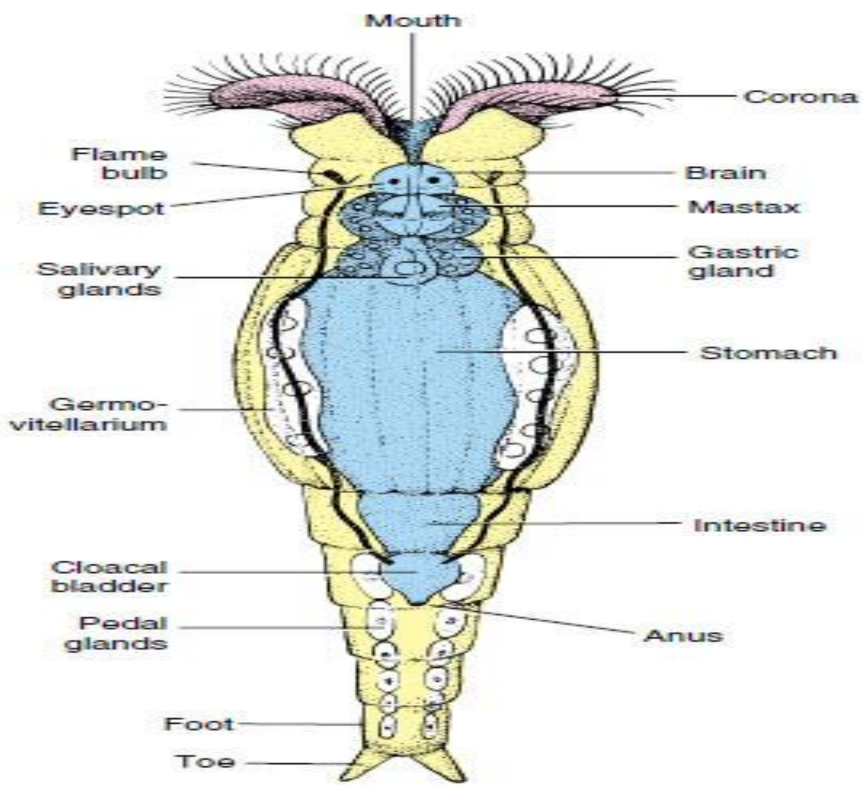
2. Trunk: Cylindrical or flattened covered with lorica, made up of cuticle. Lorica divided into telescoping rings to allow the body extend and contract. At the anterior end of the trunk, single or paired dorsal antennae are present. Lateral antennae may be present on the posterior end of the trunk. The mid-dorsal anus is located at the union of trunk and tail.

3. Tail: It is called foot and is covered by cuticular rings. It ends in an adhesive disc in sessile species. In creeping and swimming rotifers foot ends in one to four movable toes containing pedal glands The pedal glands secrete an adhesive used to attach the animal permanently or temporarily for feeding or creeping.

Body Wall of Rotifers: It consists of cuticle, epidermis and subepidermal muscles. Cuticle is made up of scleroprotein. It covers the body surface forming lorica, spines and other surface structures. The epidermis is syncytial containing a constant number of nuclei. Epidermis also give rise to subcerebral glands, pedal glands and other surface glands.

Muscles are not arranged in layers. Visceral muscles occur in some organs. Circular muscles are complete rings. Longitudinal muscles are well developed in creeping forms.

Rotifera



Body Cavity of Rotifers: It is the spacious pseudocoel derived from embryonic blastocoel. It lacks peritoneum and mesenteries. Pseudocoel is filled with a perivisceral fluid and a loose syncytial reticulum composed of amoeboid cells. These cells seem to be phagocytic and excretory in nature.

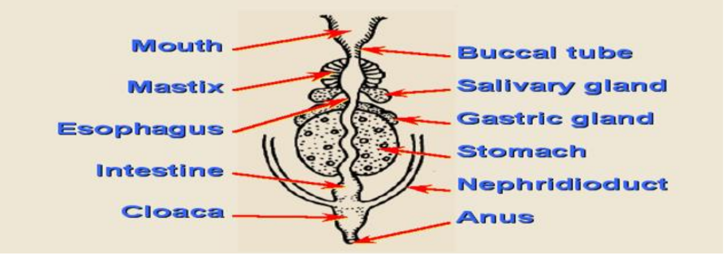
Digestive System of Rotifers: The mouth usually lies in the buccal field. Sphincter and dilator muscles may open and close it. Mouth leads, by a ciliated buccal tube, into the pharynx.

The pharynx or mastax is a unique rotifer structure. It is a muscular chamber containing hard chitinous jaws called trophi. Jaw structure is complex. A trophi consists of seven main pieces. A median fulcrum and pairs of rami, unci and manubria make up the major parts.The fulcrum and rami together form the incus the unci and manubria compose the malleus. The posterior pointed end of manubrium is known as cauda. Jaw structure is variable according to food and feeding habits. Jaw structure is important in taxonomy.

The pharynx leads through a short, narrow and dorsal oesophagus. It is followed by a thick-walled ciliated sac or tube called stomach.Stomach leads to a thin-walled syncytial intestine. It receives the protonephridia and oviducts near the anus continuing as the cloaca.
The dorsal anus often has dilator muscles. Intestine coaca and anus are lacking in pelagic forms like Asplanchna and Ascomorpha.Rotifers feed on Protozoa, other microscopic organisms and debris swept by ciliary action.

Respiratory System of Rotifers: No respiratory organs, and little is known of respiratory physiology. Some rotifers have ability to respire anaerobically.

Excretory System of Rotifers: It consists of a pair of coiled, syncytial protonephridial tubules.



Fine capillary tubules terminate in flame bulbs. Sometimes a tranverse tubule called Huxley's anastomose connects the two main tubules. Protonephridia drain into the cloaca, by the way of a common duct or a bladder. Flame-cell activity varies with the osmotic pressure of environment.

Nervous System of Rotifers: The brain consists of a single, dorsal, bilobed supra-pharyngeal ganglion situated above mastax in head. Cephalic sense organs and dorsal antennae are innervated from the brain. Lateral antennae receive nerves from the geniculate ganglion.

Caudal sense organs are innervated by nerves from the pedal or caudovesicular ganglion. A pair of longitudinal, ventrolateral nerve trunks arise from the sides of bilobed brain. There is a clear separation of sensory and motor elements in the nervous system.

Sense Organs: They include stiff bristles (styles), ciliated pits, antennae and eyespots. Stiff bristle occur along anterior edge of the body.Paired ciliated pits, probably chemoreceptive, occur on the apical field.

Most rotifers have a dorsal antenna and some have lateral antennae. These are tactile organs. A retrocerebral organ of unknown function is present inside head.

Reproductive System of Rotifers: Dioecious, sexes separate with sexual dimorphism. Most rotifers are females and all bdelloids are females producing only parthenogenetic ova.

Males are only a quarter size of females often degenerate without digestive organs. Monogononta males have a single sacciform test is occupying greater part of body.

Test isopens into a sperm duct ending in the male gonopore. The last part of the sperm duct is sometimes modified as a cirrus. One pair to many prostate glands open into the sperm duct.

Development of Rotifers: Fertilization is internal. Sperms penetrate the body-wall into the pseudocoel to fuse with ova. Few rotifers have copulatory apparatus and so copulate.

Monogononta females are two types, Amictic and Mictic. Amictic females lay egg which are incapable to fertilize. Amictic eggs are large, thin walled and diploid. They develop parthenogenctically into females of both types. Mictic females lay small, thin walled, haploid eggs. If not fertilized they develop parthenogenetically into males. If fertilized they become thick walled and diploid dormant resting or winter eggs. These eggs can survive unfavourable conditions and hatch into females during spring.

Cleavage is spiral and determinate. Gastrulation is epibolic. Stomodaeum and proctodaeum are formed by ectodermal invagination. There is no larval stage, embryo develop into adult without metamorphosis

Affinities of Rotifers: Rotifers are biologically peculiar organisms. Many zollogists still keep them as a class of phylum Aschelminthes.

The affinities of these animals can be studied under following heads

1. Affinities with Platyhelminthes,
2. Affinities with Aschelminthes.
3. Affinities with Annelida.4. Affinities with Arthropoda.

Affinities with Platyhelminthes

1. Primitive corona homologous to ventral ciliation in flatworms.
2. Presence of cuticularized parts such as trophi.
3. Presence of protonephridia.
4. Retrocerebral organ homologous to frontal ganglion of turbellaria.5. Division of female gonad into germarium and vitellarium.

Affinities with Aschelminthes

1. Somewhat worm-like body.2. No complete cephalization.
3. Presence of Syncytial epidermis.4. Presence of pseudocoel.
5. Constancy of cell in each organ.6. Lack of regenerative capacity.

Affinities with Annelida: The peculiar rotifer, Trochosphaera appears almost like a sexually mature trochophore larva with a mastax. rotifers are closely related to the ancestral annelids. rotifers are simply annelids which have remained in a larval condition

Affinities with Arthropoda

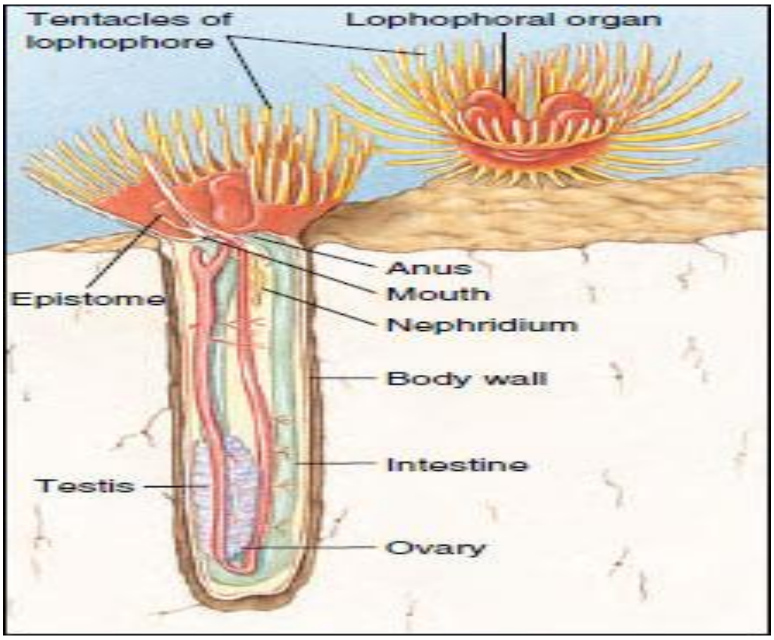
1. Body covered with cuticle.2. Superficial metamerism.3. Presence of jaws.
4. Moving bristles-bearing arms of rotifer Pedalia resemble the appendages of crustacean larva.
But there are a large number of differences between rotifers and arthropods.
Conclusion: Rotifers are included in the phylum Aschelminthes by many authors. But on account of many morphological, anatomical and embryological peculiarities, it seems preferable to treat them as a separate minor phylum.

8.2 GENERAL CHARACTERS OF PHORONIDA

Body structure: Most adult phoronids are 2 to 20 cm long and about 1.5 mm wide, although the largest are 50 cm long. Their skins have no cuticle but secrete rigid tubes of chitin, similar to the material used in arthropods' exoskeletons, and sometimes reinforced with sediment particles and other debris. Most species' tubes are erect, but those of Phoronisvancouverensis are horizontal and tangled.

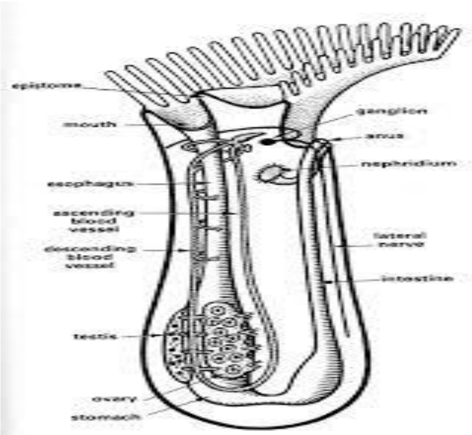
The bottom end of the body is an ampulla (a flask-like swelling in a tube-like structure),which anchors the animal in the tube and enables it to retract its body when threatened, reducing the body to 20 percent of its maximum length. Longitudinal muscles retract the body very quickly, while circular muscles slowly extend the body by compressing the Internal fluid.

For feeding and respiration each phoronid has at the top end a lophophore, a "crown" of tentacles with which the animal filter-feedsThe body is divided into coeloms,compartments lined with mesothelium. The main body cavity, under the crown of tentacles, is called the metacoelom, and the tentacles and their base share the mesocoelom.Above the mouth is the epistome, a hollow lid which can close the mouth. The cavity in the epistome is sometimes called the protocoelom,



Digestive system: For feeding and respiration each phoronid has at the top end a lophophore, a "crown" of tentacles with which the animal filter-feeds.

In small species the "crown" is a simple circle, in medium-size species it is bent into the shape of a horseshoe with tentacles on the outer and inner sides, and in the largest species the ends of the horseshoe wind into complex spirals.These more elaborate shapes increase the area available for feeding and respiration. The tentacles are hollow, held upright by fluid pressure, and can be moved individually by muscle.When the lophophore is extended, cilia (little hairs) on the sides of the tentacles draw water down between the tentacles and out at the base of the lophophore. Shorter cilia on the inner sides of the tentacles flick food particles into a groove in a circle under and just inside the tentacles, and cilia in the groove push the particles into the mouth. Phoronids direct their lophophores into the water current, and quickly reorient to maximize the food-catching area when currents change. Their diet includes algae, diatoms, flagellates, peridinians, small invertebrate larvae, and detritus. Unwanted material can be excluded by closing the epistome (lid above the mouth) or be rejected by the tentacles, whose cilia can switch into reverse. The gut uses cilia and muscles to move food towards the stomach and secretes enzymes that digest some of the food, but the stomach digests the majority of the food. Phoronids also absorb amino acids (the building blocks of proteins) through their skins, mainly in summer. Solid wastes are moved up the intestine and out through the anus, which is outside and slightly below the lophophore.



Circulatory system: A blood vessel starts from the peritoneum (the membrane that loosely encloses the stomach),with blind capillaries supplying the stomach. The blood vessel leads up the middle of the body to a circular vessel at the base of the lophophore, and from there a single blind vessel runs up each tentacle.

A pair of blood vessels near the body wall lead downward from the lophophore ring, and in most speciesthese are combined into one a little below the lophophore ring. The downward vessel(s) leads back to the peritoneum, and also to blind branches throughout the body.

There is no heart, but muscles in the major vessels contract in waves to move the blood. The blood has hemocytes containing hemoglobin, which unusual in such small animals and seems to be an adaptation to anoxic and hypoxic environments. The blood of Phoronisarchitecta carries as much oxygen per cm^3 as that of most vertebrates; the blood's volume in cm^3 per gm of body weight is twice that of a human.[Unlike many animals that live in tubes, phoronids do not ventilate their trunks with oxygenated water, but rely on respiration by the lophophore, which extends above hypoxic sediments.

Excretory system: Podocytes on the walls of the blood vessels perform first-stage filtration of soluble wastes into the main coelom's fluid. Two metanephridia, each with a funnel-like intake, filter the fluid a second time, returning any useful products to the coelom and dumping the remaining wastes through a pair of nephridiopores beside the anus.

Nervous system and movement: There is a nervous center is between the mouth and anus, and a nerve ring at the base of the lophophore. The ring supplies nerves to the tentacles and, just under the skin, to the body-wall muscles.

Phoronisovalis has two nerve trunks under the skin, whereas other species have one. The trunk(s) have giant axons (nerves that transmit signals very fast) which co-ordinate the retraction of the body when danger threatens.

Except for retracting the body into the tube, phoronids have limited and slow movement: partial emerging from the tube; bending the body when extended; and the lophophore's flicking of food into the mouth.
Phoronida in their lack of cephalization and as regards the disposition of their nervous system may be considered as Epineuriens.Reproduction and lifecycle:Only Phoronisovalis naturally builds colonies by budding or by splitting into top and bottom sections which then grow into full bodies. Other species have split successfully, but only when both parts have enough gonadal (reproductive) tissue. All phoronids breed sexually from spring to autumn. Some species are hermaphroditic (have both male and female reproductive organs) but cross-fertilize (fertilize the eggs of other members), while others are dioecious (have separate sexes).The gametes(sperms and ova) are produced in the swollen gonads, around the stomach. The gametes swim through the metacoelom to the metanephridia. Sperm exit by the nephridiopores and some are captured by the lophophores of individuals of the same species.

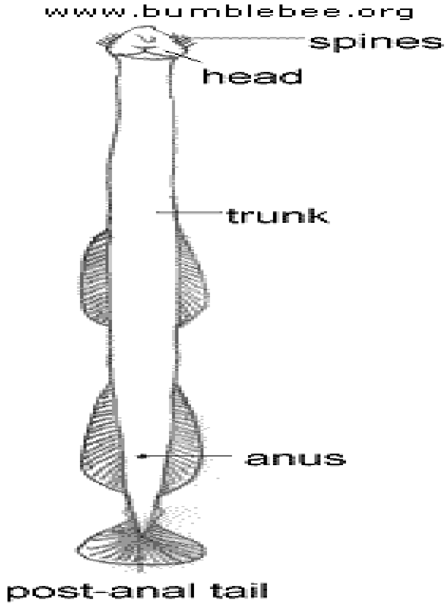
Species that lay small fertilized eggs release them into the water as plankton, while species with larger eggs brood them either in the body's tube or stuck in the center of the lophophore by adhesive. The brooded eggs are released to feed on plankton when they develop into larvaedevelopment of the egg is a mixture of deuterostome and protostome characteristics. Early divisions of the egg are holoblastic (the cells divide completely) and radial (they gradually form a stack of circles). The process is regulative (the fate of each cell depends on interaction with other cells, not on a rigid program in each cell), and experiments that divided early embryos produced complete larvae. Mesoderm is formed from mesenchyme originating from the archenteron. The coelom is formed by schizocoely, and the blastopore(a dent in the embryo) becomes the mouth.The slug-like larva of Phoronis ovalis swims for about 4 days, creeps on the sea-bed for 3 to 4 days, then bores into a carbonate floor. The remaining species develop free-swimming actinotroch larvae, which feed on plankton. The actinotroch is an upright cylinder with the anus at the bottom and fringed with cilia. At the top is a lobe or hood, under which are: a ganglion, connected to a patch of cilia outside the apex of the hood; a pair of protonephridia the mouth; and feeding tentacles that encircle the mouth.After swimming for about 20 days, the actinotroch settles on the seabed and undergoes a catastrophic metamorphosis (radical change) in 30 minutes: the hood and larval tentacles are absorbed and the adult lophophore is created round the mouth, and both now points upward; the gut develops a U-bend so that the anus is just under and outside the lophophore.Finally the adult phoronid builds a tube. Phoronids live for about one year.

8.4 GENERAL CHARACTERS OF CHAETOGNATHA

INTRODUCTION

Chaetognaths are in a separate Phylum by themselves (~100 species).

They are carnivorous marine invertebrates ranging in size from 2-120 mm. There are also known as “Arrow worms,”“Glass worms,” and “Tigers of the zooplankton.” Characterized by a slender transparent body, relatively large caudal fins, and anterior spines on either side of the mouth, these voracious meat-eaters catch large numbers of copepods, swallowing them whole. Their torpedo-like body shape allows them to move quickly through the water, and the large spines around their mouth helps them grab and restrain their prey. Chaetognaths alternate between swimming and floating. The fins along their body are not used to swim, but rather to help them float.



8.4 GENERAL CHARACTERS

The chaetognaths, or arrowworms, are coelomate animals of relatively small size, with a straight , slender, transparent body displaying perfect bilateral symmetry. Most conspicuous of the external features are the fins, paired lateral and single caudal thin horizontal extensions supported by rays and serving for flotation and equilibration rather than for locomotion. The anterior end forms a well – delimited head bearing a pair of eyes and on either side the characteristic grasping spines (hooks), hard curved spines used in seizing prey and operated by a complex musculature inside the head. The head is also typically armed with arcs of small spines anterior to the mouth.

A feature peculiar to the phylum is a fold of body wall that can be drawn over the dorsal and lateral surfaces of the head like a hood. The nervous system consists of ganglia in the head connected by a pair of circumenteric commissures with a large ventral trunk ganglion.

The digestive system is a straight tube extending from the mouth located ventrally on the head to the anus found somewhat anterior to the tail fin.The chaetognaths are hermaphrodites, the paired ovaries are situated in the trunk immediately anterior to the tail septum. Testes lie in the tail region posterior to tail septum.

Body Wall of Sagitta: The body wall is composed of an outer epidermis which secretes a thin cuticle. The epidermis consists of epidermal cells, the shapes of which may vary at different regions. In Sagitta, a peculiar structure, called corona ciliata or ciliary loop is present at the anterior end as a dorsal strip of modified epidermis. It forms a ridge over the epidermis proper where two or three rows of cells bear long fine cilia. Beneath the epidermis, a thin basement membrane exists upon which the epidermis rests.

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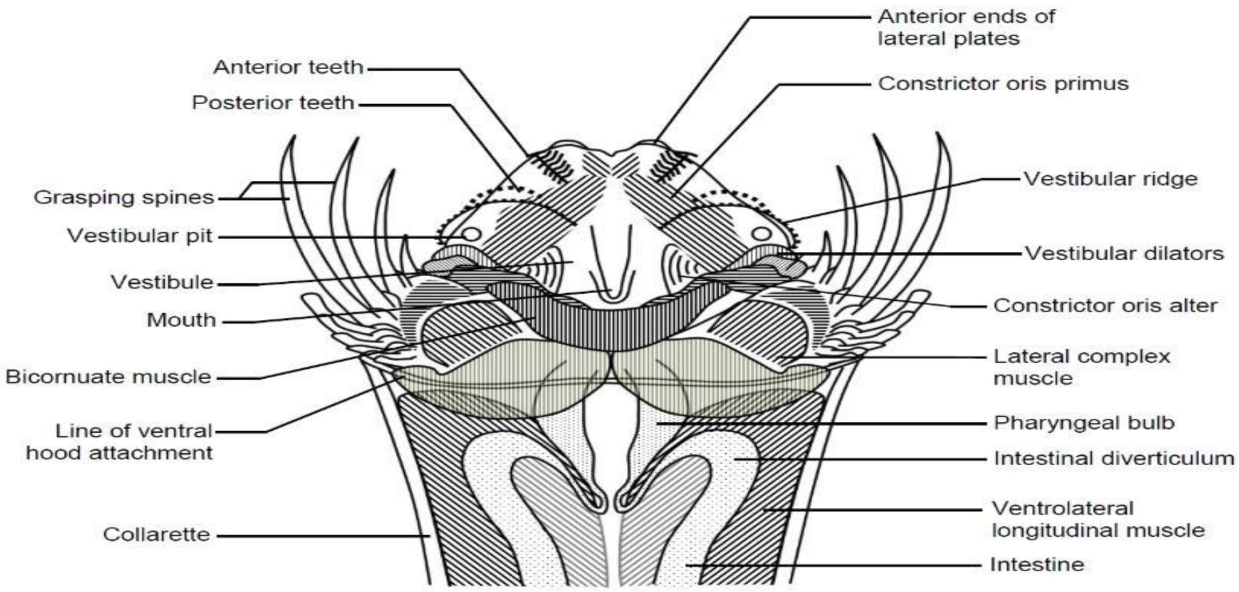
Retrocerebral Organ: The retrocerebral organ has an unknown function [check for updates on this], but is possibly glandular. It consists of a pair of sacs (or cell clusters in *Spadella*) imbedded in the posterior of the cerebral ganglion, separated from the nervous tissue by a membrane. A common duct opens behind the brain by the retrocerebral pore. Ganglion cell processes enter the sacs.



Ventral view of anterior end of a chaetognath (*Sagitta elegans*)

Ciliary loop (corona ciliata)

The ciliary loop is a dorsal strip of altered epidermis, which forms a short or long oval with simple or sinuous contour. The long axis is usually parallel to the body axis. The anterior end is usually immediately behind.

The ciliary-loop extends to the neck or far down on the trunk. The histology of the ciliary loop is varied. It may consist of a ridge or groove of a variable number of cells wide. It may also be adjacent to gland cells. The ciliary loop possibly functions as a sense organ or as an excretory organ (a possible nephridium.

MUSCULATURE

The body wall musculature lies beneath the basement membrane. This muscle layer is simple in the trunk and tail, where it comprises longitudinal fibres only, and also lacks an inner peritoneal membrane. The body wall muscles are all striated. There may also be a thin transverse layer and inside these ventrolaterals, which may occur throughout the trunk and or tail or the anterior trunk, and are of taxonomic importance. The muscle fibres are similar to those of nematodes, consisting of a fibrillar part near the basement membrane and a protoplasmic part facing the body cavity. The fibrillar part consists of longitudinal fibrous plates or lamellae at oblique angles to each other and to the body wall. This gives the fibres a feathery appearance in cross-section. The head musculature is very complex. This has been best studied in *Spadella* and *Sagitta*. Skeletal plates form a hardened head capsule for the attachment of these muscles.

Muscles of the Hood. An unpaired sphincter muscle pulls the hood forward (hood protractor or protractor preputii). One pair of hood retractors (retractor preputii) occurs in *Sagitta*. These retractors originate on the connective-tissue layer beneath the brain and insert on the skeletal plates in the neck.

Muscles of the Teeth. Two pairs of small expander muscles (expansus superior and inferior) run transversely in the anterior end of the head.These originate on a median connective-tissue lamella and function as teeth erectors. One pair of small short obliques (obliquus capitis brevis) pull down the anterior teeth.These originate on the same median lamella as the teeth erectors.

Muscles of the Grasping Spines. Spreading open of the spines is not due to particular muscles, but due to alteration of head shape. In particular the lateral complex and the bicornuate muscles shorten and broaden the head.

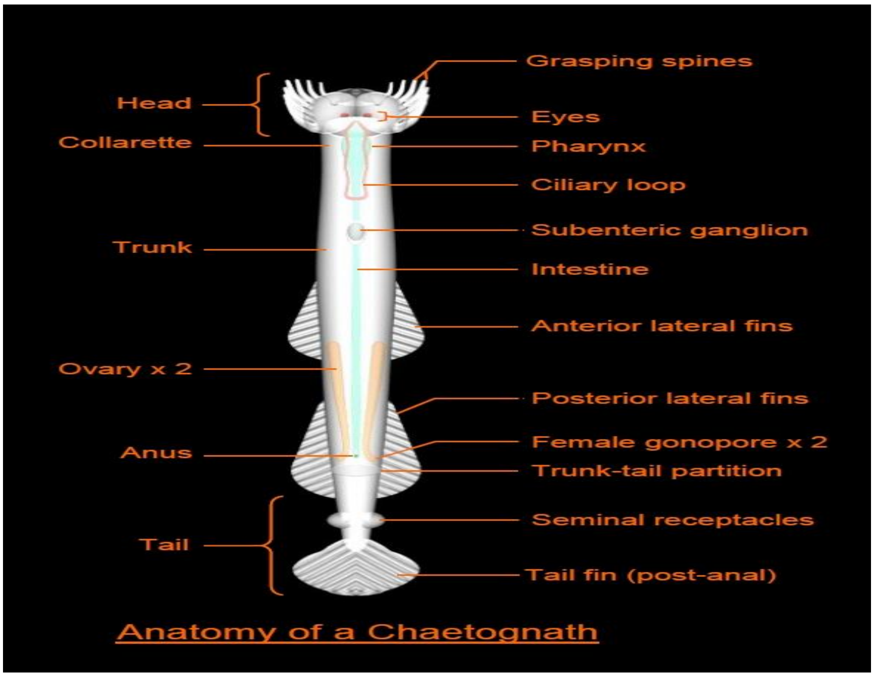
Closure of the spines is very fast. One pair of adductors form conspicuous masses on the sides of the head.They originate on the posterior parts of the lateral plates and insert on the spine bases.

General Dorsal Head Musculature. The central region of the head is occupied by longitudinal oblique muscles that insert on the anterior ends of the lateral plates and converge toward the median line and then run to their attachments at the posterior end of the head.These muscles shorten the head in the anteroposterior direction. Curved hood retractors lie above the middle of the longitudinal obliques.

Transverse fibres of short oblique muscles at the tip of the head are followed by the teeth expanders. The large spine adductors occupy the sides of the head A median triangle at the rear of the head is formed from 2 superficial oblique muscles that help to retract the hood. On either side of the triangle, dorsal transverse muscles originate on the median lamella and insert on the posterior ends of the lateral plates. These transverse muscles pull the ends of the lateral plates towards the median line and hence assist spreading of the grasping spines.The sides of the posterior end of the head contain the dorsal ends of the external neck muscles that insert on the skeletal plates at the sides of the neck. These muscles run dorsoventrally and attach to the lateral plates. They produce nodding motion of the head.

Muscles of the Mouth and Vestibule: These are seen in a ventral view of the head. The teeth expanders are visible at the anterior end of the head. Behind these are one pair of mouth constrictors (constrictor oris primus) that curve in front of the mouth and another pair of mouth constrictors (constrictor oris alter) that run alongside the mouth opening. The latter pair is absent in Spadella. Three pairs of muscles, visible in transverse sections, dilate the mouth and vestibule: one pair of dilator vestibuli externus, one pair of dilator vestibuli internus and one pair of dilator oris. This latter pair are absent in Spadella. The external dilators are visible in external ventral view, lateral to the mouth constrictors.

Other Ventral Muscles. These run across the head, behind the vestibule. The bicornuate muscle (bicornis)conspicuous sasuage shaped muscle that alters the shape of the head. The massive lateral complex muscles (complexus lateralis) consist of several bundles at the sides of the posterior part of the head. This muscle mass has dorsal attachments to the spine adductors and lateral attachments to the ventral plates. Medially, the bicornuate muscle is embedded in this muscle mass. The posterior ends of the hood protractors are visible on either side, behind the complexus.



8.5 SUMMARY

In this unit, we will understanding larval forms helps in studying evolution, development, and the ecological roles of invertebrates in marine and freshwater environments. Student will be familiar with the free- living larval forms in invertebrates. In this unit we will studied about the organization and general characters of minor phyla like rotifera, phoronida, and chaetognatha.

8.6 KEY WORDS

Larva: An insect at the stage when it has just come out of an egg and has a short fat soft body with no legs.

Parasites: An organism that lives on or in a host organism and gets its food from or at the expense of its host.

Minor phyla: Groups of animals that, while they may include a few common species, are generally not abundant in terms of species or individual numbers.

8.7 QUESTION AND ANSWER

1. What are the different types of larval forms found in free-living invertebrates?
2. How do larval stages contribute to the life cycle of free-living invertebrates?
3. What are the different larval stages found in parasitic invertebrates?
4. What are the key differences between free-living and parasitic larval forms?
5. What are the defining characteristics of minor phyla in invertebrates?
6. How are minor phyla different from major invertebrate phyla?
7. What are the key morphological features of rotifers?
8. What are the general body characteristics of phoronids?
9. How do chaetognaths capture their prey?

8.8 REFERENCE

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Prof. P. Padmavathi

LESSON - 9

PARASITIES: LIFE CYCLE AND BIOLOGY

1. TRYPANOSOMA GAMBIENSE

Habit and Habitat: Trypanosoma gambiense lives as a parasite in the blood, lymph, lymph nodes, spleen, or cerebrospinal fluid of man and in the intestine of blood-sucking fly Glossina palpalis (Tsetse fly). The parasite causes a disease called Gambian or West-African sleeping sickness in human-beings. The disease African sleeping sickness was first described by Atkins in 1724 and Winterbottom in 1803, but the causative parasite was described in human blood by Forde in 1901 and later on named as T. gambiense by Dutton in 1903.

STRUCTURE OF TRYPANOSOMA GAMBIENSE

Shape and size: Trypanosoma gambiense has a slender, elongated, colourless, sickle-shaped and flattened microscopic body which is tapering at both the ends. The anterior end is more pointed than the posterior end which is blunt. Its body length varies from 15 to 30 microns and width from 1 to 3 microns. The shape and size of its body vary with the form in which it exists.

Pellicle and Undulating Membrane: The body is covered by a thin, elastic and firm pellicle. It maintains the general shape of the body. The pellicle is made of fine fibrils which run along the whole length of the body. These fibrils are called microtubules. The pellicle is pulled out into an irregular membranous fold to one side when its flagellum beats. This fold is called undulating membrane, which is supposed to be an adaptive structure for locomotion in a viscous environment (blood, lymph) where it lives.the

Flagellum: Flagellum is single in Trypanosoma, i.e., it is uniflagellate. The flagellum arises from the basal granule situated near the posterior end of the body. The flagellum runs forward and remains attached all along the length of the body marking the boundary of undulating membrane. After reaching the anterior end of the body, the flagellum becomes free and hangs freely as free flagellum. Structurally, the flagellum is like that of Euglena’s and consists of the axoneme enclosed in a thin cytoplasmic sheath

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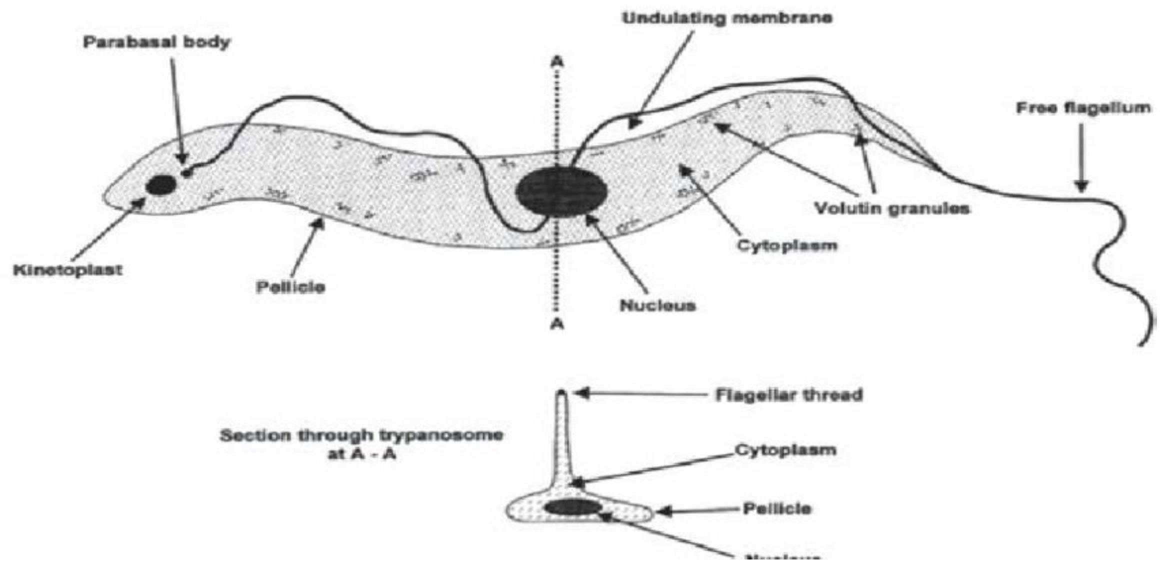


Kinetoplast: Just posterior to basal granule, there is a small, spherical or disc-shaped parabasal body or kinetoplast which contains extra-nuclear DNA and, hence, it is a self-duplicating body. The kinetoplast is related to locomotion.

Cytoplasm: Its cytoplasm is differentiated into ectoplasm and endoplasm. The cytoplasm contains numerous scattered greenish refractile deep staining granules called volutin granules. The volutin granules are metabolic food reserves and generally consist of glycogen and phosphates. In addition, cytoplasm also contains some small vacuoles having hydrolytic enzymes in them and all other cellular components like Golgi apparatus, mitochondria, endoplasmic reticulum and nucleus.

Nucleus: A single, oval or spherical and vesicular nucleus (trophonucleus) is seen in the middle of its body. The nucleus contains a large endosome surrounded by chromatin.

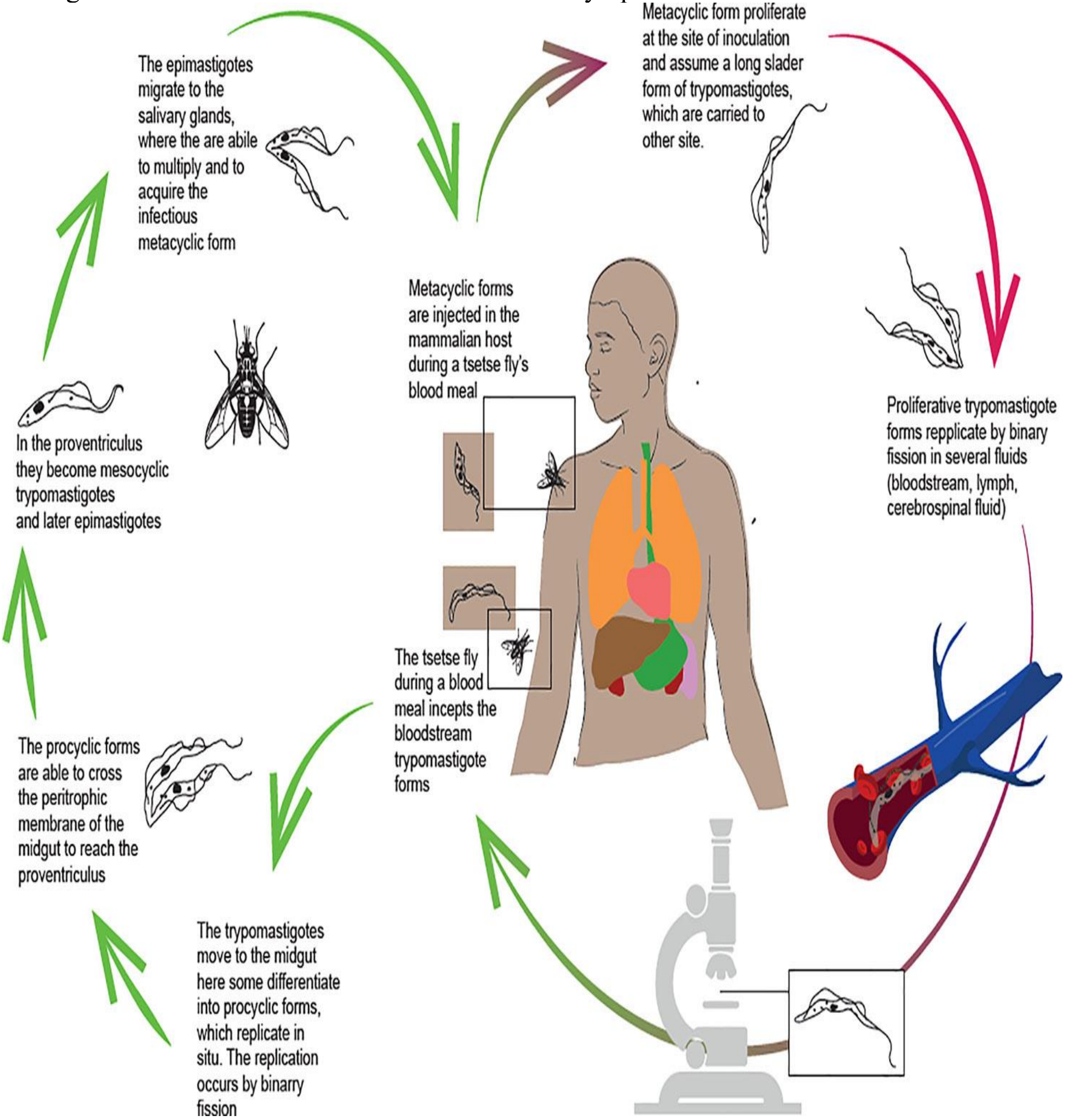
Life cycle of Trypanosoma gambiense: The life cycle of Trypanosoma gambiense is completed within two hosts, i.e., digenetic (Gr., di – double; genos = race), a primary vertebrate and secondary invertebrate host or vector. The vertebrate host is man and the invertebrate host is blood sucking fly, Glossina palpalis (Tsetse fly). Trypanosoma gambiense lives harmlessly in the blood of antelopes.

Part of Life Cycle in Man: When an infected fly bites a man, it inoculates a few parasites in the blood of man. The parasites first live in the blood of the infected man, but later find their way into the cerebrospinal fluid. While the parasites are in the blood, the infected man develops a kind of fever termed Gambia fever, but when they reach the cerebrospinal fluid, various nervous symptoms are produced in the patient leading to a lethargic condition, which has given the name sleeping sickness to the disease.

The parasites multiply by longitudinal binary fission in the blood and produce three forms of individuals, viz; (i) Long and thin form's with a free flagellum, (ii) Short and stumpy forms with a reduced flagellum and (iii) Intermediate forms. It has been observed that the parasites periodically increase and decrease in number in the blood of man. During the period of decrease the short and stumpy forms, which have great resisting power, survive the period of depression and the rest die. These short and stumpy forms are capable of development in the intermediate host, Glossina palpalis (Testse fly).

Part of Life Cycle in Tsetse Fly: When a tsetse fly sucks the blood of an infected man, a number of parasites enter into the midgut of the fly along with the blood. These parasites remain in the midgut of the fly for a few days and start multiplying by longitudinal binary fission. After tenth to fifteenth day, long slender forms appear in great numbers which move forward to the proventriculus. After several more days, the trypanosomes make their way to the fly's salivary gland. In the salivary glands they become attached to the walls and undergo another rapid phase of multiplication by longitudinal binary fission and develop into crithidial forms. The crithidial forms are characterised by a shorter flagellum and undulating membrane. Flagellum and undulating membrane do not extend in the hinder part of the body. Kinetoplast and basal granule are situated above the nucleus towards the anterior end. Here the development continues for 2-5 days and the crithidial forms produce metacyclic forms (Trypanosome forms) which are now infective. These metacyclic forms pass down through the ducts and hypopharynx. When the fly bites a man, the metacyclic forms enter the blood of man along with the saliva of the fly. The whole cycle in the fly usually takes 2-30 days.

Pathogenicity and Symptoms of Trypanosoma Gambiense: The bite of an infected fly is usually followed by itching and irritation near the wound, and frequently a local dark red lesion develops. In blood, the parasite multiplies and absorbs nutrients from it. After a few days, fever and headache develop, recurring at regular intervals accompanied by increasing weakness, loss of weight and anaemia. Usually, the parasites succeed in penetrating the lymphatic glands. Because of its infection, the lymphatic glands swell and after it the parasites enter the cerebrospinal fluid and brain causing a sleeping sickness like condition. Development of lethargic condition and recurrence of fever are the symptoms of its infection.



Disease Caused by Trypanosoma Gambiense: Trypanosoma gambiense causes trypanosomiasis; most commonly referred to as sleeping sickness leading to coma stage and finally resulting into the death of the patient. In fact, two types of diseases are caused by Trypanosome which are essentially similar in symptoms. These are Gambian and Rhodesian sleeping sickness. The Gambian sleeping sickness occurs in western part of Africa and its vector is Glossina palpalis, while Rhodesian sleeping sickness occurs in rest of Africa and its vector is Glossina morsitans. The only difference between the two is that the latter is more rapid causing the death of the patient within 3-4 months of infection.

Diagnosis, Treatment and Prevention of Disease Caused by Trypanosoma Gambiense: The diagnosis is confirmed by examining fresh or stained peripheral blood or by examining the cerebrospinal fluid obtained by lumbar puncture or by examining the extract of enlarged lymphatic glands.

Treatment (Therapy): Arsenic and antimony compounds were until recently the drugs for treatment of trypanosomiasis, but now they are rarely used except for late stages when the parasites have invaded the central nervous system. Two drugs, Bayer 205 (also called Antrypol, Germanin or Suramin), and Pentamidine or Lomidine are now widely used for both treatment and prophylaxis of human infections. These drugs are low in toxicity, effective in treatment, and prevent reinfection for several months.

Prevention (Prophylaxis): The following measures are suggested for preventing the infection of this parasite: 1. By eradicating the vectors. The infection of this parasite can be checked by completely eradicating the secondary host (Tsetse fly). For this, the endemic areas should be kept clean and regular spray of insecticides like DDT is suggested which help in eradicating the fly. 2. Care should be taken to keep the reservoir hosts free from its infection. 3. Preventive medicines should be taken frequently and periodically which help to a great extent from its infection.

2. LEISHMANIA DONOVANI

INTRODUCTION

Leishmania donovani isa species of intracellular parasitic protozoan belonging to the genus Leishmania, a group of haemoflagellatekinetoplastids that cause thedisease leishmaniasis. It is a human blood parasite responsible for visceral leishmaniasis or kala-azar, the most severe form of leishmaniasis.

It infects the mononuclear phagocyte system including spleen, liver and bone marrow. Infection is transmitted by species of sandfly belonging to the genus Phlebotomus.

The parasite is prevalent throughout tropical and temperate regionsincluding Africa (mostly in Sudan), China, India, Nepal, southern Europe, Russia and South America. It is responsible for thousands of deaths every year and has spread to 88 countries, with 350 million people at constant risk of infection and 0.5 million new cases in a year.

The parasite requires two different hosts for a complete life cycle, humans as the definitive host and sand flies as the intermediate host. In some parts of the world other mammals, especially canines, act as reservoir hosts.

In human cell they exist as small, spherical and unflagellated amastigote form; while they are elongated with flagellum as promastigote form in sandflies. Unlike other parasitic protists they are unable to directly penetrate the host cell, and are dependent upon phagocytosis.

Discovery

One of the earliest known epidemics of L. donovani infection (kala-azar as it was called in Hindi) was known in India just after the Indian Rebellion of 1857.. Donovan sent some of his slides to Ronald Ross, who was at the time in Liverpool, and toAlphonse Laveran at the Pasteur Institute in Paris. Laveran and his colleague FélixMesnil identified the protozoan (and yet wrongly) to be members of Piroplasmida, and gave thescientificname Piroplasmadonovanii.

It was Ross who resolved the conflict of priority in the discovery and correctly identified the species as member of the novel genus Leishmania. He gave the popular name "Leishman-Donovan bodies", and subsequently the valid binomial Leishmania donovani, thereby equally crediting the two rivals.

Structure

Leishmania donovani is a unicellular eukaryote having a well-defined nucleus and other cell organelles including a kinetoplast and a flagellum. Depending on its host it exists in two structural variants, as follows:Amastigote form found in the mononuclear phagocyte and circulatory systems of humans.

It is an intracellular and non-motile form, being devoid of external flagellum. The short flagellum is embedded in the anterior end without projecting out. It is oval in shape, and measures 3–6 µm in length and 1–3 µm in breadth. The kinetoplast and basal body lie towards the anterior end.

Promastigote is formed in the alimentary tract of the sandfly. It is an extracellular and motile form. It is considerably larger and more highly elongated, measuring 15–30 µm in length and 5 µm in width. It is spindle-shaped, tapering at both ends. A long flagellum (about the body length) is projected externally at the anterior end. The nucleus lies at the centre, and in front of which are kinetoplast and basal body.

Infection and life cycle

Definitive host: In humans the metacyclic promastigotes are injected by sandfly through the skin during its blood meal. When sandfly bites using its proboscis it ejects the parasites that are stored inside the hollow tube. Some promastigotes may enter the blood stream directly where some are destroyed by macrophagic cytolysis.

But many are also taken up through phagocytosis by mononuclear phagocytes in liver, spleen and bone marrow.Inside the cells they undergo spontaneous transformation into oval-shaped amastigotes. Granulocytes selectively kill the promastigotes by oxidative mechanism, while amastigotes are resistant. Then the surviving amastigotes undergo cell division using simple binary fission. Multiplication continues until the host cell can no longer hold and ruptures. In a fully congested cell there can be as many as 50 to 200 amastigotes, which are released into tissue cavities. Each individual amastigote is then capable of invading fresh cells. As a result, the entire tissue is progressively infected and destroyed. A number of free amastigotes then enters the blood stream where many are phagocytosed by macrophages. These free and phagocytosed amastigotes in peripheral bloodare then sucked up by blood-feeding sandfly.

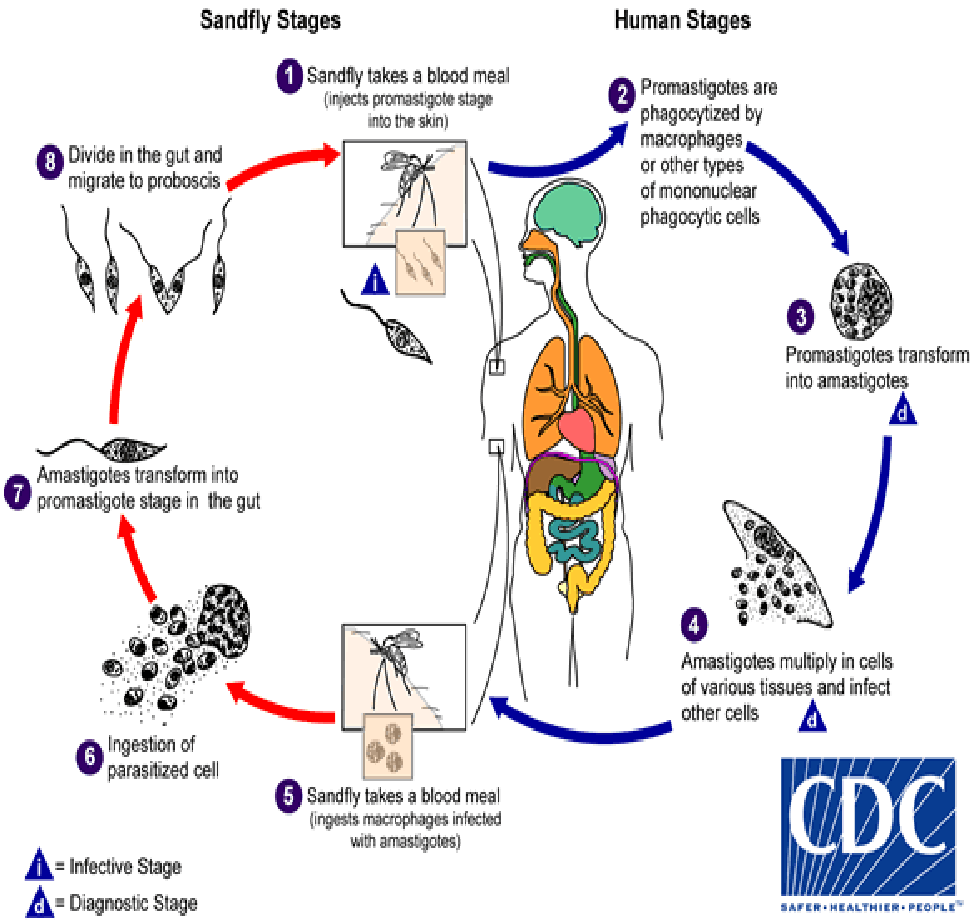
Intermediate host

L. donovani undergo further development only in the digestive tract of the female sandfly. Hence only females are responsible for transmitting the infection. Once the amastigotes are ingested, they enter the midgut of the sandfly.

Then they undergo structural modification into flagellated promastigotes, becoming larger and considerably elongated. They get attached to the gut epithelial lining where they multiply rapidly by binary fission. (They are also capable of sexual reproduction by genetic hybridisation in the sandfly gut.) They then migrate back towards the anterior part of the digestive system such blood meal. The promastigotes become infective only by this timemetacyclic stage. The metacyclic promastigotes then enter the hollow proboscis where they accumulate and stage. The metacyclic promastigotes then enter the hollow proboscis where they accumulate and completely block the food passage. Immediately upon biting a human, the parasites are released, which invariably results in infection. The stages of development in sandfly can be described as follows:Soon after entering the gut, the amastigotes get coated with peritrophic matrix, which is composed of chitin and protein complex. This protects the parasites from the digestive enzymes of the host.The amastigotes travel as far as the abdominal midgut and first transform into a weakly motile "procyclic promastigotes" on the gut wall within 1–3 days.

The young promastigotes secrete a neuropeptide that stop peristalsis of the gut. The surface lipophosphoglycan (LPG) of the promastigote serves as an attachment to the gut epithelium. These factors prevent the expulsion of promastigotes during excretion of the insect.During 4–7 days the peritrophic matrix is degraded by the activity of chitinases. This release the more actively motile "nectomonad promastigotes" which migrate anteriorly until they reach the opening of the thoracic gut.Another transformation takes place by which they turn into "leptomonad promastigotes". These are fully motile and capable of binary fission. Multiplication and migration towards thoracic midgut cause congestion of the pharynx and buccal cavity. Here they secrete promastigote secretory gel (PSG), which is composed of soluble acid phosphatase and phosphoglycoprotein.After 6–9 days the promastigotes become metacyclic. Some are also transformed into non-replicating promastigotes, which also become metacyclic. The sandfly is able to regurgitate and eject the parasites from its proboscis with the help of PSG when it bites.

Reservoir host: Dogs are known to be susceptible to *L. donovani* infection.Especially in the New World, infection is a zoonotic disease, involving different canine species, including domestic dog and the two fox species, Lycalopexvetulus and Cerdocyonthous. In the Mediterranean region domestic dogs and the three fox species Vulpesvulpes, V. corsac and V. zerdaare common reservoir hosts. In Africa and Brazil, some marsupials and rodents are also reported to harbour L. donovani.



Pathogenicity: L. donovani is the causative agent of visceral leishmaniasis, traditionally known as *kala-azar* ("black fever", particularly in India), because of its characteristic symptoms. The disease is highly lethal if not treated properly. The incubation period generally ranges from 3 to 6 months, and in some cases may be over a year. In Indian leishmaniasis, incubation can be as short as 10 days. The target cells are those of mononuclear phagocyte system. The two main tissues of infection are spleen and liver.

Clinical symptoms include pyrexia (recurring high fever which may be continuous or remittent), enlargement of spleen and liver, and heavy skin pigmentation which darkens the physical appearance (the reason for naming "black fever"). To a lesser extent mucosa of the small intestine and lymph nodes are also invaded by the parasite. Morphological symptoms are noticeable particularly on facial and abdominal regions. Skin becomes coarse and hard.
In African infections, warty eruptions are common. In a fully developed stage, the patient shows emaciation and anaemia. Where medical facilities are poor, mortality can be as high as 75–95% within 2 years of epidemics. The disease is often accompanied by complications with dysentery, tuberculosis, septicaemia and even HIV infection.

Treatment

The conventional treatment method is an intravenous injection with antimony compounds, such as pentostam.Unfortunately, thesechemotherapeutics are so poisonous that about 15% of the patients die from the treaments.To compound the situation, drug resistance has evolved in the parasites against the traditional antimonials. According to rough estimates, about 40% of patients in India are already resistant to this therapy.Another antimicrobial drug amphotericin B is also commonly used. Liposomal amphotericin B (L-AmB) has been a drug of choice in India, but is practically useless in Africa because of low effectiveness in the African strain of the parasite.Further, amphoteric in B has severe adverse effects. Its acute effects includes nausea, vomiting, rigors, fever, hypertension or hypotension, and hypoxia, and its chronic effect is nephrotoxicity. This was the first time an oral drug is effective for visceral leishmaniasis. Clinical trials showed that the new drug is relatively harmless. The most adverse effects were only vomiting and diarrhoea in 20–28% patients, which were rather mild. The drug has been officially approved in India. The recommended dosage is 100 mg per day over a period of four weeks.

Prof. K. Sunitha

LESSON - 10
LIFE CYCLE OF BIOLOGY

1. WUCHERERIA BANCROFTI

Wuchereriabancrofti is a human parasitic roundworm that is the major cause of lymphatic filariasis. It is one of the three parasitic worms, together with *Brugiamalayi* and *B. timori*, that infect the lymphatic system to cause lymphatic filariasis.

These filarial worms are spread by a variety of mosquito vector species. *W. bancrofti* is the most prevalent of the three and affects over 120 million people, primarily in Central Africa and the Nile delta, South and Central America, the tropical regions of Asia including southern China, and the Pacificisland If left untreated,
the infection can develop into a chronic disease called elephantiasis] In rare conditions it also causes tropical eosinophilia, an asthmatic disease. Limited treatment modalities exist and no vaccines have been developed.

MORPHOLOGY

As a dioecious worm, *W. bancrofti* exhibits sexual dimorphism. The adult worm is long, cylindrical, slender, and smooth with rounded ends. It is white in colour and almost transparent. The body is quite delicate making it difficult to remove from tissues. It has a short cephalic or head region connected to the main body by a short neck which appears as a constriction. There are dark spots which are dispersed nuclei throughout the body cavity, with no nuclei at the tail tip. Male and female can be differentiated by size and structure of tail tip.

The male worm is smaller, 40 millimetres (1.6 in) long and 100 micrometres (0.0039 in) wide, and features a ventrally curved tail. The tip of the tail has 15 pairs of minute caudal papillae, the sensory organs. The anal region is an elaborate structure consisting of 12 pairs of papillae, of which 8 are in front and 4 are behind the anus. In contrast, the female is 60 millimetres (2.4 in) to 100 millimetres (3.9 in) long and 300 micrometres (0.012 in) wide, nearly three times larger in diameter than the male. Its tail gradually tapers and rounded at the tip. There are no additional sensory structures. Its vulva lies towards the anterior region, about 0.25 mm from the head. Adult male and female are most often coiled together and are difficult to separate. Females are ovoviviparous and can produce thousands of juveniles known as microfilariae.

The microfilaria is a miniature adult and retains the egg membrane as a sheath, and is often considered an advanced embryo. It measures 280 µm long and 25 µm wide. It appears quite structureless 'in vivo', but histological staining makes its primitive gut, nerve ring and muscles apparent.

W. bancrofti carry out their life cycle in two hosts. Human beings serve as the definitive host and mosquitoes as their intermediate hosts. The adult parasites reside in the lymphatics of the human host. They are found mostly in the afferent lymphatic channels of the lymph glands in the lower part of the body.

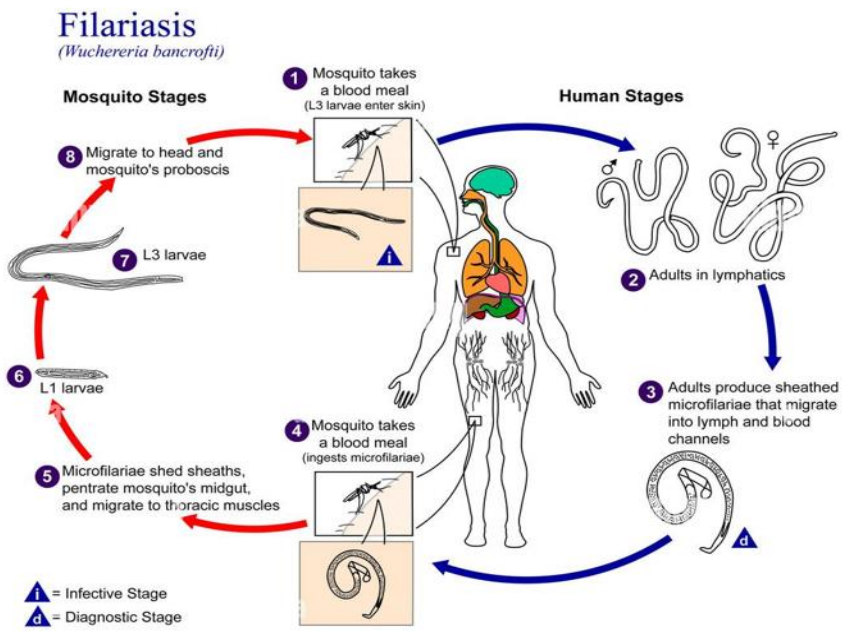
The first-stage larvae, known as microfilariae, are present in the circulation. The microfilariae have a membrane "sheath". This sheath, along with the area in which the worms reside, makes identification of the species of microfilariae in humans easier to determine.

The microfilariae are found mainly in the peripheral blood and can be found at peak amounts from 10 p.m. to 4 a.m. They migrate between the deep and the peripheral circulation exhibiting unique diurnal periodicity. During the day, they are present in the deep veins, and during the night, they migrate to the peripheral circulation.

The cause of this periodicity remains unknown, but the advantages of the microfilariae being in the peripheral blood during these hours may ensure the vector, the nighttime mosquito, will have a higher chance of transmitting them elsewhere.

Physiological changes also are associated with sleeping, such as lowered body temperature, oxygen tension and adrenal activity, and an increased carbon dioxide tension, among other physical alterations, any of which could be the signals for the rhythmic behavior of microfilarial parasites.

If the hosts sleep by day and are awake at night, their periodicity is reversed. In the South Pacific, where W. bancrofti shows diurnal periodicity, it is known as periodic.
The microfilariae are transferred into a vector, which are most commonly mosquito species of the genera Culex, Anopheles, Mansonia, and Aedes. Inside the mosquito, the microfilariae mature into motile larvae called juveniles.



When the infected mosquito has its next blood meal, *W. bancrofti* is egested via the mosquito's proboscis into the blood stream of the new human host. The larvae move through the lymphatic system to regional lymph nodes, predominantly in the legs and genital area.

The larvae develop into adult worms over the course of a year, and reach sexual maturity in the afferent lymphatic vessels. After mating, the adult female worm can produce thousands of microfilariae that migrate into the bloodstream. A mosquito vector can bite the infected human host, ingest the microfilariae, and thus repeat the life cycle.

Epidemiology: W. bancrofti is responsible for 90% of lymphatic filariasis. Recently, 120 million worldwide cases of lymphatic filariasis were estimated. *W. bancrofti* largely affects areas across the broad equatorial belt (Africa, the Nile Delta, Turkey, India, the East Indies, Southeast Asia, Philippines, Oceanic Islands, and parts of South America.)

The mosquito vectors of W. bancrofti have a preference for human blood; humans are apparently the only animals naturally infected with. bancrofti. There is no reservoir host,and the disease could therefore potentially be eradicated.

Pathology: The pathogenesis of W. bancrofti infection is dependent on the immune system and inflammatory responses of the host. After infection, the worms will mature within 6–8 months, male and female worms will mate and then release the microfilariae. These microfilariae can be released for up to ten years.

The asymptomatic phase usually consists of high microfilaremia infection, and individuals show no symptoms of being infected. This occurs due to cytokine IL-4 suppressing the activity of TH1 cells in the immune system. This can occur for years until the inflammatory reaction rises again.

In the inflammatory (acute) phase, the antigens from the female adult worms elicit inflammatory responses. The worms in the lymph channels disrupt the flow of the lymph, causing lymphedema. The individual will exhibit fever, chills, skin infections, painful lymph nodes, and tender skin of the lymphedematous extremity. These symptoms often lessen after five to seven days. Other symptoms that may occur include orchitis, an inflammation of the testes, which is accompanied by painful, immediate enlargement and epididymitis (inflammation of the spermatic cord).

The obstructive (chronic) phase is marked by lymph varices, lymph scrotum, hydrocele, chyluria (lymph in urine), and elephantiasis. Microfilariae are not normally present in this phase. A key feature of this phase is scar formation from affected tissue areas. Other features include thickening of the skin and elephantiasis, which develops gradually with the attack of the lymphatic system. Elephantiasis affects men mainly in the legs, arms, and scrotum. In women, the legs, arms, and breasts are affected.

Diagnosis blood smear is a simple and fairly accurate diagnostic tool, provided the blood sample is taken during the period in the day when the juveniles are in the peripheral circulation.Technicians analyzing the blood smear must be able to distinguish between *W. bancrofti* and other parasites potentially present.

A polymerase chain reaction test can also be performed to detect a minute fraction, as little as 1 pg, of filarial DNA.Some infected people do not have microfilariae in their blood. As a result, tests aimed to detect antigens from adult worms can be used.Ultrasonography can also be used to detect the movements and noises caused by the movement of adult worms.Dead, calcified worms can be detected by X-ray examinations.

Treatment

The severe symptoms caused by the parasite can be avoided by cleansing the skin, surgery, or the use of anthelmintic drugs, such as diethylcarbamazine (DEC), ivermectin, oralbendazole. The drug of choice is DEC, which can eliminate the microfilariae from the blood and also kill the adult worms with a dosage of 6 mg/kg semiannually or annually.[13] A polytherapy treatment that includes ivermectin with DEC or albendazole is more effective than each drug alone.[14] Protection is similar to that of other mosquito-spread illnesses; one can use barriers both physical (a mosquito net), chemical (insect repellent), or mass chemotherapy as a method to control the spread of the disease.

Mass chemotherapy should cover the entire endemic area at the same time. This will significantly decrease the overall microfilarial titer in blood in mass, hence decreasing the transmission through mosquitoes during their subsequent bites.Antibiotic active against the Wolbachia symbionts of the worm have been experimented with as treatment] Wolbachia-free worms first become sterile, and later die prematurely.

Control

Prevention focuses on protecting against mosquito bites in endemic regions. Insect repellents and mosquito nets are useful to protect against mosquito bites. Public education efforts must also be made within the endemic areas of the world to successfully lower the prevalence of *W. bancrofti* infections.

Eradication

The WHO is coordinating an effort to eradicate filarisis. The mainstay of this programme is the mass use of antifilarial drugs on a regular basis for at least five years.In April 2011, Sri Lanka was certified by the WHO as having eradicated this disease.

2. SCHISTOSOMA HAEMATOBIUM

Geographical distribution

Schistosomiasis is a parasitic disease caused by flukes (trematodes) of the genus *Schistosoma.* After malaria and intestinal helminthiasis, schistosomiasis is the third most devastating tropical disease in the world, being a major source of morbidity and mortality for developing countries in Africa, South America, the Caribbean, the Middle East, and Asia.

More than 207 million people, 85% of who live in Africa, are infected with schistosomiasis, and an estimated 700 million people are at risk of infection in 76 countries where the disease is considered endemic, as their agricultural work, domestic chores, and recreational activities expose them to infested water. Globally, 200,000 deaths are attributed to schistosomiasis annually. Transmission is interrupted in some countries.

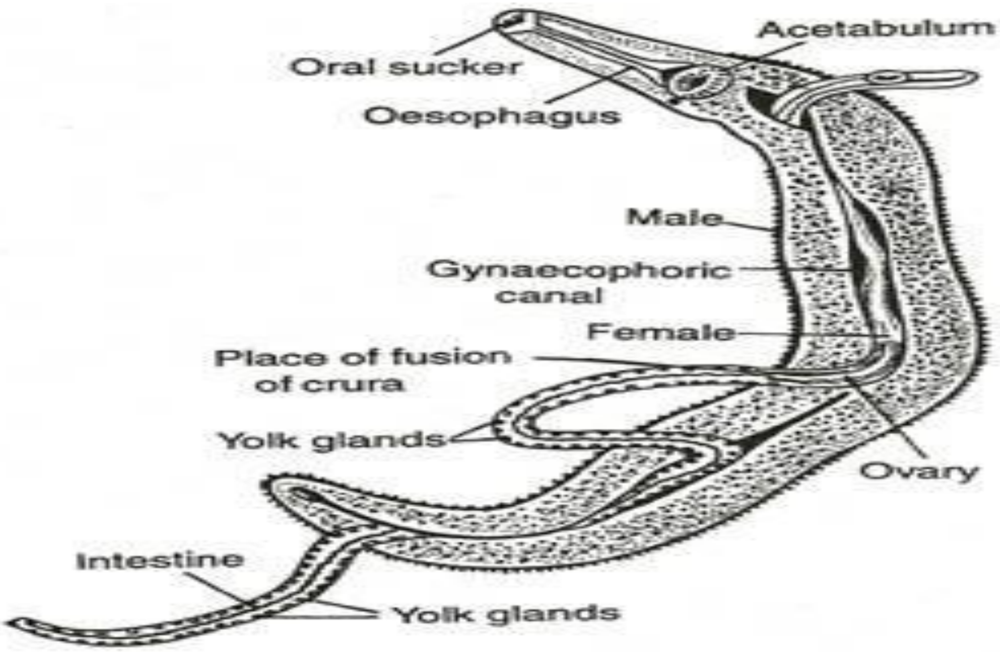


Fig. 191. *Schistosoma* (Male and female)

Life history:

Schistosoma haematobium is a digenetic parasite. Life cycle is completed in two hosts. The primary or definitive host is man, whereas the intermediate hosts are certain genera of snails (Bulinus and Planobarius). The adult worm lives in the blood vessels such as in the venous plexus of urinary bladder, prostrate gland and urinary tract. Nourishment is obtained from blood.

The sexes are separate with well recognizable sexual dimorphism. The males are smaller and broader, measuring 1 to 1.5 cm in length and 1 mm in breadth, while the females are larger and narrower, measuring 2 cm in length and 0.25 mm in breadth. The head of both male and female bears 2 suckers-oral and ventral.

In males the ventral sucker is large and powerful. Behind the ventral sucker, the body of the male rolled ventrally to form a groove called “gynecophonc canal”. During the process of copulation female enters into the gynecophoric canal of the male in such a way that the anterior and posterior end of the body of female projects out of the canal while the middle part remain enclosed. Female worm do not become sexually mature until they become associated with males. Occasionally, female remain permanently associated with her male partner.

Female, after copulation, become ready to lay eggs. She along with male, moves against the blood stream to enter the small venules of the portal system. Female lay eggs in sequence, one at a time like a chain of beads. After laying each egg, the worm retreats in the direction of the current so as the eggs get arrange linearly.

When a venule gets filled with eggs, the worm in coupla migrates to adjacent venule. The eggs now move through the vessels and enter in the cavity of the urinary bladder to escape with the urine during micturition. The eggs, less frequently, may enter into intestine and moves out of the host's body through faeces. Each egg measures about 150 pm in length and 50 um in diameter and bears terminal spine.

The embryonated eggs are passed with urine and less commonly with stool outside the body of the definitive host. If these eggs gain access to water, ciliated miracidium larva hatches out from each egg. The larvae move freely in water in search of intermediate host, which are snails. The snails acting as intermediate host belongs to the genus Bulinus and Planobarius. The miracidium enters into the snail's body by penetrating the soft tissues and ultimately reaches the liver. Inside the liver of the snail, the larva loses its cilia and within 4 to 8 weeks transform into the "sporocyst." The sporocyst multiplies to form a second generation of sporotocyst.

The daughter sporocyst gives rise to forked tail "cercaria larva" which are infective stage larvae. A single miracidium produces 100,000 to 250,000 cercana. The cercaria larva breaks off from the sporocyst and finally makes its way out of the snail body mo water. Cercariae freely swims into water for 48 hours and during this period if they come in contact with human beings taking bath or washing with infected water, penetrates the skin to enter into the body of the definitive host.

On entering the skin, the larvae cast off their tail and gain access to peripheral venules. At this stage they are called as "schistosomulae". Schistosomulae are carried to right heart from where they reach the lungs. From lungs the larvae comesleft hear, and then enters into, systemic circulation.

Now through mesenteric artery and the capillary bed of intestine, he larvae enters into the portal vein to be carried to liver. The larvae take 5 days to reach entering into host's body. In liver, the larvae mature into adult within 3 weeks from the time of initial infection.

The adult male and female worms move against the blood current to enter into the inferior mesenteric vein, rectal venous plexus, and pelvic veins and finally reach the vesica plexus of veins. The time taken to reach this stage is 1 to 3 months from the time of entering infective larvae. After attaining sexual maturity the worms copulate to repeat the life-cycle. The life span of adult worm in

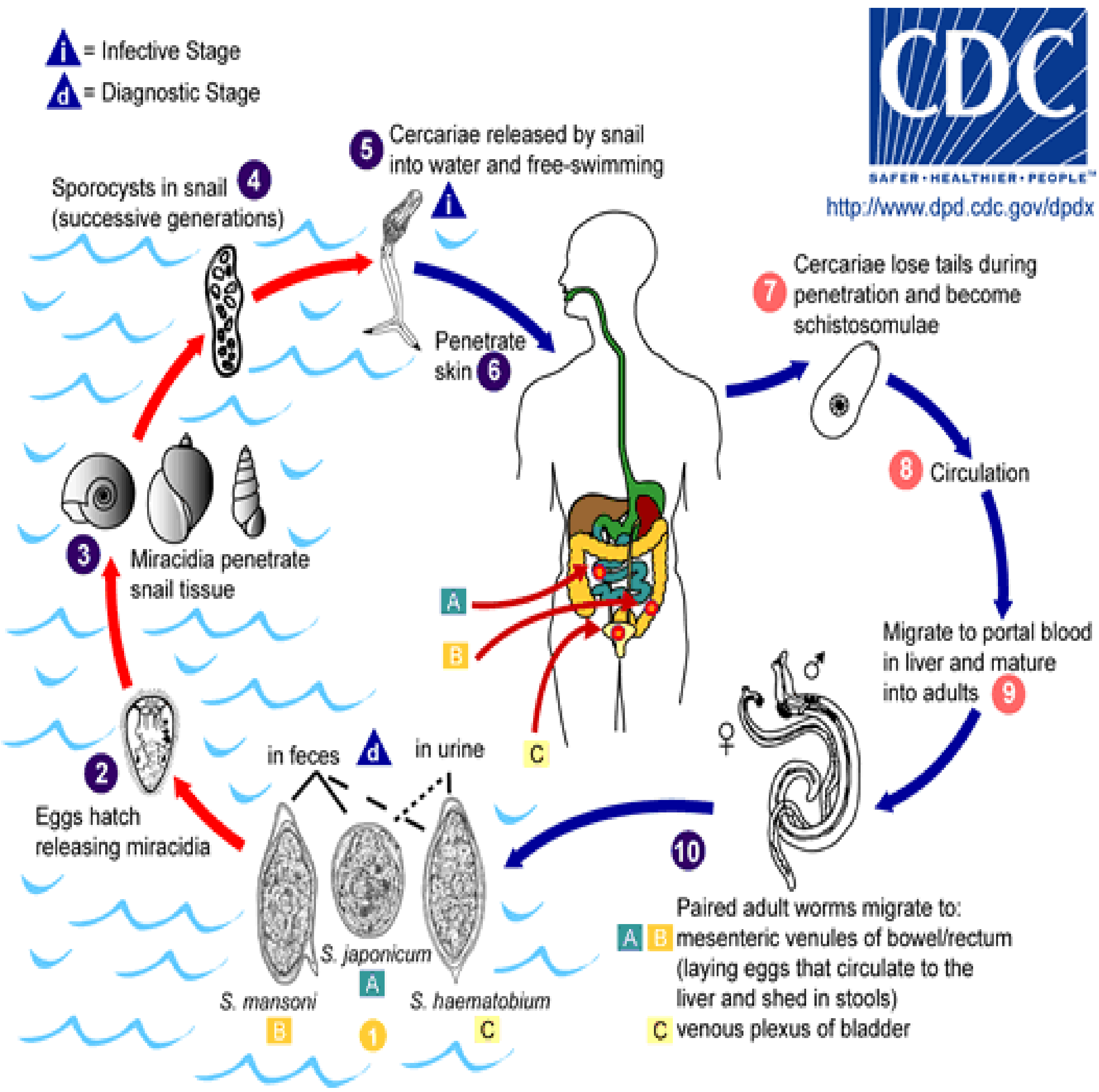
Mode of infection: Infection is acquired while a man is wading, bathing and washing in infected water carrying the cercariae of S. haematobium. The larva first stick to the surface of the hosts skin by their ventral sucker and as the water begins to evaporate penetrates the s in o reach the peripheral circulation.Rarely, the infection may occur due to drinking of infected water. The larvae in such cases penetrate the buccal mucosa to reach the blood circulation.

Pathology:

The disease caused by S. haematobium is known as schistosomiasis or bilharziasis, with following characteristics:

1. Toxin liberated by the worm produces symptoms like headache, anorexia, pain in back and extremities, fever with rigor and sweating.
2. The terminal-spinned eggs of S. haematobium may erode blood vessels and cause haemorrhoges.
3. The presence of eggs inside blood vessels causes irritational behaviour leading to abscess formation and fibrosis (pseudotubercle) around eggs producing inflammatory changes.

4.At the site of the entrance of cercariae into host body itching occurs's (swimmer's itch), a condition called as cercarial dermatitis.
5. Hepatitis, diarrhoea, anaemia, eosinophilia are the other symptoms associated with schistosomiasis.



Treatment:

The effective drugs are dehydroemetine, nilodin and hycanthone. The specific drugs for schistosomiasis are trivalent antimony compounds like fouadian, anthiomaline, tart emetic, antimony dimercaptosuccinate. Nindazole (Ambilhar) is also used.

Treatment of the patient

DOC – Praziquantel (40mg/kg for 1 day),
Alternative DOC – Metriphonate

Prophylaxis(prevention)

Eradication of intermediate molluscan hosts.
Prevention of environmental pollution with urine and faeces.
Avoid swimming, bathing and washing in infected water.
Effective sanitary and urinary disposal.
Prevention of water pollution by human urine and faeces.
Destruction of snails in endemic areas.

Prof. K. Sunitha

LESSON - 11
INSECTS AND DISEASES

INSECTS AND DISEASES

Sandfly-transmitted diseases, primarily leishmaniasis, are caused by protozoan parasites of the genus Leishmania spread by the bite of infected female phlebotomine sandflies. Leishmaniasis

TRANSMISSION

Leishmaniasis is a vector-borne disease transmitted by the bite of infected female phlebotomine sandflies.

Diseases Caused by Insects and Arachnids

Methods of Disease Transmission. There are many insects that are the primary or intermediate hosts or carriers of human diseases. Pathogens that are capable of being transmitted by insects include protozoa, bacteria, viruses, and such helminths as tapeworms, flukes, and roundworms. There are two methods of transmission of a pathogen by insects: mechanical and biological.

Malaria. The foremost disease carried by insects is malaria, involving a Plasmodium protozoan that is transmitted by mosquitoes of the genus Anopheles. Malaria is the most deadly Arthropod-borne disease in the world, affecting some 250 million people in the world, with as many as 2 million deaths annually. In the United States, a few cases of malaria occur each year, but only in individuals who have traveled in diseased areas of foreign countries.

Arboviruses. These diseases are caused by viruses that are biologically transmitted by the bite of mosquitoes. There are about 28 viruses of major public health importance that are transmitted by a variety of mosquitoes. Dengue and Yellow Fever are transmitted by mosquitoes in the genus Aedes. There are several kinds of Encephalitis, and these are transmitted by mosquitoes in the genera Aedes and Culex.

Plague. Fleas are the vector for the plague (or black death), which infects man as well as rats and other rodents. There are three forms of plague that occur in humans: bubonic, pneumonic, and septicemic. The bubonic type, in the form of the bacterium, Yersina pestis, is transmitted by fleas. The disease is passed as fleas regurgitate plague bacilli when biting, when flea feces are scratched into the skin, or when the host ingests an infected flea. The plague has killed millions of people in history, especially in the 14th and 17th centuries. In 14th century Europe, the great pandemic resulted in twenty-five million deaths. The plague is still a problem to society, with some 5,000 cases annually.

Enteric diseases. There are many bacterial diseases that are transmitted by some form of fecal contamination of food or water, either directly or indirectly. House flies are a primary agent in transmitting these diseases, and do so mechanically. Typhoid Fever (Salmonella typhi) is a well-known enteric disease, and affects humans worldwide. Cholera is another enteric disease of great importance. Shigella, causing dysentery and diarrhea, and Escherichia coli, causing urogenital and intestinal infections, are widespread enteric diseases.

Lyme disease. This disease is caused by an arachnid, the deer tick, which carries a bacterium called Borrelia bugdorferi. When a person or warm-blooded mammal is bitten, the bacterium enters the bloodstream, and Lyme disease may occur. The disease was first described in New England and the mid-Atlantic states, but is now known from all of the Northern Hemisphere.

Sleeping Sickness. This disease is also known as African Trypanosomiasis. The disease is transmitted by the Tsetse Fly, in the genus Glossina. The causative agent of African trypanosomiasis is Trypanosoma brucei (two forms). The disease is known to have a high mortality rate, not only among people, but among cattle, which was one of the reasons that parts of Africa could not be settled. Wholesale destruction of habitat and reservoir hosts has had some positive impact on the distribution of the disease.

American Trypanosomiasis. This disease is also known as Chagas' Disease. Trvpanosoma cruzi, a protozoan and causative agent of Chagas' Disease, invades the muscle cells of the digestive tract and heart, and sometimes also the skeletal muscle. There the protozoa multiply. Adult trypanosomes may circulate in the blood, but they do not invade blood cells the way malaria parasites do. Transmission of the protozoa is by Conenose Bugs, also known as Kissing Bugs, and is by the bug's feces, not the bite. Conenose Bugs feed at night on their sleeping victims.

Types

- Cutaneous Leishmaniasis (CL): The most common form, causing skin sores.
- Mucosal Leishmaniasis (ML): A severe type of CL that can cause sores in the nose, mouth, or throat.
- Visceral Leishmaniasis (VL): A less common form that affects internal organs, potentially leading to a life-threatening illness.

Geographical Distribution

Leishmaniasis occurs in parts of approximately 90 countries, usually in tropical or subtropical climates.

Prevention

- Use nets treated with insecticide or insect repellent while sleeping.
- Fine mesh sizes of 0.6 mm or less are needed for good protection against sandflies.
- Consider using nets over doors and windows or insect repellents.

Treatment:

- Pentavalent antimonial (SbV) compounds, such as sodium stibogluconate (Pentostam®) and meglumine antimoniate (Glucantime), are the traditional mainstays for treating leishmaniasis.

Other Sandfly-Borne Diseases

- Sandfly Fever: A febrile illness lasting 2-4 days, caused by phleboviruses.
- Carrion's Disease (Oroya Fever): A sandfly-transmitted biphasic illness caused by Bartonella bacilliformis bacteria.

Chandipura Virus

A deadly virus carried by sandflies, with outbreaks reported in India.

Many tickborne diseases can have similar signs and symptoms. If you get a tick bite and develop the symptoms below within a few weeks, see your healthcare provider.

The most common symptoms of tick-related illnesses include:

- **Fever/chills.** All tickborne diseases can cause fever.
- **Aches and pains.** Tickborne diseases can cause headache, fatigue, and muscle aches. People with Lyme disease may also have joint pain.
- **Rash.** Lyme disease, Southern tick-associated rash illness (STARI), Rocky Mountain spotted fever (RMSF), ehrlichiosis, and tularemia can cause distinctive rashes.

Your healthcare provider should evaluate the following before deciding on a plan for treatment:

Your symptoms

- The geographic region where you were bitten, and
- lab tests, depending on the symptoms and the geographic region where you were bitten.

Tick paralysis

Tick paralysis is thought to be caused by a toxin in the saliva of an attached tick. People with tick paralysis can experience weakness or paralysis that gradually moves up the body. These symptoms can sometimes resemble other neurologic conditions (for example, Guillain-Barré syndrome or botulism). Patients typically regain movement within 24 hours of removing the tick.

Types of Insects:

Insects transmit diseases in two main ways:

1. Mechanical Transmission: The insect carries the pathogen on its body (e.g., legs, mouthparts) and spreads it by direct contact. Example: Flies spreading bacteria from garbage to food.
2. Biological Transmission: The pathogen develops inside the insect before being transmitted to another host through a bite or saliva. Example: Mosquitoes transmitting malaria.

The six types of mouthparts are important in identifying and controlling insects.

1. Chewing
2. Piercing
3. Rasping
4. Siphoning
5. Sponging
6. Sucking

Chewing Insects
Parts of leaves are eaten away, beetles, cutworms, caterpillars, grasshoppers

Piercing Insects
Punctures plant and sucks the sap-Brown Stinkbug.

Rasping insect
Rasps or breaks surface and sucks sap
Example-Thrips

Siphoning insects
Have a coiled tube they dip into liquid food such as nectar and draw it in
Example-butterfly

Sponging Insects
Have two sponge-like structures that collect liquid food and move it into the food canal
Example-housefly.

Sucking Insects
Suck on underside of leaf (usually young) to collect nutrients
Example-Spider mites, Aphids, Squash Bug

1. **Insects as Disease Vectors in Humans and Animals:** Many insects serve as carriers (vectors) of harmful pathogens such as viruses, bacteria, and parasites. Some major examples include:

Mosquitoes: Transmit malaria (Plasmodium parasite), dengue fever, Zika virus, chikungunya, and West Nile virus.

Ticks: Carry Lyme disease (Borrelia bacteria) and Rocky Mountain spotted fever.

Fleas: Responsible for spreading plague (Yersinia pestis) and typhus.

Tsetse flies: Transmit African sleeping sickness (Trypanosoma parasite).

Sandflies: Spread leishmaniasis.

Triatomine bugs (kissing bugs): Carry Chagas disease.

2. Insects and Plant Diseases

Disease	Bestad	Wector	Pathogen
malaria	people	mosquitoes	protozoan
West Nile fever	people	mosquitoes, black flies	virus
yellow fever	people, monkeys, rodents	mosquitoes	virus
filariasis	people	mosquitoes	nematode
African meningitis	people	tze tze fly	protozoan
brain inflammation	people, horses, birds	mosquitoes	virus
tularemia	people, rodents, birds	fleas, louses	bacteria
spotted typhus	people	clothes louses	Rickettsia
pestilence	people, rodents	fleas	bacteria
dysentery	people	flies	amoeba, bacteria
typhoid	people	flies	bacteria
myxomatosis	rabbits	horseflies, mosquitoes	virus
anthrax	people, animals	horseflies	bacteria

Insects can also transmit diseases to plants, leading to significant agricultural losses. Examples include:

Aphids: Spread plant viruses such as the potato virus and cucumber mosaic virus.
Aphids are small sap-sucking insects and members of the superfamily Aphidoidea. Common names include greenfly and blackfly, although individuals within a species can vary widely in color. The group includes the fluffy white woolly aphids.

Whiteflies: Carry tomato yellow leaf curl virus.

Beetles: Some species, like the cucumber beetle, transmit bacterial wilt.
Leafhoppers: Spread diseases such as the maize streak virus'

Prevention and Control

To prevent insect-borne diseases, various strategies are used:

1. Human Disease Prevention

Use mosquito nets and repellents.
Vaccination for diseases like Yellow Fever.
Eliminate standing water to prevent mosquito breeding.

2. Plant Disease Prevention

Use pesticides and natural predators like ladybugs.
Rotate crops to break insect life cycles.
Grow resistant plant varieties.

Insect-borne diseases

Insect-borne diseases are viral and bacterial illnesses from insect (bug) bites. The most common insects that pass on disease are mosquitoes, sand flies, ticks, and fleas. For example, mosquitoes are known for spreading the Zika virus, Yellow Fever, and Malaria. Ticks are known to spread Lyme disease and Rocky Mountain spotted fever.

Symptoms of insect-borne diseases Symptoms will vary depending upon the type of insect that bit you. Common symptoms of insect-borne diseases can include:

- Fever
- Chills
- Headache
- Sore muscles
- Skin rash
- Nausea
- Stomach pain

More serious symptoms can include:

- Difficulty breathing
- The feeling that your throat is closing
- Swelling of your lips, tongue, or face
- Chest pain
- A racing heartbeat that lasts more than a few minutes
- Dizziness
- Vomiting

Causes Insect-Borne Diseases

The diseases are caused by blood-sucking insects that infect humans when they bite. You increase your risk of being infected by an insect when you are in areas where they gather. This would include tall grass, bushes, spots near still water (ponds), sand, forests, and places around the globe with heavy outbreaks

Insect-borne diseases diagnosed

Your doctor can typically diagnose an insect-borne disease with a physical exam, a review of your symptoms, and a look at your recent travel. Lab tests (blood and urine) can help diagnose certain insect-borne diseases.

Can insect-borne diseases be prevented or avoided?
There are many actions you can take to reduce the threat of being infected by an insect. You should:

- Stay out of tall grass and bushes.
- Wear long pants, long sleeves, and a hat if you must be in tall grass and bushes. Tuck your pants into long, white socks.
- Wear light-colored clothing. This makes it easier to spot insects.
- Wear insect-repellant clothing.
- Use bug spray that contains the ingredient DEET. Read the product's label to see how much you should use.
- Examine your skin and scalp when you get back to check for bugs or bites. Always shower with plenty of soap after being in the outdoors.
- To discourage mosquitoes from living around your home, drain or change standing water on your property. For example, make sure your rain gutters are clear. Also change the water in a bird bath every four or five days.
- Pay attention to outbreaks through the travel health notices posted by the Centers for Disease Control and Prevention (CDC). If you can, avoid travel to those places during outbreaks.

Insect-borne diseases treatment

As soon as you recognize a bite, clean it with soap and water. Pat it dry and apply rubbing alcohol.

If you were bitten by a tick, remove the tick right away before cleaning the area. Use tweezers to slowly pull it off your skin. Be careful not to leave any part of the tick on your skin. Dispose of the tick. Wash your hands and the bite area with soap and water and wipe with alcohol. Apply an over-the-counter antibiotic cream to the bite area.

If you have any of the symptoms listed, see your doctor. Your doctor may give you a prescription for antibiotic medicine. Take the entire prescription. Your doctor may suggest other treatments to ease the symptoms. For example, over-the-counter pain medicine can relieve sore muscles and a fever.

Living with insect-borne diseases

Some insect-borne diseases cause long-term symptoms that affect your quality of life. Lyme disease, for example, can leave you with sore muscles and fatigue. Zika virus can be passed on to a baby and cause microcephaly (a condition that causes the head to be abnormally small) and intellectual disability.

How ticks find their hosts

Ticks find their hosts by detecting animals´ breath and body odors, or by sensing body heat, moisture, and vibrations. Some species can even recognize a shadow. In addition, ticks pick a place to wait by identifying well-used paths. Then they wait for a host, resting on the tips of grasses and shrubs. Ticks can't fly or jump, but many tick species wait in a position known as "questing".

While questing, ticks hold onto leaves and grass by their third and fourth pair of legs. They hold the first pair of legs outstretched, waiting to climb on to the host. When a host brushes the spot where a tick is waiting, it quickly climbs aboard. Some ticks will attach quickly and others will wander, looking for places like the ear, or other areas where the skin is thinner.

How ticks spread disease

Ticks transmit pathogens that cause disease through the process of feeding.

- Depending on the tick species and its stage of life, preparing to feed can take from 10 minutes to 2 hours. When the tick finds a feeding spot, it grasps the skin and cuts into the surface.
- The tick then inserts its feeding tube. Many species also secrete a cement-like substance that keeps them firmly attached during the meal. The feeding tube can have barbs which help keep the tick in place.
- Ticks also can secrete small amounts of saliva with anesthetic properties so that the animal or person can't feel that the tick has attached itself. If the tick is in a sheltered spot, it can go unnoticed.

- Ticks suck blood anywhere from minutes to days, depending on the tick species. If the host animal has a bloodborne infection, the tick will ingest the pathogens with the blood.
- Small amounts of saliva from the tick may also enter the skin of the host animal during the feeding process. If the tick contains a pathogen, the organism may be transmitted to the host animal in this way.
- After feeding, most ticks will drop off and prepare for the next life stage. At its next feeding, it can then transmit an acquired disease to the new host.

Fleas are tiny insects that are found in the environment, such as in grass, fields, and wooded areas but can even be in the crevices within your home. Fleas survive by taking blood meals from susceptible animals, such as dogs or cats. One flea can lay as many as fifty eggs per day so it's easy to see how they can quickly become a serious concern.

Fleas transmit a surprising number of diseases to animals and humans through their bites or when they are ingested (such as when self-grooming).
Let's look at four types of diseases that can be spread by fleas.

1. Typhus

According to the Texas Department of State Health Services, humans usually get typhus from flea bites. Two types of fleas —the Oriental rat flea and the cat flea—become carriers of the disease after biting rats, cats, or opossums.

When the fleas bite, they usually defecate at the same time. A type of bacteria found in the feces, Rickettsia typhi, enters the body through the bite wound or from a person scratching the bite area and causes typhus.

Symptoms of typhus include:

- Headache
- Fever
- Nausea
- Body aches
- Reduced appetite
- Coughing
- Vomiting

Five or six days after the initial symptoms, a rash may appear on the trunk of the body and spreads to a person's arms and legs. The disease can be treated with antibiotics, but if treatment is delayed, hospitalization may be needed. If left untreated, typhus may linger for several months.

2. Mycoplasma haemofelis

Mycoplasma haemofelis (*M. haemofelis*) is a parasitic bacterial disease that is transmitted to cats through tick, mosquito, and flea bites. An infection of the red blood cells, M. haemofelis can cause fever and anemia in cats.
There is also some evidence that *M. haemofelis* can infect humans, especially those with compromised immune systems. Because fleas get their meals from a variety of hosts, an infected flea can transmit the parasite to both you and your pet.
M. haemofelis attaches to and destroys red blood cells. This destruction of large numbers of red blood cells leads to anemia in both cats and people.
Veterinarians often prescribe antibiotics, such as doxycycline, to treat pets with Mycoplasma haemofelis. In severe cases, cats may need a blood transfusion.

3. Tapeworms

Tapeworms are harmful parasites that make themselves at home in the intestines of dogs, cats, and humans. Pets can get tapeworms by swallowing infected adult fleas, which can occur when they groom themselves or other animals.

Cats can also get the disease by eating infected rodents. Adults and more commonly, children, may get infected by accidentally swallowing an infected flea, which they can encounter while spending time outdoors, according to the Centers for Disease Control and Prevention (CDC).

Children and pets pass segments of tapeworms, known as proglottids, during bowel movements.

Cats with tapeworms are given a drug called praziquantel orally or by injection. The medication causes the tapeworm to dissolve within the intestines.

4. Cat Scratch Disease

Bartonella henselae (*B. henselae*)—the bacteria that causes cat scratch disease and is spread through flea bites—is common in felines. The CDC reports about 40% of cats, especially kittens, will encounter this disease at some point in their lives.

Most cats who contract this disease do not become sick. Their immune systems are able to control the infection. If they do show symptoms, it is usually a fever that lasts a couple days and resolves.

However, immunocompromised cats, such as those undergoing chemotherapy or who have underlying FeLV/FIV, may develop more serious symptoms, which can include the following:

- Vomiting
- Lethargy
- Red eyes
- Swollen lymph nodes
- Decreased appetite

Even if a cat isn't showing symptoms and seems healthy, they can still make you sick. Cats pass this disease on to humans by biting or scratching a person hard enough to break the skin, or by licking on or near wounds or scabs.
According to the CDC, cat scratch disease can affect the human brain, eyes, heart, or other internal organs—though these rare complications are more likely to occur in children under the age of five and in people with compromised or weakened immune systems.

How To Rid Your House of Fleas

Fleas are difficult to get rid of once they make their way into your home.
They can gain access to your home by attaching to your clothing or hopping in through windows or open doors. They find tiny cracks and crevices to live in while feeding on vulnerable pets or people.

The most important way to keep fleas out of the house is to protect your pets with preventatives. Pet parents should use a flea preventative year-round, even in indoor only cats.
A few products that are effective include Bravecto® and NexGard®. Your veterinarian can recommend the best product to meet your pet's individual needs.

All cats and dogs in the household should be on preventatives.

Tsetse flies transmit the parasitic disease Trypanosoma brucei, causing human African trypanosomiasis, also known as sleeping sickness, which is a life-threatening disease in sub-Saharan Africa.

Here's a more detailed explanation:

- **Disease:** Human African trypanosomiasis (HAT), or sleeping sickness, is a parasitic disease caused by the protozoa Trypanosoma brucei.
- **Transmission:** It's transmitted by the bite of infected tsetse flies (Genus Glossina).
- **Geographic Location:** Sleeping sickness is primarily found in sub-Saharan Africa.
- **Symptoms:** Initial symptoms include fever, headaches, tiredness, and inflammation of the lymph nodes.
- **Progression:** If left untreated, the parasite can invade the central nervous system, leading to severe neurological problems and potentially death.
- **Two Forms:** There are two main forms of HAT: Trypanosoma brucei gambiense (West African form) and Trypanosoma brucei rhodesiense (East African form).
- **Treatment:** Early diagnosis and treatment are crucial for survival, with various drugs used depending on the stage and form of the disease.
- **Control:** Control measures include early detection and treatment, as well as vector control (reducing tsetse fly populations).

Other diseases: Tsetse flies also transmit Trypanosoma brucei to animals, causing animal African trypanosomiasis (AAT), also known as nagana.

Triatomine bugs, also known as "kissing bugs," are the primary vectors of the parasite Trypanosoma cruzi, which causes Chagas disease. Infected triatomine bugs transmit the parasite to humans when they defecate near the bite site, and the parasite enters the body through a wound or the eyes, mouth, or mucous membranes.
Here's a more detailed explanation:

Triatomine Bugs and Chagas Disease:

Chagas disease, or American trypanosomiasis, is a parasitic disease primarily transmitted by triatomine bugs.

Transmission

When a triatomine bug feeds on an infected person or animal, it can become infected with the T. cruzi parasite. After feeding, the bug may defecate near the bite site, and the parasite, if scratched into the wound or if the bite site is near the eyes, mouth, or other mucous membranes, can enter the human body.

Life Cycle of T. cruzi

The parasite replicates in the host and can cause a range of symptoms from mild, flu-like symptoms to severe complications like heart and digestive problems if left untreated.

Prevention:

Preventing Chagas disease involves minimizing contact with triatomine bugs, especially in endemic areas.

Treatment:
Chagas disease can be treated with antiparasitic medications if diagnosed early, but there is no cure for the chronic phase.

Aphids can cause plant diseases by transmitting viruses and sucking sap, leading to symptoms like stunted growth, yellowing, and curling of leaves, and in some cases, plant death.
Here's a more detailed explanation:

How Aphids Cause Plant Damage:

- **Sap Sucking:**
  Aphids feed on the sap of plants, which can weaken the plant and cause stunted growth, yellowing, and curling of leaves.

- **Virus Transmission:**
  Aphids are known to transmit plant viruses from one plant to another.

- **Honeydew and Sooty Mold:**
  Aphids secrete a sugary substance called honeydew, which can attract ants and promote the growth of sooty mold, further damaging the plant.

- **Specific Diseases Transmitted:**
- **Potato Virus Y (PVY):** Transmitted by aphids, causing mosaic and mottling patterns on leaves, leaf drop-off, and tuber malformations.
- **Bean Common Mosaic Virus (BCMV):** Transmitted by aphids, causing mosaic and mottling patterns on leaves, stunted growth, and reduced pod size.

- **Barley Yellow Dwarf Virus (BYDV):** Transmitted by aphids, causing yellowing and reddening of leaves, stunted growth, reduced grain quality, and increased susceptibility to other stresses.

- **Other Viruses:** Aphids are known to transmit a wide variety of plant viruses, including beet mosaic, cabbage black ringspot, carnation latent, cauliflower mosaic, cherry ringspot, cucumber mosaic, onion yellow dwarf, pea wilt, tobacco etch, tobacco mosaic, tomato spotted wilt, and turnip yellow mosaic.

Identifying Aphid Infestations:

Aphid Colonies:
Look for small, soft-bodied insects, often in clusters, on the undersides of leaves, new shoots, and flower buds.

Symptoms of Damage

- Stunted growth
- Yellowing or curling leaves
- Mottled or distorted leaves
- Presence of honeydew and sooty mold
- Wilting or death of plant in severe cases

Specific Aphid Types

- **Green Peach Aphid:** Slender, dark green to yellow, and has no waxy bloom.
- **Melon Aphid:** Variable in color but often light green mottled with dark green, able to tolerate hot weather.
- **Potato Aphid:** Larger aphid, can distort leaves and stems, stunt plants, and cause necrotic spots on leaves.

Managing Aphids and Plant Diseases:

- **Early Detection:** Regularly inspect plants for aphids and signs of damage.
- **Physical Removal:** Remove aphids by hand, hosing them off with water, or using sticky traps.
- **Encourage Natural Predators:** Introduce or encourage beneficial insects like ladybugs and lacewings, which prey on aphids.
- **Horticultural Soaps and Insecticides:** Use horticultural soaps or insecticides to control aphid populations, but be mindful of their impact on beneficial insects.
- **Promote Healthy Plants:** Ensure plants have proper nutrition, water, and sunlight to help them resist pests and diseases.
- **Remove Ants:** Ants often protect aphids, so remove them by using sticky barriers around the trunk.
- **Prevent Over-Fertilization:** Avoid overusing nitrogen fertilizer, which can attract aphids.

Whitefly disease refers to the damage and diseases caused by whiteflies, small, sap-sucking insects that can transmit plant viruses. They are a significant agricultural pest, especially in tropical and subtropical regions, and can cause significant economic losses. Whiteflies not only damage plants directly by feeding on their sap but also transmit various plant viruses, leading to further plant stress and disease.

Damage and Symptoms:

Direct Feeding Damage:

Whiteflies feed on the plant sap, causing yellowing of leaves, stunting of growth, and premature leaf drop.

Honeydew Excretion:

They excrete a sticky substance called honeydew, which can promote the growth of sooty mold on the leaves and stems, further impacting plant health.

Transmission of Viruses

Whiteflies transmit plant viruses, leading to various diseases like leaf curl, mosaic, and crumple diseases, affecting crops like cotton, tomato, cassava, and beans.

Whitefly-Transmitted Viruses and Their Effects:

Begomoviruses:

A large group of viruses transmitted by whiteflies, causing diseases like cotton leaf curl, tomato yellow leaf curl, and cassava mosaic disease.

Other Viruses:

Whiteflies also transmit other viruses, including criniviruses, ipomoviruses, torradoviruses, and some carlaviruses.

Management Strategies

Cultural Practices:

Pruning affected plants and removing weeds can help reduce whitefly populations.

Biological Control:

Using natural predators like lacewing larvae, predaceous mites, and parasitic wasps can help control whitefly populations.

Chemical Control:

Insecticides can be used to control whitefly populations, but it's crucial to use them judiciously and consider the potential impact on beneficial insects and pollinators.

Host Resistance:

Developing and using crop varieties resistant to whiteflies and the diseases they transmit can be an effective long-term solution.

Prof. K. Sunitha

LESSON - 12

ECONOMIC IMPORTANCE OF INSECTS

The estimated annual value of the ecological services provided by insects in the United States alone is at least $57 billion, an amount that justifies greater investment in the conservation of these services. Without the activities of insects, human life on earth would eventually be extinguished. Over one lakh currently living species of insects have been identified, but the true number is surely much.

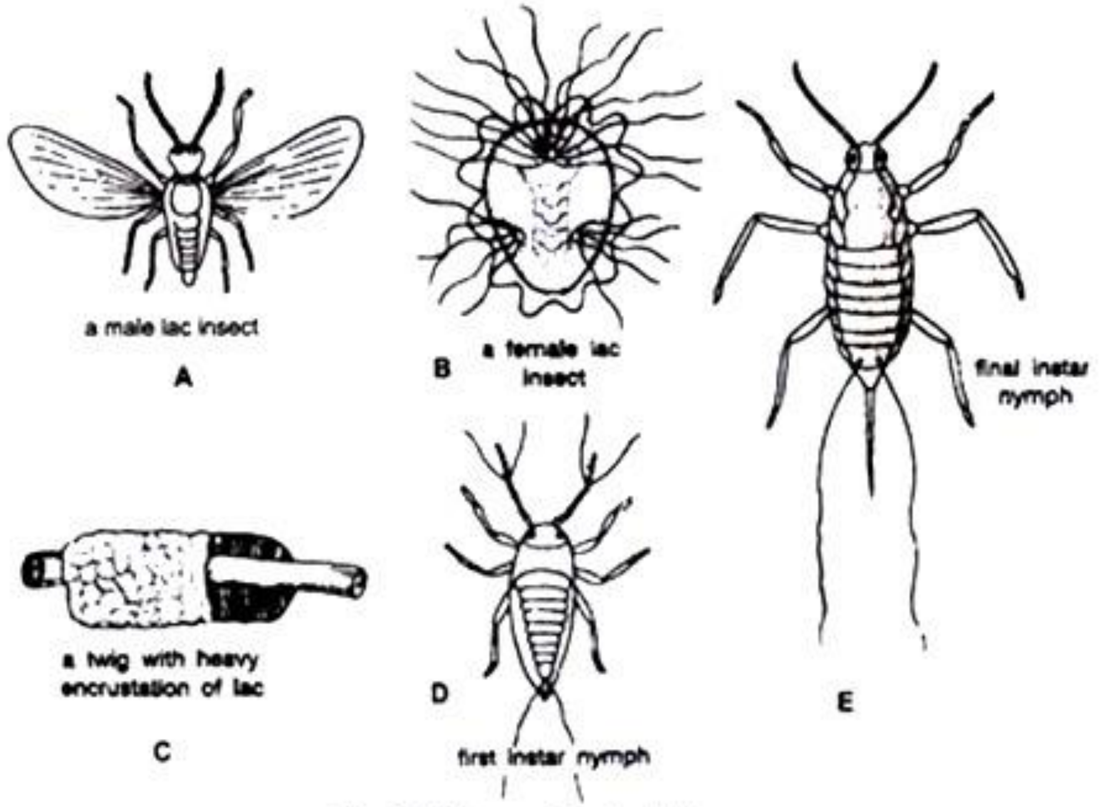


Fig. Life history of Tachardia lacca.

BENEFICIAL INSECTS

Pollinators of crops (Bees, wasps, butterflies, moths, hoverflies, beetles) Many plants depend on insects to transfer pollen as they forage. Plants attract insects in various ways, by offering pollen or nectar meals and by guiding them to the flower using scent and visual cues. This has resulted in strong relationships between plants and insects. Value of crop production from pollination by native insects is estimated to be about $3 billion in US alone. When we talk about pollinators the ones that come to mind are honey bees and butterflies, but there are also many other insects that perform this job for flowering plants, as well. There are flies, wasps, beetles and even some other insects that most people know nothing about, such as Hemiptera and thrips.

There are many important pollinating insect species in the orders: Hymenoptera (bees, wasps, and ants), Lepidoptera (butterflies and moths), Diptera (flies) and Coleoptera (beetles). As adults these insects feed on pollen and nectar from flowers. They forage from plant to plant and may initiate pollination by transferring pollen from an anther to a stigma. Female bees and pollen wasps provision their nests with pollen and nectar that they actively collect onto their bodies. Their larvae then feed on the collected pollen and nectar. Yucca moth larvae do not feed on pollen or nectar but on the seeds of yucca plants. The adults pollinate the yucca plant by actively collecting pollen onto their palps and then placing the collected pollen on a receptive stigma to ensure proper seed set for their offspring. Economic value of insect pollination worldwide is estimated at U.S. $217 billion (Science Daily, Sept. 15, 2008). German scientist found that the worldwide economic value of the pollination service provided by insect pollinators, bees mainly was dollar153 billion in 2005 for the main crops that feed the world. This figure amounted to 9.5% of the total value of the world agricultural food production. The study also determined that pollinator disappearance would translate into a consumer loss of food estimated between dollar 190 to 310 billion.

Predators of pests (Dragonflies, beetles, bugs, lacewings, wasps) The arthropods predator of insects and mites include beetles, true bugs, lacewings, flies, midges, spiders, wasps, and predatory mites. Insect predators can be found throughout plants, including the parts below ground, as well as in nearby shrubs and trees. Some predators are specialized in their choice of prey, others are generalists. Some are extremely useful natural enemies of insect pests. Unfortunately, some prey on other beneficial insects as well as pests.

Major characteristics of arthropod predators

- Adults and immature stages are often generalists rather than specialists.
- They generally are larger than their prey.
- They kill or consume many preys.
- Males, females, immature stages and adults may be predatory.
- They attack immature and adult prey.

Important insect predators include lady beetles, ground beetles, rove beetles, flower bugs and other predatory true bugs, lacewings and hover flies. Spiders and some families of mites are also predators of insects and mite pests. Natural enemies play an important role in limiting potential pest populations.

Parasites of pests (Hymenoptera and Diptera) Parasitoids are insects with an immature stage that develops on or in an insect host, and ultimately kills the host. Adults are typically free-living, and may be predators. They may also feed on other resources, such as honeydew, plant nectar or pollen. Because parasitoids must be adapted to the life cycle, physiology and defenses of their hosts, many are limited to one or a few closely related host species. Crop losses averted by beneficial insects from predators or parasites of agricultural pests are estimated to be $4.5 billion. The most valuable insect parasites belong to the following groups:

- Tachinid Flies (Diptera)
- Ichneumonid Wasps (Hymenoptera)

These parasites live in or on one host insect pest which is killed after the parasite completes its development. Parasite (also called parasitoid) adults are free-living; the immature stage lives on or inside a host and kills the host before the host completes its development. Parasites lay one or more eggs on the outside of the host body or they insert the eggs inside their host. The immature parasite feeds on the host and requires only a single individual prey to complete its development. Free-living adults may feed on nectar from flowering plants or obtain nutrients by piercing the body of host insects and withdrawing fluids (host-feeding). Parasites are often considered more effective natural enemies than predators because many have a narrower host range, require only one host to complete development, have an excellent ability to locate and kill their host and can respond rapidly to increases in host populations.

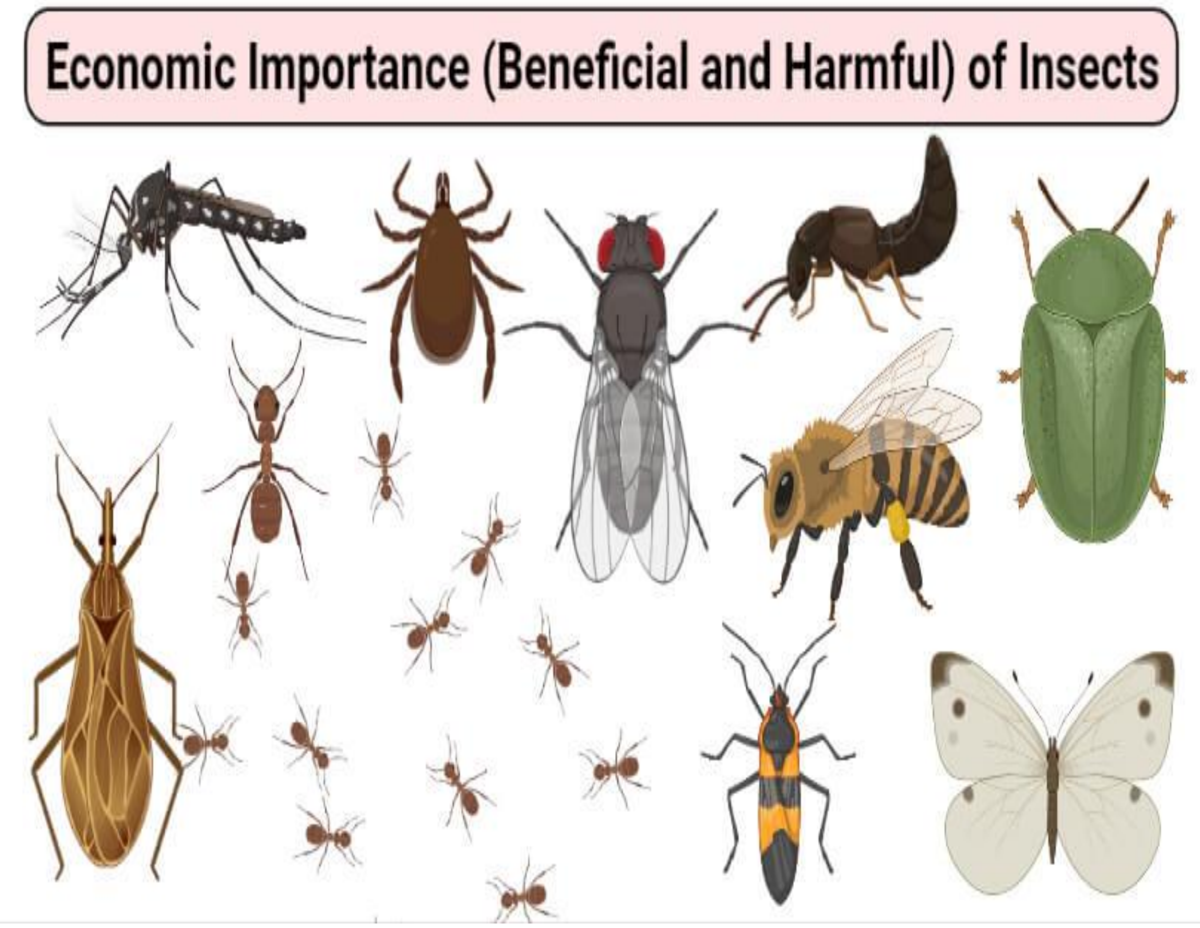
Productive insects (Silkworm, Honey bees, Lac insects) Sericulture is an agro-based industry. It involves rearing of silkworms for the production of raw silk, which is the yarn obtained out of cocoons spun by certain species of insects. The major activities of sericulture comprises of food-plant cultivation to feed the silkworms which spin silk cocoons and reeling the cocoons for unwinding the silk filament for value added benefits such as processing and weaving. Five varieties of silk worms are reared in India for producing this natural fibre. Bombyx mori, the silk worm, feeds on the leaves of mulbery to produce the best quality of fibre among the different varieties of silk produced in the country. Of the total production of 2,969 tonnes of silk in India, as much as 2,445 tonnes is produced by the mulberry silkworms, Bombyx mori. Lac Insect any of the species of Metatachardia, Laccifer, Tachordiella,Austrotacharidia, Afrotachardina, and Tachardina of the superfamlyCoccoidea, order Homoptera that are noted for resinous exudation from the bodies of females. Members of two of the families viz. Lacciferidae and Tachardinidae appear to be more concerned with lac secretion. There are several lac insects, some of which secrete highly pigmented wax. The Indian lac insect Lacciferlacca is important commercially. It is found in tropical or subtropical regions on banyan and other plants. The females are globular in form and live on twigs in cells of resin created by exudations of lac. Of the many species of lac insect,Lacciferlacca, (Tachardialacca) is the commercially cultured lac insect. It is mainly cultured in India and Bangladesh on the host plant, Zizyphusmauritianaand Z. jujuba. The insect starts its life as a larva or nymph which is about 0.6 mm long and 0.25 mm wide across the thorax. The young settles down on a suitable place of the host plant gregariously. On the average some 150 of such larvae may be present per square inch of the twig. Apiculture or beekeeping is the maintenance of honey bee colonies, commonly in hives by a beekeeper in apiary in order to collect honey and beeswax, and for the purpose of pollinating crops.

The genus Apis is comprised of a comparatively small number of species including the western honeybee Apis mellifera, the eastern honeybee Apis cerana, the giant bee Apis dorsata, and the small honeybee Apis florea.. Nectar is a sugar solution produced by flowers containing about 80% water and 20% sugars. Foraging bees store the nectar in the honey sacwhere the enzyme invertase will change complex sugars into simple sugars called mono-saccharides. Upon return to the hive, the foraging bee will disgorge the partially converted nectar solution and offer it to other bees. Housekeeping bees will complete the enzymatic conversion, further removing water until the honey solution contains between 14 – 20% water.

Essential Insects Examples

1. **Butterflies** – Pollinators of flowering and citrus plants, garden-friendly, and a good indicator of a healthy environment.
2. **Dragonflies** – Natural pest controller of the environment and great indicator of clean aquatic systems.
3. **Grasshoppers** – Rich in protein, hence used as a nutrient source by humans and as prey by birds.
4. **Ants** – Soil aerators, and scavengers feeding on dead organic matter, hence helping in the recycling of nutrients.

Honeybees – Great cross-pollinators, wild honey is widely commercialized as a nutrient-rich food source.



Economic Importance of Insects

They seemed to be of high importance to nature as well as to mankind. Hence, they and their products are commercially advertised for various purposes. For example, honey and honey wax from honeybees (Apis species) is cultured by humans, silk from silkworms is widely used to design and make beautiful clothes, good for maintaining body temperature and also good for skin, and many more uses.

Insects in the Food Industry

- These edible insects are safe for human consumption.
- They are **rich in nutrients like protein, minerals, dietary fibers**, riboflavin, and vitamins, serving as delicacies in some countries.
- To increase the interest of consumers in markets, food industries have processed insects into food products such as flour, fitness bars, pasta, and snacks.
- Some insects that are mass-produced for human consumption include crickets, locusts, houseflies, mealworms, ants, mantis, and many more.

Insects in the Pharmaceutical Industry

- **Antimicrobial peptides (AMP)** like alloferons, defensin, etc are obtained from insects like ants and wasps which help in fighting against bacterial, fungal, and viral infections.
- Insects like mealworms (*Tenebrio molitor*), leafworms (*Spodoptera littoralis*), silkworms (*Bombyx mori*), etc, have been observed to have **"angiotensin-converting enzyme (ACE) inhibitors"** which are used in drugs for treating high blood pressure.
- Silkworm cocoon formation **proteins fibroin and sericin** aid in lowering obesity by increasing fat metabolism, and also help in stimulating wound healing.
- Insects produce **antioxidant enzymes** catalase (CAT), Peroxiredoxin (Prx), superoxide dismutase, etc, which are used in improving metabolism, and in food storage.
- **Chitin and chitosan** from insects are rich in dietary fibre, used in baked goods, and also as flavours, and colouring agents.
- **Apitoxin and melittin** from honeybees are seen to relieve pain, and swelling associated with multiple sclerosis, rheumatoid arthritis, and more. **'ApitoxR'**, a drug that has been approved by FDA for use in relieving pain due to inflammation.
- **Cantharidin** is a fatty acid extracted from beetles and is used as the treatment for cutaneous warts, and as the tumour-fighting substance that attacks infected cells.
- And so many more substances extracted from insects have been benefitting mankind.

Insects in the Cosmetics

- **Carmine dye** – It is a red-colored dye used in cosmetics and is obtained from the female insect *Dactylopius coccus,* native species of Mexico and South America.
- **Shellac** is a resin obtained from lac insects, Lacciferlacca, and is widely used in nail polish remover, mascara, hair spray, eyeliner, etc. They are found in the forest of Thailand and India.
- **Essential oils** extracted from locusts, crickets, and spider flies have been shown to be safe for facial usage. A cosmetic product named 'Point68' contains insect oil which improves skin hydration, cellular healing, and rejuvenation.
- **Beeswax and honey** have been used for centuries as cosmetics that soften, moisturize, and heal skin tissue. They are used in products like face wash, face scrub, lip balms, hair conditioners, and many more.
- **Sericin** extracted from silkworms is used in creams and shampoos. They improve skin hydration and elasticity, leading to anti-wrinkle and anti-aging effects.

Insects in the Agriculture

18% of the world's agricultural production is damaged by herbivorous insects like aphids. And farmers heavily rely on insect pollinators for the pollination of crops. Around 72% of the world's crops depend on pollinator insects. So the two most important roles insects play in the enhanced quality and production of crops include pest control and pollination.

Pest control insects include ladybird beetles, lacewings, syrphid flies, and many more. They are economically important for crop production as they help control the pest population and keep the crops safe from their attack.

Pollinator insects including bees, wasps, butterflies, moths, etc, ingest nectars from many flowers and hence pollinate the plants in return, aiding in the fertilization of plants.

SUMMARY

In this unit we have studied about the life cycle and biology of trypanosomagambiense, leishmaniadonovani,wuchereriabrancrofti, schistosomiahaematobium and also studided about their prevention and treatment. Students will understand the diseases caused by harmfulinsects and economic imporanceof beneficial insects.

KEY WORDS

Insect-borne diseases: They are viral and bacterial illnesses from insect (bug) bites.
Predator: An animal that kills and eats other animal.
Pollinator:A pollinator is anything that helps carry pollen from the male part of the flower (stamen) to the female part of the same or another flower (stigma)

QUESTION AND ANSWER

1. Explain any one of life cycle of parasites?
2. Explain the economic importance of insects?
3. Write about the insects and their diseases?
4. Explain the life cycle of trypanosoma gambiense and their prevention &treatment

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Prof. K. Sunitha

LESSON - 13

GENERAL CHARACTERISTICS OF VERTEBRATES

characteristics are: 1. Habitat 2. Numerical, Strength 3. Shape 4. Size 5. Symmetry6. Grades of Organization 7.Germ Layers 8.Integument 9. Movement 10. Segmentation and Others.

Habitat: All the 30 phyla most probably originated in the sea, but not all have successfully invaded the land or its freshwater habitats. About 80 per cent are found in the terrestrial habitats.

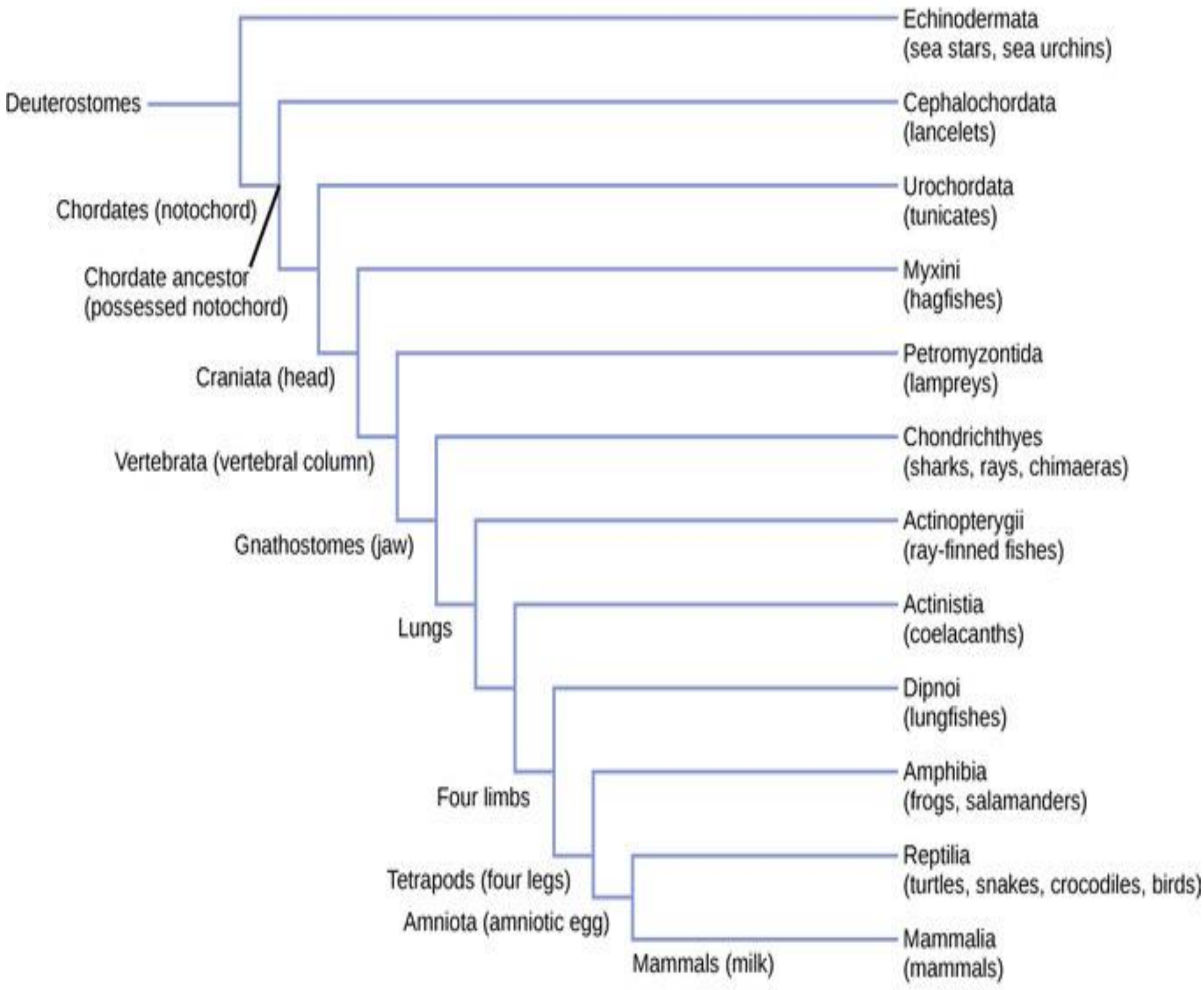
Numerical Strength: At present nearly one million living species of animals are known, out of which about 95 percent are the invertebrates. It has been estimated that the number of extinct species is around seven times more then number of living species

Shape: Animals of varied shapes are included amongst the invertebrates. Amoeba possesses an irregular ever-changing body shape, sponges and coelenterates display plant-like appearance, flatworms are leaf-like and ribbon-shaped and annelids,nemertean's and nematodes are vermiform, while the starfishes are star-shaped, etc., display spectra of body shape.

Size: The invertebrate animals exhibit a great variation in size. They range from microscopic protozoans to large-sized cephalopods. The malaria parasite is at the lowest extremity. It occupies only about one-fifth of a human red blood corpuscle (RBC). The uppermost extremity is occupied by a species of the giant squids of North Atlantic, Architeuthis, has been reported to have attained a total body length of 16.5 metres including tentacles.

Symmetry: Invertebrates represent all types of symmetries. Protozoans display bilateral as well as radial symmetry. Some are asymmetrical. Sponges are either asymmetrical or radially symmetrical. Coelenterates are radially symmetrical. Ctenophores exhibit biradial symmetry. The members of the remaining phyla are mostly bilaterally symmetrical. Invertebrates also represent spherical symmetry, principally in spherical protozoans such as Heliozoa and Radiolaria.

Grades of Organization: Invertebrates display all grades of organisation. The protoplasmic grade is seen in Protozoa, as all activities at this level are carried on within the limits of plasma membrane (plasma lemma). The cellular grade is characteristic of sponges. In sponges only, the cells exhibit division of labour for performing various specialised functions. The cell-tissue grade is observed in coelenterates as their cells are not only specialised for different functions but also certain similar cells gather together to form tissues as well. The tissue-organ grade is exhibited by flatworms with arrangement of tissues to form organs. The organ-system grade organisation is characteristic of all higher invertebrates. In this type of organisation, organs join together in a system to perform some functions.



Germ Layers: The germ layers or embryonic cell layers are absent in Protozoa due to its uni-cellularity. All other invertebrates are either diploblastic, i.e., they are derived form two germ layers, an outer ectoderm and an inner endoderm or triploblastic with an extra third layer, the mesoderm. Sponges and coelenterates are diploblastic, whereas other invertebrates are triploblastic.

Integument: The body covering with simple integument. In protozoa, it is a delicate plasma membrane, while some Invertebrates represent a protective covering, pellicle. Most invertebrates possess an outer protective epidermis, which is made of single layer of cells, while in others have further added a non-cellular cuticle or chitinoid covering secreted by underlying epidermis.

Movement: Various devices for movements found in invertebrates. Some invertebrate animals are sessile, such as sponges and corals, while others move from one place to another. Protozoa move by pseudopodia, flagella and cilia and contractile myonemes. Coelenterates and molluscs exhibit tentacular movements. Annelids move by setae, parapodia and suckers. Arthropods move with jointed legs, while echinoderms take the help of arms which are with or without tube feet, for their movement.

Segmentation: Several invertebrate phyla are characterised by segmentation in their bodies. Certain flatworms exhibit pseudo segmentation, as their long bodies are made up of numerous sections. True segmentation is found in Annelida and Arthropoda.The body is divided into more or less similar segments.

Endoskeleton: The invertebrate animals do not possess any kind of rigid internal skeleton to give support to the body and provide surface for attachment of muscles. Many invertebrates are soft bodied, while some, like arthropods and molluscs, possess hard exoskeleton for supporting and protecting their body.

Coelom: In sponges and coelenterates, the body is a double-layered sac surrounding a single cavity, which opens to the outside through a mouth. Such animals are acoelomate as they have no coelom. Other invertebrates possess a cavity in between the body wall and the gut. This cavity is called pseudo-coelom in nematodes as it is not lined by mesoderm. In higher invertebrates, the coelom is lined by mesoderm and, hence, it is the true coelom.

Dorsal Gut: The alimentary canal is either absent or partially formed or complete. In case, it is present, it lies dorsal to the nerve cord, and runs from the anterior terminal mouth up to the posterior terminal anus. The gill-slits are never formed in the pharyngeal wall.

Digestion: In invertebrates, the digestion of food takes place within the cell (intracellular digestion) as well as outside the cell (extracellular digestion). In protozoans and sponges, the digestion of food takes place intracellularly. In coelenterates, the digestion of food lakes place both intracellularly as well as extracellularly. All other invertebrates exhibit extracellular digestion, which in higher invertebrates occurs within a well defined gut.

Circulatory System: Blood vascular system is well developed in higher invertebrates. Some, like arthropods and molluscs, possess open or lacunar circulatory system, while in others the blood flows in closed vessels, i.e., closed circulatory system. The heart is always located dorsal to the gut.

Respiratory System: Protozoans, sponges, coelenterates and many worms have a direct diffusion of gases between the general surface of the organism and the environment. In most annelids, the exchange of gases takes place through the moist skin. Gills are common in most higher invertebrates. Echinoderms possess branchiate and tube feet for this purpose. Sea cucumbers have respiratory trees which act as respiratory organs. In insects, the tracheal system is adapted for aerial respiration.

Excretory Mechanisms: In protozoans, sponges and coelenterates, excretion is performed by direct diffusion through cell membranes. Flatworms possess characteristic flame cells, while annelids and molluscs possess true nephridia. In insects, the excretory organs are Malpighian tubules. Echinoderms and some other invertebrates have amoeboid cells or phagocytes for storage and disposal of excretory products to outside.

Nervous System: In radially symmetrical invertebrates, e.g., coelenterates, the head is absent and the central nervous system is represented by a ring of nerve-tissue encircling the body. In bilaterally symmetrical invertebrates, the central nervous system comprises a pair of nerve cord running along the mid-ventral line of the body. The nerve ring and the nerve cords bear ganglia. In higher invertebrates, the head ganglia forms the brain. Invertebrate nervous system is characterised by solid nerves, these are not hollow within.

Sense Organs: In protozoans protoplasm acts as receptor, while in flagellates, the stigma or eyespot acts as a photoreceptor. Coelenterates possess long sensory cells, scattered throughout the body wall, while some also possess eyespots for the reception of light, statocysts for equilibrium and sensory pits for chemoreception. Eyespots and chemoreceptors are also found in flatworms. Annelids possess various sensory receptors including simple eyes, present in the epidermis. In arthropods, compound eyes are found in addition to simple eyes. Statocysts for equilibrium; tactile receptors and chemoreceptors are common in arthropods and molluscs.

Characteristics of Vertebrates

	How it Breathes	Body Covering	Born Alive or Eggs	Warm or Cold Blooded	Something that makes them distinctive
Amphibians	Gills as tadpoles, lungs as frogs	Slimy wet skin (moist)	Eggs	Cold	Can live on land and in water
Birds	Lungs	Feathers	Eggs	Warm	Most can fly. All have wings.
Fish	Gills	Scales	Eggs	Cold	Breathe under water. Fins for locomotion.
Mammals	Lungs	Skin and fur (or hair)	Alive. Except the platypus!	Warm	Give birth to live, fully developed young. Suckle young. Mammary glands.
Reptiles	Lungs	Scaly skin	Eggs	Cold	Have scaly skin.

Reproduction: Modes of reproduction vary from simple asexual binary fission to most complicated sexual reproduction. In certain cases, parthenogenesis has also been observed in which an unfertilized egg develops into a complete individual. Ex: rotifers, bees, some other insects and certain crustaceans. In sexually reproducing invertebrates, hermaphrodites or bisexual forms are found, particularly in coelenterates, platyhelminthes, annelids and crustaceans.

Fertilization is either external or internal. Development is direct or indirect. In the indirect development, the development includes both larval stages and metamorphosis.

Cold-Blooded Animals: All invertebrates are cold-blooded, i.e., they cannot keep body temperature constant all the time.

Prof. M. Jagadish Naik

LESSON - 14
COMPARATIVE ACCOUNT OF RESPIRATORY ORGANS IN VERTEBRATES

Different points of view have shaped the scientific study of the origin of life. Some of these argue that primeval life was based on simple anaerobic microorganisms able to use a wide inventory of abiotic organic materials (heterotrophic origin), whereas others invoke a more sophisticated organization, one that thrived on simple inorganic molecules (autotrophic origin).

The organization and mechanisms allowing a chemical system to be materially and energetically connected with the environment, and equipped with the ability to self-construct, emerged first, and then appeared the complex chemical structures that provide the system with a temporal connection throughout successive generations. Thus, the origin of life was a process initiated within ecologically interconnected autonomous compartments that evolved into cells with hereditary and true Darwinian evolutionary capabilities.

Nevertheless there is a consensus that life started in an anaerobic environment in the so called "primordial broth", a mixture of organic molecules in the absence of oxygen.

Molecular phylogenetic studies have revealed a tripartite division of the living world into two procaryotic groups, Bacteria and Archae, and one eukaryotic group, Eucarya. To know which group is the most "primitive" would help to delineate the characters of the last common ancestors to all living beings. According to several investigators and to the procaryotic dogma, the universal ancestor was probably a thermophile because primitive Earth was hotter than today. Nevertheless it is possible that the ancestor would have been a mesophile and, in this case, the root of the tree of life should be located in the eucaryal branch, with Archae and Bacteria sharing a common ancestor.

Almost four billion years ago, living beings that inhabited the earth were very primitive microorganisms, perhaps methanogenic bacteria, living in absolute anaerobiosis. These organisms still exist in our days and are included in the Archae domain, and for this reason are central to the paleoenvironment and paleobiology studies.

Anaerobic fermentation was a very inefficient metabolic process of extracting energy from organic molecules and the rise of an oxygenic environment was a momentous event in the diversification of life that dramatically shifted from inefficient to sophisticated oxygen dependent oxidizing eco- systems. Subsequently, oxygen became an indispensable factor for aerobic metabolism, especially in the higher life forms.

There are two widely accepted views of aerobic metabolism: first, that it was only possible after oxygen release by photosynthesis became abundant, and second, that it developed independently in diverse evolutionary lines. Analysis of the temporal distribution and geochemistry, suggest that the transition from reducing to sable oxygenic environment occurred later, between 2.3 and 1.8 billion years ago.

Molecular evidence shows that aerobic respiration evolved before oxygenic photosynthesis, or, in other words, cyto- chrome oxidase appeared before the water-splitting system. This hypothesis considers that denitrification (NO reductase) is the probable origin of aerobic respiration, that aerobic respiration arose only once the last universal ancestor was already present and that oxygenic photosynthesis developed in a single evolutionary line, the cyanobacteria, after the origin of aerobic respiration.

The rise of atmospheric oxygen caused by photosynthetic activity of evolving cyanobacteria must have created a remarkably strong selective pressure on organisms in both domains. Adaptations to use the new, chemically superior, electron receptor might have taken place, with similar molecular solutions creating the oxygen-reducing active sites. This would mean that the aerobic respiration has a single origin and may have evolved before the oxygen was released to the atmosphere by photosynthetic organisms and that the appearance of aerobic respiration was polyphyletic.

This new and more profitable method of extracting energy, aerobic respiration, should have led to a domain of aerobic organisms in the biological community, and prob- ably even leading to the extinction of some anaerobic organisms.

The evolution to multicellular organisms determined the appearance of more sophisticated and specialized systems for the gas exchange, in order to develop an effective system of exchange. The existence of multicellular organisms, led to rapid and progressive morpho functional differentiation of groups of cells that became the precursors of tissues, organs and systems currently present in more complex organisms. In most cases, this cellular specialization does not imply the loss of genetic material but only changes in the genes expression.

The respiratory systems from different groups of animals, although morphologically different, have in common the following characteristics: they have a large capillary network, the gas exchange surfaces are thin and moist; constant renewal of oxygen-rich fluid (air or water) order to provide oxygen and remove carbon dioxide; free movement of blood within the capillary network. According to Atwood, the assumptions stated above, are present either external respiration is carried out by 1) cutaneous diffusion (earthworm and some amphibians), 2) by thin tubes called tracheae (some insects); 3) by gills, the respiratory system of fish or 4) by diffusion through the lungs, respiratory organs present in amphibians, reptiles, birds and mammals.

Respiration in animals: Whether they live in water or on land, all animals must respire. To respire means to take in oxygen and give off carbon dioxide. Some animals rely of simple diffusion through their skin to respire. While others have developed large complex organ systems for respiration.

Respiration is the process of obtaining oxygen from the external environment & eliminating CO_2.

1. External respiration - oxygen and carbon dioxide exchanged between the external environment & the body cells.
2. Internal respiration - cells use oxygen for ATP production (& produce carbon dioxide in the process)

Adaptations for external respiration

1 Primary organs in adult vertebrates are external & internal gills, swim bladders or lungs, skin, & the buccopharyngeal mucosa 2 Less common respiratory devices include filamentous outgrowths of the posterior trunk & thigh (African hairy frog), lining of the cloaca, & lining of esophagus.

Function: To provide oxygen gas need for cellular respiration and remove carbon dioxide from the body.

Chordates have one of two basic structures for respiration

1. Gills –for aquatic chordates Example: tunicates, fish and amphibians
2. Lungs for terrestrial chordates Examples: adult amphibians, reptiles, birds, and mammals

The body structures which are needed for gaseous exchange between the blood and the surrounding medium are known as respiratory organs.

Depending on the type of medium, vertebrates have two principal types of respiratory organs: gills for aquatic respiration (in water) and lungs for terrestrial respiration (in air).

Gills and lungs are derivatives of the embryonic pharynx.

Gills: Gills are used for aquatic respiration found in fishes and amphibians. Besides exchange of gases at the surface of gills, salts are also eliminated from the gills surface in marine teleosts. Gills are of two types on the basis of their position-

1. External gills
2. Internal gills.

I. External Gills: In larvae of most amphibians the integument covering the outer surface of visceral arches gives off branching outgrowths which are tufts of filaments and are respiratory. Thus, these are of ectodermal origin.

In some tailed amphibians, external gills and gill-slits are retained throughout life, but in some tailed and all tailless amphibians they are lost during metamorphosis and, hence, called larval gills.

External gills are in direct contact with water and an exchange of gases occurs through their surface epithelium.

Later an operculum arises and covers these gill clefts and gills externally in tadpoles so that the gills become enclosed in an opercular chamber lined with ectoderm.

External gills, though rare in fishes, are found in some larval forms of lampreys, Polypterus (bichir) has one pair of external gills. Dipnoi (Lepidosireri) have four pairs of filamentous external gills attached to the outer edges of the branchial arches.
The external gills of fishes disappear in the adult. Gills may be pectinate, bipinnate, dendritic or leaf-like.

A gill has a narrow central axis bearing double row of filaments. These are richly vascularised by aortic arches. Gill-slits are not found.

These external gills soon degenerate and a new set of gills, called internal gills develop from the same visceral arches. However, these internal gills and operculum are not homologous with those of fishes.

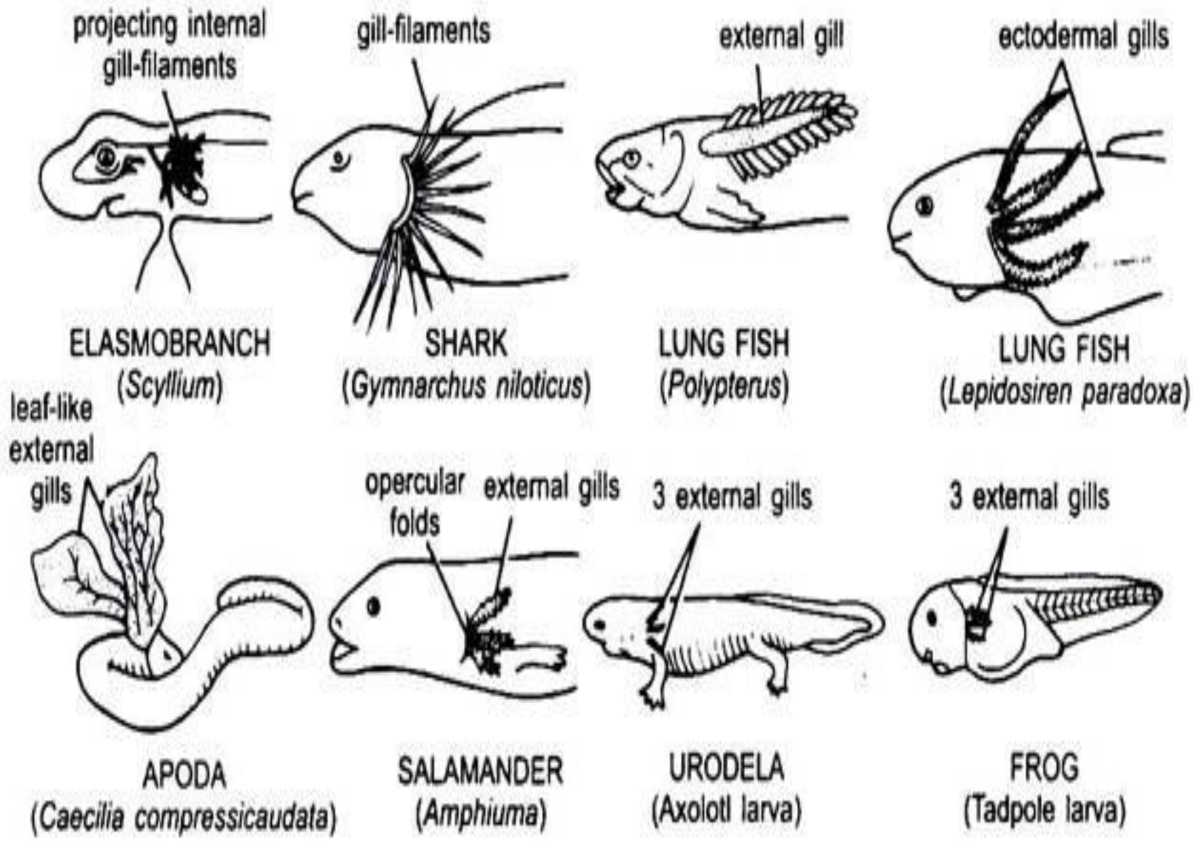


Fig. 44.1. Larval external gills of fishes and amphibians.

Internal or True Gills: Internal gills are characteristic of fishes. These are placed in the gill-slits and attached to the visceral arches. In amniotes embryonic pharyngeal pouches do not communicate to the outside through gill-slits in the adults. Gills are not found in them.

Gill-Slits: Embryologically gill-cleft develops as a result of a series of evaginations from the pharynx which grow outward and meet corresponding ectodermal invaginations from the outside. At each point of function a cleft or pouch is formed so that water coming into the pharynx from the mouth may pass to outside. The partitions between these passage ways contain cartilaginous or bony supports the gill-filaments which are located on each side. These gill-slits persist in the adults of cyclostomes, fishes and certain amphibians, but become abolished in higher vertebrates. The number of gill-slits is 6-14 pairs in cyclostomes, 5 to 7 pairs in sharks and rays, 4 pairs in most bony fishes.

Structure of a True Gill: These gills develop on the walls of gill-pouches or gill-arches. A gill is formed of two rows of a series of gill-filaments or gill-lamellae develop from the epithelium covering the interbranchial septum on both sides.

a) operculum: In a bony fish, a bony flap, called operculum or gill cover, arises from the hyoid arch and covers the gills in a common opercular cavity which opens by a single slit-like crescentic external gill opening behind.

b) Interbranchial septum extends outward from the cartilaginous arch. A single row of gill-filaments on one side of interbranchial septum forms a half gill called a hemibranch or demibranch. An interbranchial septum with two hemibranchs (anterior and posterior) forms a complete gill or holobranch. These are richly supplied with blood vessels associated with aortic arches so that carbon dioxide in the blood may be exchanged for dissolved oxygen in the water. Sharks and rays have generalised structure of gills. In higher bony fishes the interbranchial septum is lacking so that the hemibranchs on the anterior and posterior part of each branchial arch are no longer separated from one another. The gill-apertures also no longer open separately to the outside. Instead, the gills are enclosed in a single chamber and covered externally by a large bony operculum which opens and closes posteriorly to permit water to pass to the outside. In bony fishes there are four pairs of functional gills.

c) Spiracles: In sharks and rays an anterior pair of non-respiratory openings, one on either side between mandibular and hyoid arches are called spiracles or pseudobranchs. These are internally closed or lost in lung fishes and bony fishes.

Lungs and ducts: Most adult amphibians and all amniotes breathe by means of lungs, though lungs are also present in lung fishes. In an embryo a hollow outpushing, called lung primordium arises from the ventral wall of the pharynx. It grows backwards and divides into two, right and left lung buds. The undivided proximal portion develops into trachea and larynx, and opens into pharynx by glottis. Later lung buds grow posteriorly into coelom and branch repeatedly and get covered by mesoderm. Thus, each lung has an endodermal lining and an outer visceral peritoneum and in between the two mesodermal mesenchyme having blood and lymph vessels, nerves, and smooth muscle fibres and connective tissue. Inner endodermal epithelium of lungs is raised into a network of ridges to increase the vascularised surface exposed to the action of air.

In lower forms, the lungs are hollow bags, but in higher forms the ridges increase in number and unite with one another across the lumen of the lung to convert it into a solid but spongy structure with innumerable air spaces. In mammals, the internal surface area of lungs may be thirty times that of the external surface area of the body. The original duct of the lung sac connecting the pharynx to the lungs becomes a trachea. Trachea is absent in anurans. In many tetrapoda the anterior end of the trachea becomes modified into a larynx or sound box which opens into the pharynx by a glottis. At its lower end, the trachea divides into two bronchi, each of which enters a lung. The bronchi divide to form an immense system of bronchioles carrying air into minute bags or alveoli. The alveoli have very thin walls invested with blood capillaries, an exchange of gases occur in the alveoli.

Larynx: The upper end of trachea is enlarged, especially in frogs and toads, to form the larynx or sound box in which the vocal cords are located. In Necturus, it is supported by a pair of lateral cartilages bounding the glottis. In other amphibians, each lateral cartilage is divided into a dorsal arytenoid and a ventral cricoid cartilage. In frog, both the cricoid fuse to form a cartilaginous ring. Larynx is not more developed in reptiles. Larynx is not sound producing organ in birds, but serves to modulate tones that originate in the syrinx. Syrinx lies at the lower end of trachea where it divides into two bronchi.

It is the sound producing organ. Larynx is greatly developed in mammals. Its wall is supported by a pair of arytenoid, single cricoid and a single thyroid cartilage on the ventral surface. Glottis may be closed at the time of swallowing of food by a flap of muscular epiglottis.

Trachea: Trachea is extremely short or absent in Anura. It is merged with the larynx to form laryngotracheal chamber. Many caudate amphibians possess a short trachea, supported by cartilages. Trachea is simple in reptiles as in amphibians or may be long in long-necked reptiles such as turtles, trachea is long and convoluted. Tracheal cartilages are sometimes in the form of complete rings. In birds, the trachea is long.

In swans and cranes, trachea is longer than the neck and tracheal rings are complete and ossified. Trachea in mammals is variable and tracheal rings are usually incomplete on the upper side.

Lungs: In Protopterus (African bichir) paired ventral lungs are present which enable these to survive during periods of draught. Dipnoans belonging to subclass Sarcopterygii which branched off from Actinopterygii also have a lung-like structure. In all the living lung fishes, the lung is dorsal to the gut connected by a tube to the ventral side of the oesophagus.

In Protopterus (African) and South American Lepidosiren it is bilobed and unpaired in Australian lung fish. Their lungs unlike Protopterus contain internal chambers or pockets to increase the respiratory surface and highly vascularised by branches of pulmonary arteries and veins.

In bony fishes and presumably the crossopterygians also, the primitive lung has modified into a gas or swim bladder or hydrostatic organ. Itconnected with the oesophagus by a dorsal connection. In amphibians the lungs are simple, sac-like structures with a central large cavity. In aquatic amphibians the inner surface of lungs is smoothIn frogs and toads the inner walls contain numerous folds lined with alveoli so as to increase the respiratory surface. They are richly vascular and lined with mucous epithelium whose cells are columnar and ciliated.

In reptiles, lungs are more complex than those of amphibians with an increase in the number of internal chambers and alveoli.

In some lizards one lung is considerably larger than the other, and in snakes the left lung is reduced or even absent in some species. Crocodilians possess lungs that are quite similar to those of mammals.

A few lizards possess diverticula, extending posteriorly from the lungs, resembling air sacs of birds. In some lizards, the bronchi are subdivided into primary, secondary and tertiary bronchi. In birds, the lungs are small and incapable of the great amount of expansion. The lungs, however, are connected with nine air sacs that are situated in various parts of the body.

The air sacs have no respiratory epithelium, serve essentially as reservoirs. Air passes through the bronchial circuit into the air sacs and then returns, generally by a separate set of bronchi, to the air capillaries in the lungs.

The respiratory system of the mammal is much less complicated than that of the bird. The primary bronchi after entering the lung into secondary bronchi which divide into smaller and smaller bronchioles, finally terminating in tiny alveoli or blind pockets in which there is an exchange of gases. In most mammals, lungs are subdivided externally into lobes, i.e., left lung has two lobes and right lung has three lobes in man and four lobes in rabbit. Lungs are simple and without lobes in whales, sirenians, elephants, hyrax and several perissodactyles. Right lung is lobulated in monotremes and rats. In sirenians, the lungs are elongated.

Accessory Respiratory Organs: Gills are the chief respiratory organs in aquatic vertebrates, like fishes and some aquatic urodeles, etc. The land vertebrates have the lungs for respiration. There are also other accessory structures for respiration, i.e., for taking oxygen directly from water or air.

1. Skin: Some fishes are able to survive outside water. The common eel, Anguilla can travel by wriggling on damp grass though it has no special respiratory organs, but it has vascular areas in the skin by which it can breathe both in water and on land. Secondly the opening of the operculum is small and rounded so that the eel can retain water in the branchial chamber and journey on land.

In amphibiansthe moist skin is highly vascular. Lungless salamanders (plethodonts) respire only through skin. Their larvae loses gills at metamorphosis and lungs do not develop in adults. African male hairy frog, Astylosternus have vascular hairy cutaneous outgrowths which act as respiratory surface.

Vascular caudal fin of Periophthalmus (mud-skipper) acts as respiratory organ during submergence. Indian and Pacific Oceans the caudal fin is highly vascular, the head and trunk of the fish project above water when it perches on a rock, only the caudal fin remains submerged and acts as a respiratory organ.

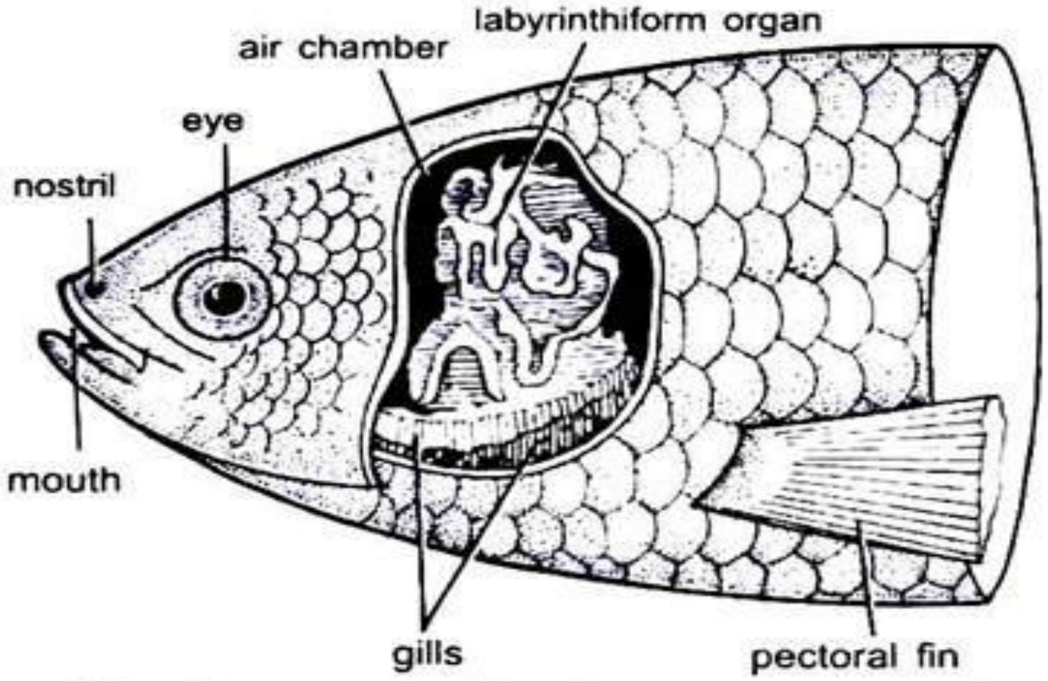


Fig. 44.6. Diagram showing the accessory respiratory organs of *Anabas*.

2. Swim-Bladders

(i) The Indian climbing perch Anabas scandens has special air chambers above the gills, where three concentrically folded bony laminae, called labyrinth form organs are developed from the first epibranchial bone on each side. Their covering vascular mucous membrane brings about respiration. Anabas is so dependent on air that even in water it comes to the surface to gulp air and it is asphyxiated if prevented from doing so. It can survive for long periods on land and makes excursions by means of its many long spines on the operculum and ventral fins.
(ii) In Ophiocephalus there is an accessory branchial cavity on each side above the gills.

3. Epithelial Lining: The loach Misgurnus swallows air which passes through the intestine and is voided by the anus, the highly vascular mucous membrane absorbs oxygen from the air, and carbon dioxide is also passed through the anus.

There may be other special organs for gaseous interchange. In Calichthys rectal respiration takes place, the rectum is highly vascular into which water is alternately taken in and pumped out.

4. Pharyngeal Diverticula: The Indian 'Cuchia eel' Amphipnous has poorly developed gills, but on each side of the body there is a vascular sac as an outgrowth of the pharynx which opens anteriorly into the first gill-cleft. These are respiratory sacs.

Branchial Diverticula: In the Indian catfish Saccobranchus there is a pair of large air sacs, each arising from the branchial chamber and extending laterally backwards into the trunk muscles. They can be filled with air for respiration.

The catfish Clarias found in Indian and African rivers, has a pair of supra-branchial organs, each lying on one side and divided into two parts, a highly branched arborescent organ formed from second and fourth branchial arches, and a vascular sac of the branchial chamber which encloses the arborescent organ. Several gill-fans formed by coalescing of gill-filaments close the entrance of the suprabranchial organ.

Air is taken into the organ through the mouth continuously, and Clarias cannot only live outside water for several hours but it can move along on damp grass. Accessory respiratory organs are found generally in tropical fishes of amphibious habit, they are devices for sustaining life out of water.

Swim or Air-Bladders: Swim or air-bladder arises as a diverticulum from the pharynx or oesophagus in bony fishes. It is originally lateral in position but becomes dorsal. It usually lies below or lateral to the vertebral column outside the coelom.

RESPIRATORYSYSTEMINFISH

The fish gill adapted a structure for extraction of oxygen from water that is formed by a large number of filaments spaced out along the gill arches on either side of the pharynx. Each filament has a series of plates projecting at right angles from its upper and lower surfaces, the secondary lamellae, which are extremely numerous, are the site of gaseous exchange and form a fine sieve which ensures that all the water comes into close contact with the blood.

The gills are multifunctional organs that are responsible for the gas exchange (respiration) but also for the osmoregulation, acid-base regulation, and excretion of nitrogenous waste.

The epithelial surface of a gill arch is structurally and functionally zoned. The filaments are covered by two distinct epithelial surfaces, the lamellar and filament epithelia, also termed the secondary and primary epithelia respectively. Gas exchange occurs through the secondary lamellae, and the non-respiratory functions of the gills take place in the primary epithelium.

Theprimaryepitheliumcontainsthe chloride cells, which vary in morphology and number according to the milieu where the fish lives. The presence of an accessory cell beside the chloride cell is characteristic of seawater or seawater- adapted fish. The secondary epithelium that covers the free part of the secondary lamellae has an exclusive relationship with the arterio arterial vasculature,i.e., the pillar cells. This epithelium consists of an outermost layer of pavement cells that exhibits structural characteristics suggestive of cell coat secretion and an innermost layer of less differentiated cells. In contrast to the primary epithelium, the secondary epithelium does not exhibit any obvious differences between freshwater and seawater fish.

The lamellar structure helps to increase the surface area but depends on the following complex anatomy to maintain the flat space necessary for circulation: separation between epithelial sheets (bypillarcells) and connection between the basal lamina of epithelial sheets by groups of strands (collagen columns).

To prevent ballooning and to ensure the sheet-flow dynamics of blood, the two layers of respiratory epithelium are connected by many strands of extracellular matrix materials, which are called collagen columns. These columns, made of collagen fibers, are essential for reinforcing the lamellae structure and the internal force of blood pressure. Since collagen triggers the coagulation cascade when exposed to blood, the collagen columns are surrounded by the plasma membrane of pillar cells, which isolate them from circulation.

In the interface between pillar cells and collagen columns, exist adhesion junctions termed as"column junctions" and"auto celullar junctions",both of which are essential constituents of the gill lamellae. The "column junctions" isa cell-ECM adhesion and "autocelullar junctions" a mem- brane-membrane adhesion, both involved in maintaining structural integrity and hemodynamic of branchial lamellae.

The pillar cells are a type of endothelial cells that delimits a network of vascular compartments within the lamellae of gill fish, but since they share characteristics with smooth muscle cells, we can say that these cells are specialized vascular cells with characteristics of both endothelial and smooth muscle cells.

The contractile apparatuses of the pillar cells possibly prevent collagen columns from being stretched and provide plasticity to the vascular network of the lamella against changes in blood pressure. Other possible function for the contractile structures of the pillar cells is that they can change the diameter of the vascular channels, and therefore contribute to the regulation of blood flow through the lamellae.

Besides the pillar cells, the gill epithelium of freshwater fishes have pavement cells (also termed as respiratory cellsin older literature), mucus cells, neuro-epithelial cells and chloride cells.

The neuroepithelial cells are isolated or clustered on the internal side of the primary lamellae facing the respiratory water flow. They are probably involved in local and central modulation of the branchial functions by interacting with the branchial nervous system and by paracrine secretion of substances such as serotonin. These cells share several morpho functional features with the cells of the neuroepithelial bodies in the lungs of air-breathing vertebrates.

The chloride cells are described as large, granular, acidophilic and mitochondria-rich cells and exhibit an extensive tubular system emanating from the basolateral membrane, an array of sub-apical vesicles, large ovoid nucleus and abundance of Na^+, K^+ -ATPase enzyme. There is a marked difference between species in the structure of the apical membrane of chloride cells which precludes their absolute identification.

hey are located in the primary epithelium in close proximity to the blood vessels and are sites of active chloride secretion and high ionic permeability, performing an integral role in acid-base regulation. Asin other vertebrates, fish must maintain homeostasis of intra and extracellular pH and therefore use the parallel strategies of buffering and excretion to defend against pH changes. During alkalosis conditions, the area of exposed chloride cells is increased, which serves to enhance base equivalent excretion as the rate of Cl-/ HCO_3- exchange is increased. Conversely, during acidosis, the chloride cells surface area is diminished by an expansion of the adjacent pavement cells, and this response reduces the number of functional Cl-/HCO_3- exchangers.

- Under soft water or toxic conditions, chloride cells proliferate on both surfaces of the gill and might impair gas transfer owing to a thickening of the lamellar blood-to-water diffusion barrier.
- Water enters through the fish's mouth and out through the gill, slits in a direction that is opposite to the blood flow in the gill , providing a constant renewal of the oxygen supply in contact with the respiratory organ.
- The exchange of oxygen and carbon dioxide takes place by diffusion from the surrounding water and the blood that flows within the capillary network of the gills, and because of this countercurrent flow fish can extract 80 to 90% of dissolved oxygen in water .
- During the larval development of fish, the teleosts in particular, the skin is the cutaneous surface that ensures gas exchange, and only in the final stage of this period begins the hematosis through the gills, when the muscle-skeleton structure of the oral cavity becomes able to coordinate food intake with the flow of water through the branchial system.

Lungfishes

- Changing conditions of life imposed new requirements on the morphology and physiology of the organisms. One of these changes is the evolutionary transition from aquatic to terrestrial life, leading to adaptations in locomotion, breath- ing, hearing, mechanism for food capture and other functions.
- The first air-breathing vertebrates were fishes, and a Devonian air-breathing sarcopterygian (lobefin) occupies the basal position in the lineage extending from the Paleozoic fishes to the most derived tetrapods.
- The evolution of tetrapods from sarcopterygian fish is one of the major transformations in the history of life and involved numerous structural and functional innovations. The *Styloichthys changae,* one fossil of sarcopterygian fish, exhibits the character combination in a stem group close to the last common ancestor of tetrapods and lungfish.
- The recent discovery of a well-preserved species of fossil sarcopterygian fish form in the late Devonian of Artic Canada, that represents an intermediate between fish with fins and tetrapods with limbs, provides unique insights into
- Blood flow in oxygenation system in fish and lungfish.
- how and in what order important tetrapod characters arose. The morphological features and geological setting of this new animal are suggestive of life in shallow-water, marginal and subaerial habitats.

The relevance of the extant air-breathing fishes as models for events in the Paleozoic has been a recurring theme for more than one century. The lungfish is considered homo- logous to the lungs of all higher vertebrates and the precursor of the enteleost gas bladder how and in what order important tetrapod characters arose. The morphological features and geological setting of this new animal are suggestive of life in shallow-water, marginal and subaerial habitats.

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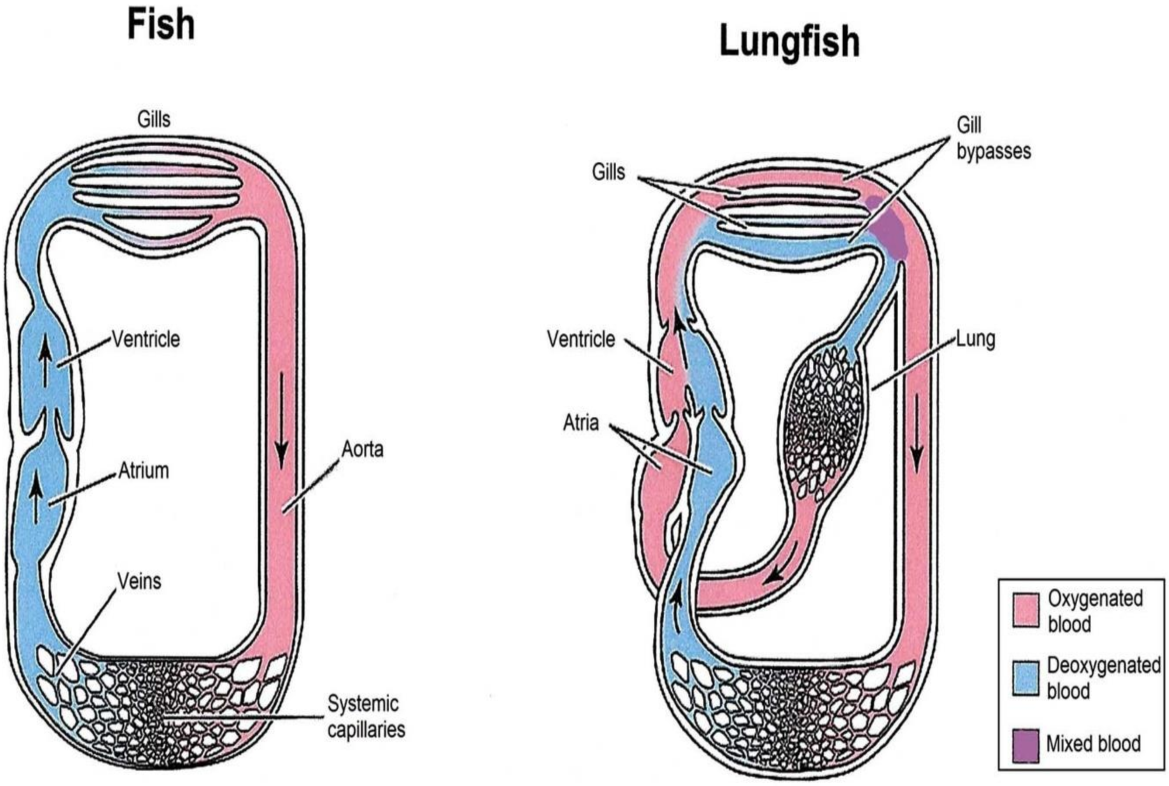


- In our days the lungfish are represented by three genera, the Australian lungfish, *Neoceratodus forsteri*, and the other two genera: the African (Protopterus) and South American (Lepidosiren) lungfish.
- The Australian Neoceratodus differ from the other lungfish because they breathe air for short periods and for this reason the lung is an accessory organ which is only used during periods of high activity in its natural habitat. They have efficient gills and possess only a single lung, unlike both Protopterus and Lepidosiren which have paired lungs and much reduced gills.

The lung of N. *forsteri* consists of a single elongated chamber compartmentalized by a thick cartilaginous struc- tural framework. The epithelial lining of these support- ing structures comprised abundant capillaries interspersed with cells resembling alveolar type II and type I cells. These epithelial cells which appear to be the only cell type lining the gas-diffusing surface, have long cytoplasmic plates bearing microvilli, which form part of the gas-exchange membrane. The cells contain large numbers of osmiophilic bodies resembling mammalian lamellar bodies, and it is possible that these lungfish cells may be the common ancestral cell for the alveolar type I and II found in the mammalian lung. They also have a surfactant-like material containing both SP-A and SP-B like proteins,

Suggesting that even in this primitive lung, these proteins are still involved in surfactant homeostasis.

To breathe air the *Neoceratodus* may rise to surface, exhale through the mouth, inhale and dive forward or rise to the surface, breathe and reverse back into the water.

Protopterus and Lepidosiren are bimodal breathers, that use both gills and lungs for respiratory gas transfer, but they are obligate breathers because they die if denied access to air. The Protopterus occupy a variety of habitats both lentic (standing water) and lotic (running water) and possess the capacity to aestivate, reducing their metabolic rate, which allow them to survive to extreme heat or for long dry period. In the Protopterus, the gills and skin uptake only 10% of the total O_2 uptake and these structures are much more effective in removing the CO_2.

The reedfish *Calamoichthys calabaricus* is one of the phylogenetically most primitive extant air-breathing fishes, and represents an animal successfully adapted not only for air breathing but also for making short-term use of terrestrial environments. In this primitive living actinopterygian fish the oxygen uptake is achieved by the gills, skin and a paired lungs and in the total volume oxygen uptake, the lungs account for 40%, the gills 28%, and the skin 32%.

In the Lepidosiren 99.15% of the total diffusing capacity lies in the lungs, 0.85% in the skin and only an insignificant 0.0013% in the gills, which shows that the gills don't have any importance as a gas exchange organ in this species. Oxygen uptake is accomplished by the lungs and dioxide carbon is eliminated by the skin.

The structure of the gills lamellae of Lepidosiren consists of a stratified epithelium that rests on the basal membrane and has at least three layers of cuboidal cells with large nuclei. Close to the epithelium there are numerous capillaries.

Tetrapods evolution.

Each lung of these lungfish has a main duct and numerous chambers of different sizes, which decrease in size as they progress caudally. The honeycomb-like edicular parenchyma is disposed in these chambers and most cham- bers contain a central lumen, which connects with the air duct. The duct, the chambers and edicular parenchyma consist of connective tissue septa held upright by smooth muscular/elastic trabeculae and are supplied and drained by branches of the pulmonary artery and vein. Most interedi- cular septa have a double capillary net. The air-blood barrier consists of three layers: a simple squamous epithelium made up of a single type of cell, the endothelial cells of the blood capillaries and the combined basal lamina of the epithelial and endothelial cells.

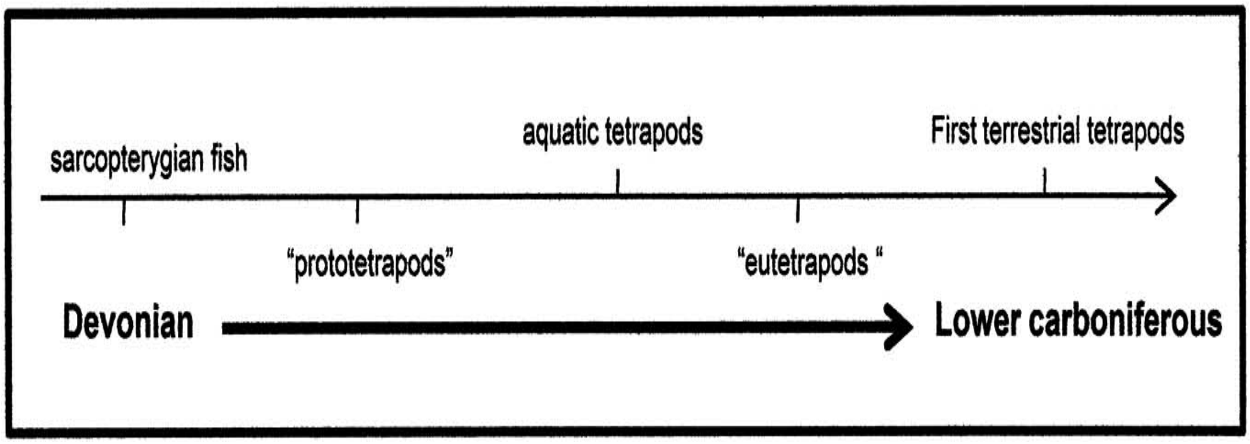
The skin of these fish has two layers, the epidermis and the dermis. The epidermis consists of a stratified epithelium with six to ten layers of diverse cell types. Most prominent are superficially located cuboidal cells with a large central nucleus and the mucous cells that are dispersed among the other cell layers. The dermis is a dense connective tissue, with blood vessels and small ossified scales. Numerous blood capillaries and melanophores lie beneath the basal membrane and between the subjacent layers.

In the Protopterus and Lepidosiren the ventilation of the gills occurs through the action of a positive pressure buccal pump anterior to the gills and an opercular suction pump posterior to the gills. These pumps generate a nearly conti- nuous water pressure gradient favouring a water flow in the mouth, through the gills and out the opercular opening. The ventilation of the lungs in Protopterus is achieved by the same musculoskeletal elements involved in aquatic ventila- tion, the buccal force pump mechanisms.

Early in their history, fish developed supplementary air breathing organs in two taxonomic lines – Actinopterygians and Sarcopterygians. The onset of aerial respiration in primitive fish was an important milestone in the evolution of terrestrial vertebrates.

The fish-tetrapod transition was one of the greatest events in the vertebrate evolution. Tetrapods first appeared in the late Devonian about 360 million years ago, but appear to have been primarily aquatic animals. For some investi- gators the freshwater origin of tetrapods remains the most likely scenario, but several recent findings raise the possi- bility that the tetrapod land invasion could come from a marine habitat.

The evolution of tetrapods occured under environmental influences and presumption that hypoxia habitat conditions were similar to those commonly encountered in tropical lowland habitats during dry seasons.



The sequence of evolution begun with sarcopterygian fish, followed by the appearance of a "prototetrapods" (e.g. *Elginerpeton*), the emergence of aquatic tetrapods (e.g. *Acanthostega*), the appearance of "eutetrapods (e.g. *Tulerpeton*) and the first truly terrestrial tetrapods (e.g. *Pederpes*) in the lower Carboniferous. Several morpho- logical changes were observed during the evolution process, developing specialized features that allowed land locomotion and air breathing.

The sudden change from gill respiration to lung breathing would pose considerable physiological problems. One of the consequences of gill loss, would be the concentration of respiratory CO2 within the body, which required buffering by bicarbonate ion and affected processes such as acid-base balance, O2 binding by haemoglobin, ventilation rate, res- piratory control and also affected nitrogen excretion, ion regulation and water balance, vital processes that would need to be assumed by others organs.

The advantages of tetrapod gill loss included head mobility, development of hearing and the origin of different ventilatory and feeding mechanisms.

In the primitive pure buccal pumping, found in most air- breathing fishes, including lungfishes, the axial musculature does not contribute to expiration or inspiration. In fact, the buccal pump breathing has been proposed to constrain the evolution of tongue morphology and head shape.

The aspiration breathing was present in some early tetrapods, but it only arised when the early amniotes app- eared. Aspiration breathing evolved in two steps: first, from pure buccal pump breathing to the use of axial muscles for expiration and buccal pump for inspiration; second, to pure aspiration-breathing, in which axial muscles are used for both expiration and inspiration.

The musculoskeletal units responsible for breathing also serve other functions such as feeding or locomotion, and the conflicting mechanical requirements of multiple functions possibly constrain the performance and evolution of one or both functions. The evolution of aspiration breathing may have allowed the musculoskeletal systems of the head and tongue of amniotes to diversify, but the ribs and intercostal musculature became constrained by their dual function in aspiration breathing and high speed locomotion.

The loss of gills is also in connexion to the cutaneous respiration as a site gaseous exchange which can function in water and land.

So, the possible evolution of the respiratory mechanisms maybe begun with an ancestral fish adapted for oxygen uptake and CO_2 elimination in aquatic medium, but under conditions of low oxygen, developed adaptations that allowed the fish to come to the surface to obtain extra oxygen from the air, but the gills still functioned for CO_2 elimination.

At this stage of evolution, the skin would function mainly for CO_2 elimination and, as the lung became more efficient and more involved, not only in uptake of oxygen but also in elimination of carbon dioxide, the skin became less impor- tant and probably covered with hardened scales to reduce water loss and the animal could now remain away from water for longer periods. It seems possible to accept that the cutaneous respiration was important for the earliest land vertebrates.

RESPIRATORY ORGANS IN AMPHIBIANS

Based on paleontological criteria, the first amphibians have arisen by evolution of fish *Crossopterígeos ripidistios*, extinct in the late Devonian period.

Modern amphibians occupy a central position in under- standing the fundamental changes that have occurred in the evolution of air breathing. Dual subsistence in water and land has required development of certain respiratory adaptations.

The transition from aquatic to land environment exposed the gas exchange organ to a much richer oxygen ambience, which allowed a drastic reduction in the ventilation require- ments, but at the same time created problems for the disposal of carbon dioxide, because at 20ºC the water solubility of this gas is 28 times greater than that of oxygen.

To prevent a severe respiratory acidosis, the Terran animal began to use the skin as an important respiratory organ, designed especially for the removal of carbon dioxide, which required a substantially reduction of the barrier represented by the scales that covered the surface of their aquatic ancestors. At the same time there must have occurred an increased bicarbonate concentration in plasma, in order to compensate the increase of carbon dioxide.

These animals are mainly characterized for presenting an aquatic larval form, the tadpole stage, where hematosis takes place through the gills. Next they suffered a metamorphosis that allowed them to reach adulthood in terrestrial habitat and in which the breathing air was carried out by the lungs, skin and mouth. The amount of cutaneous and buccal gas exchange and its percentage in the total gas exchange, varied from species to species and also during seasons.

Amphibians have the simplest lungs, rudimentary lungs that are adequate for ectothermic and low aerobic meta- bolism animals.

The paired lungs of recent amphibians are unicameral lying in the dorsal pleuroperitoneal cavity. In the various amphibian species the lungs differ greatly in size, their topographic extension and the dimension of exchange surface by the development of interconnected folds with highly varying number of subdivisions and height of their folds. The highly varying extent in lung exchange is due to differences in the amount of gas exchange performed by via lungs in concert with cutaneous and buccal cavity exchange.

Moreover, the absence of an individualized chest well, with no ribs or diaphragm, the amphibian's pulmonary venti- lation is mainly accomplished at the expense of swallowing air, carried out by rising of the oral cavity floor.

The remarkable heterogeneity of the morphology of the amphibian gas exchangers matches that of the diversity of the environments in which the animals live, the lifestyle they pursue, and their pattern of interrupted development. The skin is the main pathway for gas transfer in aquatic species while in terrestrial ones, it has been relegated or rendered redundant.

In the salamanders (Plethodontidae), some of which live in cold well-aerated waters, gas exchange occurs across the skin and buccal cavity. Skin breathing is important in all extant amphibians but is the only means of gas exchange in those salamanders (terrestrial and aquatic) which possess neither lungs nor gills. Gas exchange takes place in the dense subepithelial capillary network, the inflow to which is in part from the arterial system and in part from a branch of the pulmonary arch carrying venous blood. The oxygenated cutaneous blood flows into the venous system. This is in contrast to the arrangement of pulmonary outflow in tetra- pods and lungfish which allows (complete or partial) separa- tion of oxygenated from venous blood.

The caecilians (Apoda) possess long, tubular lungs, but in some species the left lung is remarkably reduced or totally missing. The lungs of caecilians are internally sub- divided, forming air cells that are supported by diametrically placed trabeculae.

In the newts (Urodela), animals that are mostly aquatic, the lungs are poorly vascularised with the internal surface being smooth. Lungs of most amphibians such as *Amphiuma tridactum* and the cane toad, *Bufo marinus*, have an abundance of smooth muscle tissue, a feature that may explain the high compliance of the lungs. In *Amphiuma*, during expiration, the lung virtually collapses, producing an almost 100% turn-over of inspired air. *Amphiuma* is aquatic but has very well developed lungs.

The lungs of terrestrial species are highly elaborate pre- senting a series of stratified septa that divided the lung into small air cells and the lungs of Anura and Apoda are more complex than those of Urodela.

RESPIRATORY ORGANS IN REPTILES

It is assumed that reptiles made their appearance on Earth about 310 million years ago, and their adaptation was so perfect that they dominated the planet for over a hundred million years. The innumerous fossils that have been dis- covered allow us to group them in a numerous orders capable for living in different habitats, such as land, air or aquatic environment.

Reptilians are the first vertebrates adequately adapted for terrestrial habitation and utilization of lungs as a sole pathway for acquisition of oxygen. The skin that was no longer necessary for gas exchange, became an armor to protect against dehydration, being waterproof, dry, covered with keratinized epidermal scales or developing dermal bone plates.

Compared with their gigantic prehistoric ancestors, cur- rent reptiles are small and insignificant and can be grouped in four orders: chelonians, such as turtles and tortoises; rincocéfalos, like Sphenodon of New Zealand; crocodiles (crocodiles and caimans) and squamata order (lizards and snakes).

The reptilian display great pulmonary structural hetero- geneity and there is no single model of reptilian lung. Based on complexity of internal organization, different classification suggested that the turtles, monitor lizard, crocodiles and snakes have a profusely subdivided (multicameral) lung, the chameleons and iguanids have a simpler (paucicameral) lung and the teju lizard (*Tupinambis nigropunctatus*) have a saccular, smooth-walled, transparent (unicameral) lung.

Division of the lumen of the lung into a number of chambers, by septation, enlarges the exchange area, fact that is observed in turtles, lizards and crocodiles.

The lungs are localized in the pleuroperitoneal cavity and there is no diaphragm separating the thoracic from the abdominal cavity. Presence of ribs and intercostal muscles in reptiles, allow the development of more effective pulmonary ventilation than that of the amphibians which do not have these anatomical structures.

Generally, the pattern of organization of the respiratory system of reptiles is identical to mammals, with the lungs coated externally by a serosa. The conducting portions are supported by complete cartilaginous rings, which con- tinue through the extra and intrapulmonary bronchi. The branching of the bronchial intrapulmonary tree in reptiles is similar to mammals', however they have specific designations, which appear sequentially bronchus, tubular chambers, niches and aedicules.

The intrapulmonary bronchi of the reptiles that give immediate access to respiratory areas correspond to the mammalian respiratory bronchioles, the tubular chambers, according to their position and morphofunctional structure, are equivalent to the alveolar channels in mammals, and the niche are similar to alveolar sacs. By its position in the respiratory system and anatomical constitution the aedicules are equivalent to the alveoli of mammals, however they have an oblong structure compared with the spherical form of mammal's alveoli.

The intrapulmonary bronchi of turtles that live essentially in aquatic environment have a reinforcement that extends to or near the respiratory areas [64], characteristic that is similar to the aquatic mammals that have the ability to dive to great depths, such as seals, dolphins and whales. This reinforcement, along with the presence of a smooth muscle, appear to be adaptations that allow these animals to support the high pressures to which they are subjected during the immersion to great depths.

The epithelium of the trachea and bronchi is pseudo- stratified columnar ciliated, with non ciliated secretory cells and basal cells, all in direct contact with the basal membrane. Isolated or groups of neuroendocrine cells were also identified within the conducting portion of the lung of turtles and crocodiles.

The epithelial cells lining the respiratory surface of reptilian lungs are differentiated into type I and type II cells and it is possible to observe multilamellar bodies similar to those present in mammals. These suggest that also in reptiles occurs the synthesis of surfactant lipo- protein material responsible for the stability of their respiratory unit, the aedicula.

The role of surfactant in reptiles, which are not highly susceptible to collapse from surface tension forces, is obscure, and may have other important functions such as prevention of transendothelial transudation of blood plasma across the blood-gas barrier, immune suppression and attraction of macrophages.

Reptilian lungs have preponderance of smooth muscle tissue and this tissue has been associated with intrapul- monary connective movement of air.

RESPIRATORY SYSTEM IN BIRDS

Birds' respiratory system, the lung – air sac system, is the most complex and efficient gas exchanger that has evolved in air-breathing vertebrates. The compact and virtually cons- tant-volume avian lung has been totally uncoupled from the compliant, avascular air sacs.

The main properties that impart high respiratory efficiency on the lung–air sac system of birds are a cross-current design and inbuilt multicapillary serial arterialisation system; auxiliary counter-current system; large tidal volume; large cardiac output; continuous and unidirectional parabronchial ventilation; short pulmonary circulatory time; superior mor- phometric parameters a particularly large respiratory surface area and a remarkably thin blood-gas (tissue) barrier.

Their respiratory system allows them to breathe at alti- tudes that can reach nine thousand meters without acclimatization, fact that is impossible for humans and other mammals, in which the barometric pressure of high altitudes can at least induce a comatose state.

To maintain physiological function at high altitude, under reduced environmental oxygen availability, the capacity to transport O_2 must increase. The exposure to hypoxia causes an immediate increase in breathing due to stimulation of arterial chemoreceptors and changes in metabolic state. The ability to adjust peripheral heat dissipation to facilitate the depression of body temperature during hypoxia, which reduced the metabolic demand, allows birds to fly high and for long periods, and is a result of an evolutionary adaptation. The bar-headed goose, a typical high altitude bird, depresses metabolism less than low-altitude birds during hypoxia and breathes substantially more than birds that fly at low altitudes. The bar-headed goose has a haemoglobin with higher O_2 affinity and may be capable of generating higher inspiratory airflows.

The respiratory system of birds is separated into lung (the gas exchanging part) and a series of airs sacs (non res- piratory) with anastomosing air capillaries and pneumatized bones, that allow unidirectional flow of air, compared to the blind sac and tidal flow in mammalian lungs.

Lack of diaphragm displaced the lungs to the coelomic cavity where they are closely attached to the ribs. Inter- calated between the sacs, the lungs are largely continuously ventilated back-to-front by a concerted action of the cranial and caudal groups of air sacs.

There are fundamental differences in the breathing mechanics of different birds, driven in part by the morpho- logical differences of the rib cage and sternum associated with skeletal adaptations to locomotion. The uncinate processes are bony projections that extend from the vertebral ribs, providing attachment sites for respiratory muscles.

The elongation of ribs, rib cage and sternum associated with diving species, as well as longer uncinates, maybe important upon resurfacing when inspiration occurs against the pressure of water against the body. The reduction in the sternum and the shortest uncinate length found in the walking species, suggests that they may play a reduced role during breathing in these species.

The circular lumen of the trachea has a cartilaginous or partially ossified support ring, whose number varies accord- ing to species [76] and is lined by a cilindric pseudociliated epithelium with goblet cells [83]. The trachea bifurcates into two primary bronchi, with an epithelial lining similar to the trachea but with incomplete cartilaginous rings, which disappear or are reduced when they reach the bronchial lung parenchyma [83].

The connection between the primary bronchus and the secondary and tertiary bronchi is labyrinthic, markedly opposed to the monopodic branch of mammal. The primary bronchus gives rise to four craneo-medium secondary bron- chus and to seven caudal-dorsal secondary bronchus [11, 76]. In the secondary bronchus the mucosa is lined by a simple cuboidal or columnar epithelium, without goblet cells [83]. Tertiary bronchus or parabronchus are arranged in a series of parallel lines, whose ends are open to the secondary bronchus. All the way through the parabronchus have recurrent anastomoses between them . The number of parabronchus varies from species to species, but is higher in the birds that fly better has been estimated in *Gallus domesticus* between 300 and 500 parabronchus. Parabronchus have an average diameter of 500 μm, and are lined by a simple squamous epithelium, just like the mammals' alveolar channels.

The circular lumen of the trachea has a cartilaginous or partially ossified support ring, Along the inner surface of parabronchus, small vesicular structures with hexagonal shape emerge, with 100 to 200 μm in diameter. These structures called atria are separated from each other by septa mainly consisting of smooth muscle cells located in the freeboard, and collagen and elastic fibers, located at the base. The atria epithelium has two types of cells, one of which are the granular cells that are confined to the atria, have a cytoplasm that contains multilamellar bodies and are considered analogous to the cells of type II pneumocytes of the mammal's lungs. The other are the squamous cells, which line the inner surface of the atria and are based on a continuous basal membrane, forming the simple squamous epithelium. From the deepest area of each atria arise 2 to 4 infundibula that continue with the air capillaries with 3 to 10 µm diameter. They are lined by squamous cells, that are similar to the cells of the atria, but they are not based on the basal membrane. The infundibula and air capillaries of adjacent atria form anastomosis to one another.

The blood capillaries are surrounded by extremely small air capillaries and other capillaries, which give an appearance of a dense network. The blood capillaries are embedded in a rigid structure with numerous cross-braces that provide mechanical support of the small vessels at numerous points. This feature contributes to mechanical strength of blood capillaries and allows them to have a remarkably thin blood-gas barrier (BGB) that is uniformly arranged all around the circumference of the blood capillary.

The diameters of the air capillaries are comparable to those of blood capillaries and as a consequence of the very small diameter, the surface tension of these air capillaries is so high, despite their very well-differentiated surfactant, that they can only remain patent as rigid structures in a volume- constant lung . The surfactant of these rigid air capillaries lowers the high air capillary surface tension to such an extent that the remaining surface tension cannot suck fluid from the blood into the air capillary, thus preventing edema and maintaining gas exchange.

Together with the extensive network of blood capillaries, the air capillaries form the gas exchange surface of the bird's lungs.

Unlike those observed in lung alveoli of mammals, the air capillaries are not terminal fund sacs formations, and therefore allow an unidirectional air flow through the lungs of birds.

The lung air sacs are pair formations, and their total number for the two lungs varies between 6 and 14 depending on the species, are generally referred to as cranial group and caudal group, and all cranial bags communicate with all secondary bronchi, fact that does not occur with caudal bags. The oxygen concentration is higher inside the caudal bags whereas the concentration of carbon dioxide reaches higher values inside the cranial bags. This qualitative difference is explained by the particular pattern of unidirectional airflow that occurs in the lungs of birds.

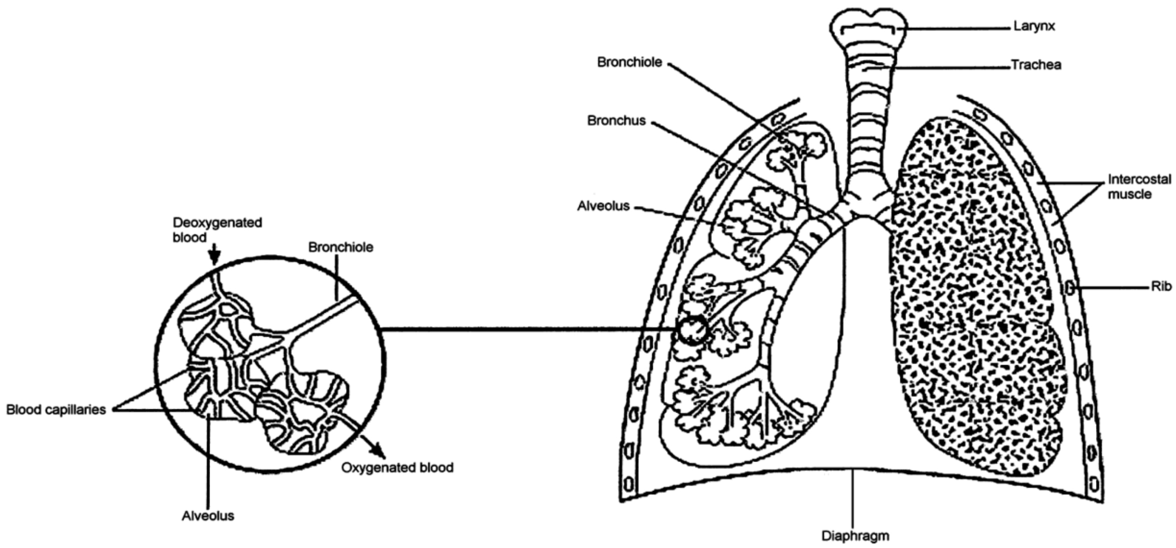
The inhaled air moves into the respiratory system, when- ever the chest cavity expands by the action of inspiratory muscles, and during expiration the air is expelled by action of the expiratory muscles. Although the birds do not have diaphragm, the entry and exit of air in to the respiratory system is a process similar to the observed in mammals.

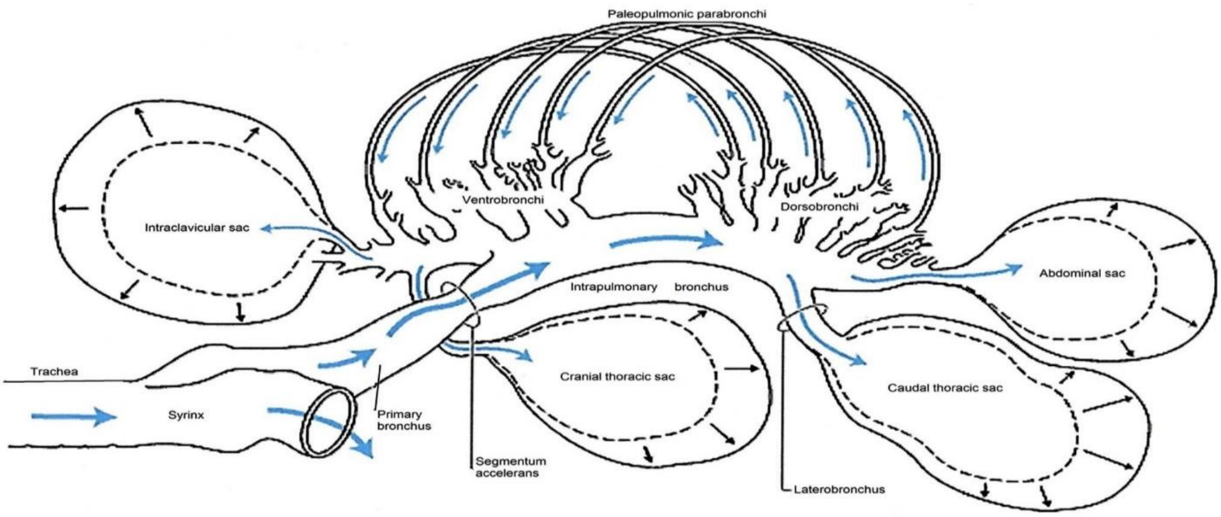
During inhalation, air flows through the mesobronchus in to the posterior air sacs, and at the same time, the air enters the anterior air sacs via the dorsal secondary bronchus and parabronchus. During exhalation, the air leaves the posterior air sacs and passes through the parabronchus, and to a lesser extent, through the mesobronchus, to the trachea. At the same time in the anterior air sacs, the air moves through the secondary ventral bronchus towards the trachea

There is thus, during the two phases of the respiratory cycle, a continuous unidirectional flow through the parabronchus.

The flow inside the air capillaries and inside the blood capillaries occurs in opposite directions, i.e., in the blood capillaries the flow goes from the most peripheral areas of the parabronchus into its axis, while in the air capillaries move away from the axis of parabronchus. It is established a counter-current system of gas exchange between air capillaries and blood capillaries.

Briefly we can say that the anatomical and physiological features that have just been summarily exposed, such as a continuous and unidirectional ventilation of parabronchus, lower capacity of the air sacs, large surface for gas exchange and a very thin air-blood barrier, explain the unique charac- teristics of the respiratory system of birds, allowing them to extract oxygen from the highly rarefied air atmosphere.





RESPIRATORY SYSTEM IN MAMMALS

Some 300 million years ago, the ancestors of modern reptiles finally emerged completely from water and made a commitment to air breathing. From them, developed the two great classes of vertebrates with high maximal oxygen consumption: the mammals and the birds. A remarkable feature of these two groups is that although the cardiovas- cular, renal, gastrointestinal, endocrine and nervous systems

Comparation between the birds (A) and mammals (B) respiratory systems.

show many similarities, the lungs are radically different. The distinct morphology of avian and mammalian lungs reflects not only an increased demand for gas exchange, but is historically correlated with the divergent modes of locomotion that facilitate higher rates of ventilations.

It is thought that mammals made their appearance on Earth during the Jurassic Period, the age of reptiles, when the process of divergence of the continents begun.

Mammals evolved homoiothermy independently from birds, but in a very similar way. For the mandatory increased metabolism, they required a correspondingly increased gas exchange surface, which became available by the develop- ment of the broncho-alveolar lung.

The nearest ancestors of mammals appear to have been same group of reptiles and the lung of the mammals derived from a multicameral reptilian lung with three rows of lung chambers. The branched conducting bronchial system originated by stepwise further subdivision of these lung chambers, terminating in the branched respiratory bronchioli and ductus, covered with alveoli.

of all tetrapods' breathing systems, the mammals' respi- ratory system has been the most extensively studied, often with the aim to acquire knowledge with medical relevance.

In mammals there is no dissociation between locomotion and respiratory movements and both are closely coupled especially during exercise.

The strong musculature of the diaphragm does not only act as a forceful inspiratory muscle together with the inter- costals musculature, but is also responsible for maintaining a pressure gradient between the pleural and the peritoneal activity during strong exercise. During respiration at rest, expiration is performed by elastic retractile forces of the extended rib cage and by the retraction forces of the lung itself out of the surface tension of the alveoli together with their extended elastic fibre systems. During exercise, expiratory movement of the intercostals musculature is strongly supported by the muscles of the abdominal wall, which is also the case for all sound productions, speech and singing.

In mammals the lungs do not empty completely during the expiration, and the result is that convective flow alone cannot take the inspired gas to the periphery of the lung where some of the gas-exchanging alveoli are located. Instead the last part of the distance is accomplished by a relatively large peripheral airways to allow mixing of the inspired air with that already in the lung, and the resulting large alveoli cause additional problems.

In the mammalian lung, the airway and vascular systems form a complex multigenerational dichotomous branching tree-like arrangement. Transported by bulk-flow (con- vention) in the initial (large) parts of the bronchial system and mainly by diffusion in the terminal (fine) sections of the airway system, the inspired air ultimately reaches the alveoli where it is exposed to capillary blood across a thin, extensive tissue barrier.

The alveolar surface is mainly lined by type I and type II cells. Type II cells secrete surfactant.

In mammals the capillaries are located in the alveolar walls which are widely separated from each other. Thus the BGB has to withstand the full transmural pressure. The capillary is typically polarized with one side having very thin BGB whereas on the other side the barrier is thicker and contains strands of type collagen which provides support for the alveolar wall and maintains the integrity of the alveoli. In contrast to an uniform thin BGB in the birds, in mammals half of the surface area of the capillaries provides inefficient gas exchange due to its increased thickness.

MECHANISM OF RESPIRATION

Fish: Blood passing through the gills is pumped in the opposite direction to the water flowing over these structures to increase oxygen absorption efficiency.
This also ensures that the blood oxygen level is always less than the surrounding water, to encourage diffusion. The oxygen itself enters the blood because there is less concentration in the blood than in the

water: it passes through the thin membranes and is picked up by hemoglobin in red blood cells, then transported throughout the fish's body.

Aquatic Gills Water flows through the mouth then over the gills where oxygen is removed. Carbon dioxide and water are then pumped out through the operculum.
Amphibians: Most amphibians breathe with gills as larvae and with lungs as adults. Additional oxygen is absorbed through the skin in most species. The skin is kept moist by mucus, which is secreted by mucous glands. In some species, mucous glands also produce toxins, which help protect the amphibians from predators.

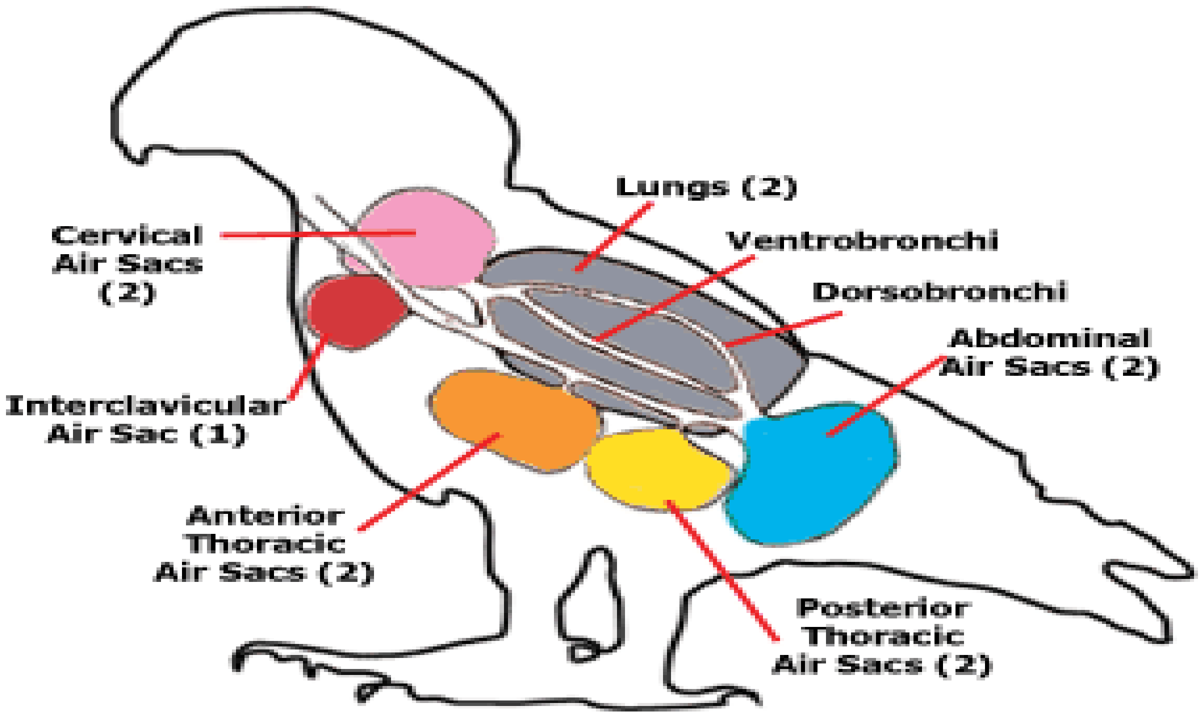
Reptiles: The scales of reptiles prevent them from absorbing oxygen through their skin, as amphibians can. Reptiles breathe air only through their lungs. Their lungs are more efficient than the lungs of amphibians, with more surface area for gas exchange.

This is another important reptile adaptation for life on land. Reptiles have various ways of moving air into and out of their lungs. Lizards and snakes use muscles of the chest wall for this purpose. These are the same muscles used for running, so lizards have to hold their breath when they run. Crocodiles and alligators have a large sheet of muscle below the lungs, called a diaphragm, that controls their breathing.

This structure is also found in mammals. Gas exchange in reptiles still occurs in alveoli however, reptiles do not possess a diaphragm. Breathing occurs via a change in the volume of the body cavity which is controlled by contraction of muscles in all reptiles except turtles.

Birds: Respiration in birds is much different than in mammals. Birds have a larynx, but it is not used to make sounds. Birds have lungs and air sacs. Depending upon the species, the bird has seven or nine air sacs. The air sacs permit a unidirectional flow of air through the lungs. Unidirectional flow means that air moving through bird lungs is largely 'fresh' air & has a higher oxygen content. As a result, air coming into a mammal's lungs is mixed with 'old' air (air that has been in the lungs for a while) & this 'mixed air' has less oxygen. So, in bird lungs, more oxygen is available to diffuse into the blood. In contrast, air flow is 'bidirectional' in mammals, moving back and forth into and out of the lungs.

Mammals: The chief organ in mammalian respiration is the lungs. Breathing is dependent upon the rib muscles and the diaphragm, a structure shaped like a dome-shaped floor just beneath the lungs. Inhalation happens when the rib cage opens up and the diaphragm flattens and moves downward.



The lungs expand into the larger space, causing the air pressure inside to decrease. Drop in air pressure inside the lung makes the outside air rush in. Exhalation is the opposite process. The diaphragm and the rib muscles relax to their neutral state, causing the lungs to contract. The squashing of the lungs increases their air pressure and forces the air to flow out.

Oxygen enters the body in the mouth and nose, passes through the larynx and the trachea. The trachea splits into two bronchial tubes, which lead to smaller tubes that lead to 600 million alveoli surrounded by capillaries. The capillaries take oxygen into the arteries, and the oxygen-rich blood is pumped into every cell of body. Once the oxygen has been absorbed, carbon dioxide and water are eliminated through the lungs.

Prof. M. Jagadish Naik

LESSON - 15
CIRCULATORY SYSTEM

EVOLUTION OF HEART IN VERTEBRATES

The heart is an unpaired organ but its origin is bilateral. In an embryo the mesenchyme forms a group of endocardial cells below the pharynx. These cells become arranged to form a pair of thin endothelial tubes. The two endothelial tubes soon fuse to form a single endocardial tube lying longitudinally below the pharynx. The splanchnic mesoderm lying below the endoderm gets folded longitudinally around the endocardial tube. This two-layered tube will form the heart in which the splanchnic mesoderm thickens to form a myocardium or muscular wall of the heart and an outer thin epicardium or visceral pericardium. The endocardial tube becomes the lining of the heart known as endocardium. Folds of splanchnic mesoderm meet above to form a dorsal mesocardium which suspends the heart in the coelom. Soon a transverse septum is formed behind the heart which divides the coelom into two chambers, an anterior pericardial cavity enclosing the heart and a posterior abdominal cavity. The heart is a straight tube but it increases in length and becomes S-shaped because its ends are fixed. Appearance of valves, constriction, partitions in the heart, and differential thickenings of its walls form three or four chambers in the heart.

1. Single-Chambered Heart: In Amphioxus (primitive chordate), a true heart is not found. A part of ventral aorta beneath the pharynx is muscular and contractile and acts as heart.

CephaIochordata. In a primitive chordate, such as Branchiostoma, a true heart is lacking. Instead a part of ventral, am1a below pharynx becomes muscular and contractile. Some zoologists consider it as a single-chambered heart. Progressive modifications of heart from primitive to higher chordates occurs on the following lines :

(l) Cardiac tube constrictions. forms chambers due
(2) Each chamber tends to divide into two separate chambers due to formations of partitions.
(3) Heart gradually shifts from just behind head (fishes, amphibians) near gills' into thoracic cavity (amniotes) with elongation of neck and development of lungs.

2. Two-Chambered Heart: In cyclostomes, there are four chambers arranged in a linear order- a thin-walled sinus venosus, a slightly muscular atrium (auricle), a muscular ventricle and a muscular conus arteriosus or bulbus cordis. It lies in the body cavity in which other visceral organs are also present.

Out of four chambers, only atrium and ventricle correspond to the four chambers (paired atria and paired ventricles) of the higher vertebrates. In the evolution of heart many changes have taken place.

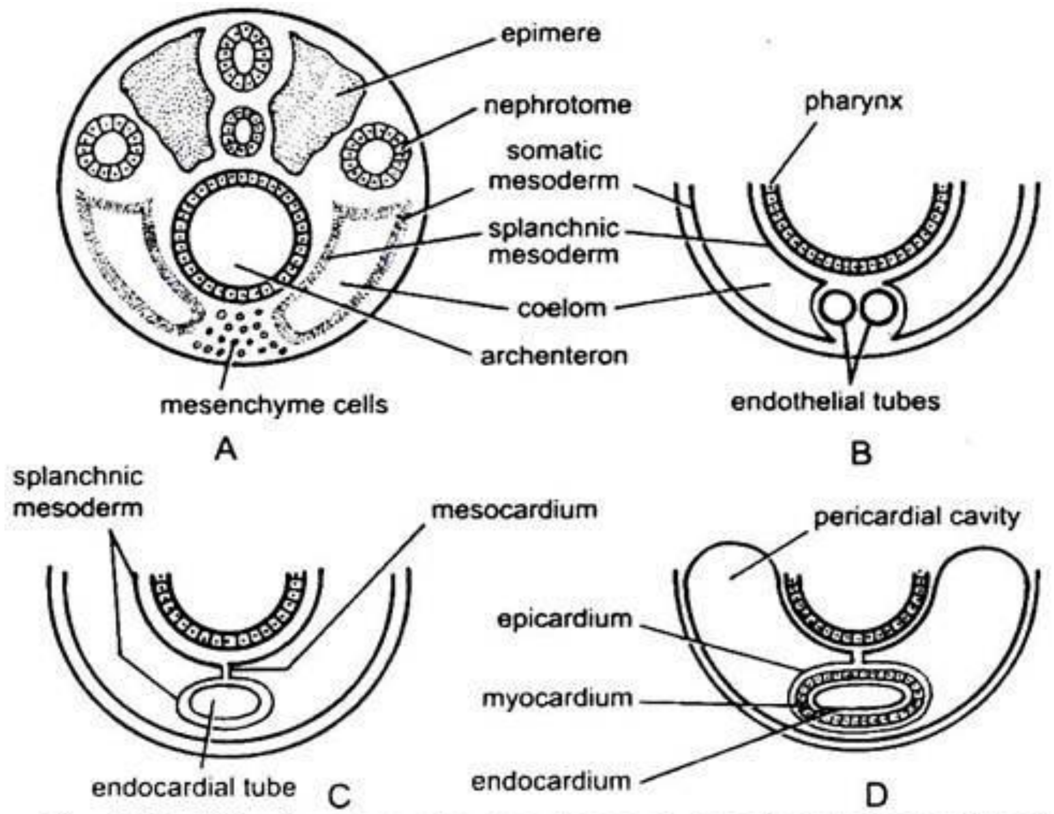
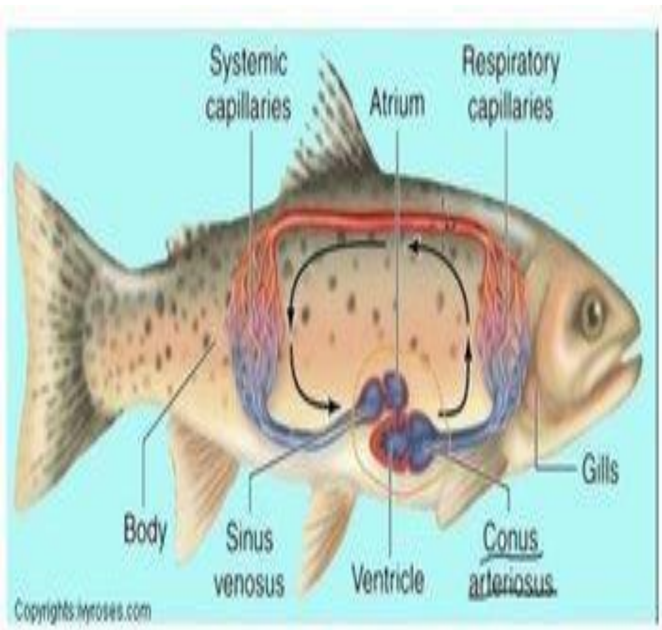


Fig. 45.2. T.S. of embryo showing stages in the development of heart.



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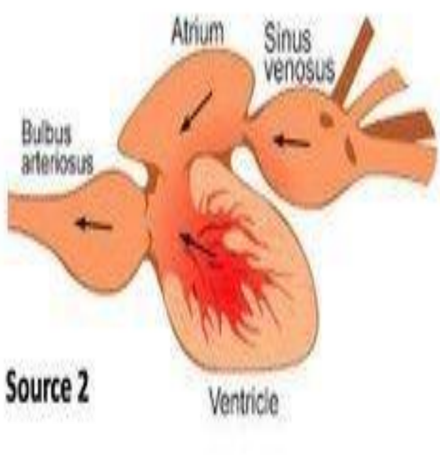


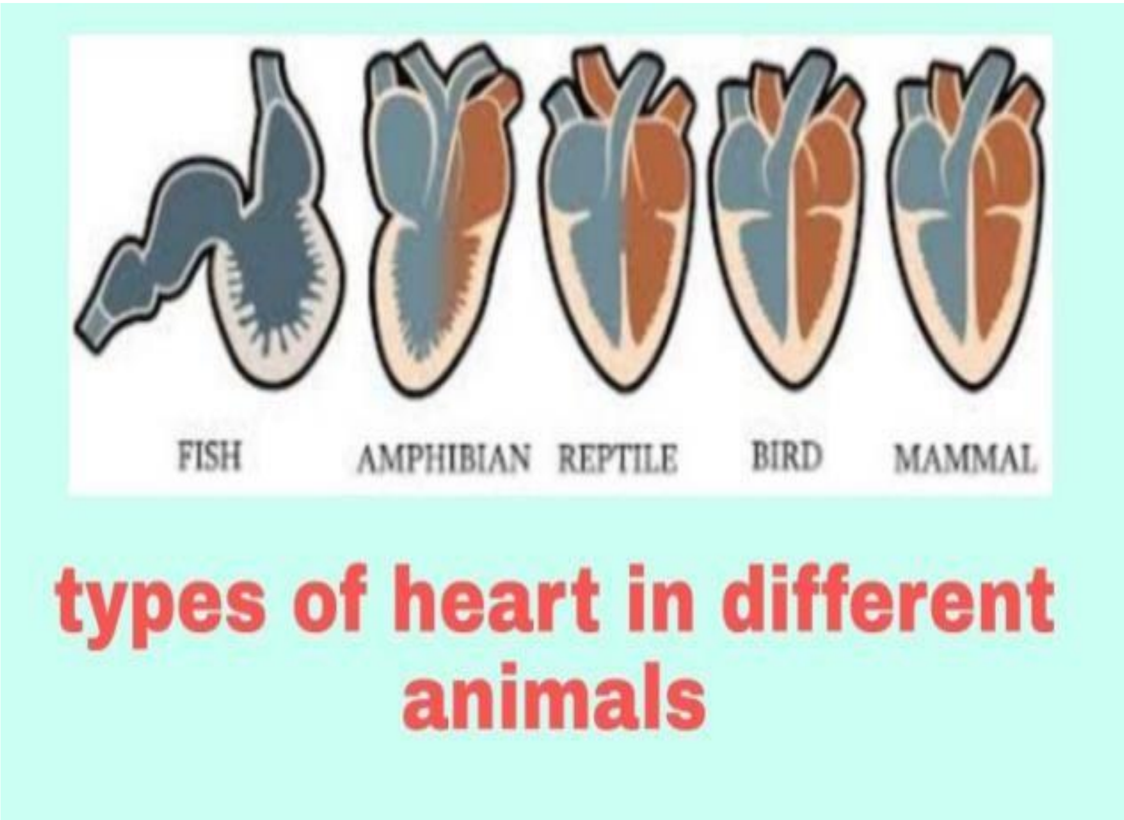
Elasmobranchs: Except Dipnoi, the circulatory system in fishes from cyclostomes to teleosts, only unoxygenated blood goes to the heart, from there it is pumped to the gills, aerated and then distributed to the body. The heart of cartilaginous dogfish is muscular and dorsoventrally bent S-shaped tube with four compartments in a linear series.

They are sinus venosus and atrium for receiving venous blood, and a ventricle and conus arteriosus for pumping this blood. The heart is a branchial venous heart. The sinus venosus and conus arteriosus are accessory chambers. Atrium and ventricle are true chambers, thus, it is a 2-chambered heart. The sinus venosus opens anteriorly into atrium through sinu-atrial aperture guarded by a pair of valves. Atrium lies dorsal to ventricle and opens ventrally into ventricle through an atrio-ventricular aperture guarded by a pair of valves. The thick-walled, muscular ventricle opens into a narrow conus arteriosus containing valves in two series

The heart is enclosed within pericardial cavity separated from body cavity by a transverse septum. Conus pierces the pericardium and becomes continuous with the ventral aorta. Pericardial cavity communicates with the body cavity through two perforations in the transverse septum.

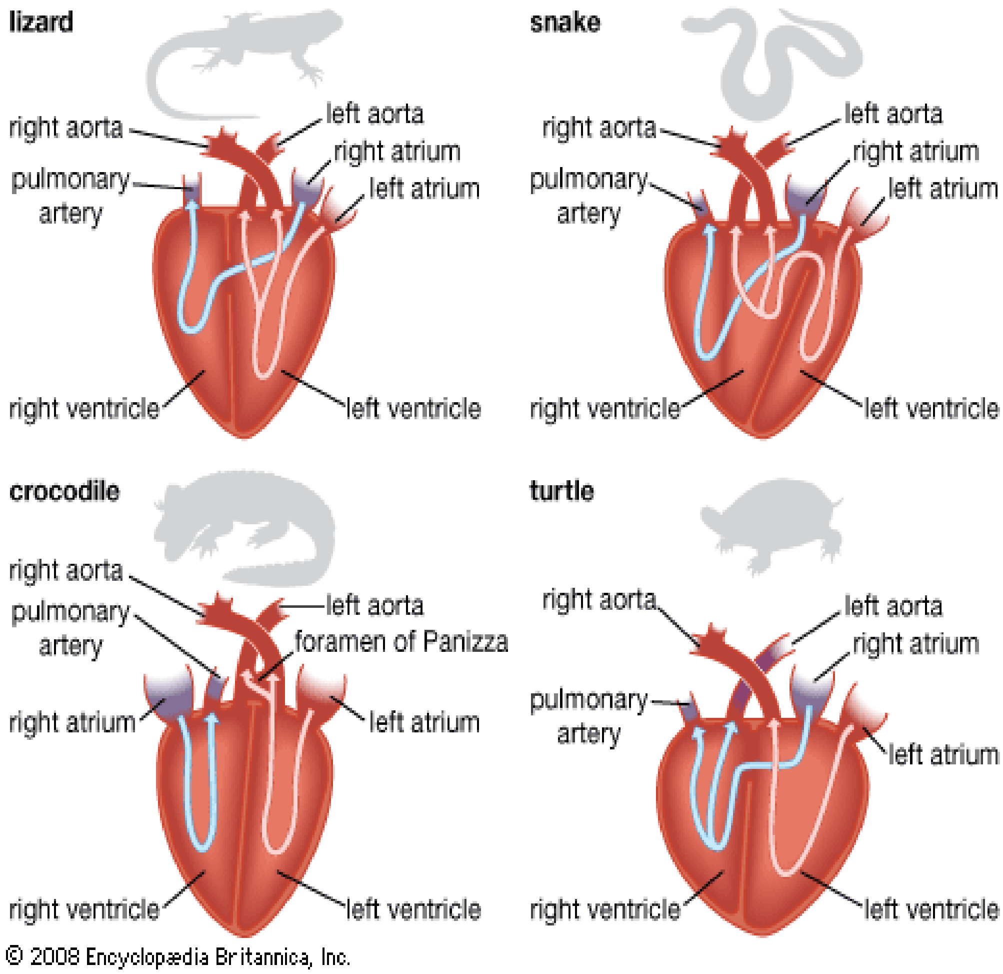
Teleosts: Their heart resembles to that of clasmobranchs. In teleosts, the conus is reduced and has a single pair of valves. The proximal part of ventral aorta close to conus becomes greatly enlarged and thick-walled, called bulbus arteriosus. It is elastic and dilates at the time of ventricular contraction. The heart is, thus, 2-chambered with a single circulation of blood.

3. Three-Chambered Heart: In diphoans a septum divides the atrium into a right and left chamber. This is correlated with the use of the swim-bladder as an organ of respiration and represents the first step toward the development of the double-type circulatory system whereby both oxygenated and unoxygenated blood enter the heart and are kept separate. Blood from right auricle of the lungfish passes into the right ventricle and is then pumped into the primitive lung-like gas bladder by pulmonary arteries which branch off from the sixth pair of aortic arches. The oxygenated blood returns to the left atrium by way of pulmonary veins like amphibians.



Amphibia: In amphibians, the dorsal atrium shifts anterior to ventricle. The sinus venosus opens into right atrium dorsally and not posteriorly. The atrium is completely divided into right and left chambers and has no foramen ovale in the inter-auricular septum, which remains open in dipnoans. Deep pockets develop in the ventricular cavity. The conus arteriosus divides into systemic and pulmonary vessels by a spiral valve. In lung less salamanders, the inter atrial septum is incomplete and pulmonary veins are absent.

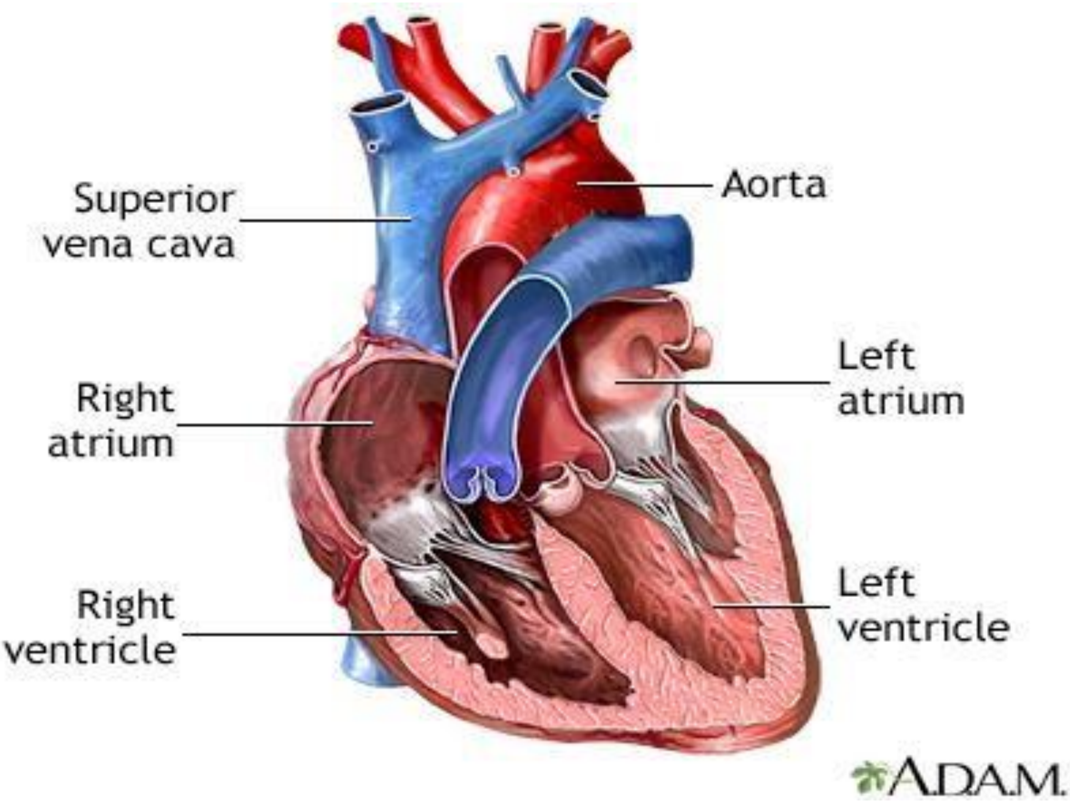
Reptilia: In reptiles, the heart is further advanced. The atrium is always completely separated into a right and left chamber, and in many forms the sinus venosus is incorporated into the wall of the right atrium. The ventricle is also partly divided by a septum in most reptiles, and in the alligators and crocodiles is completely two-chambered. This means that oxygenated blood coming from the lungs to the left side of the heart is essentially separated from the non-oxygenated blood from the body to the right side. Thus, in crocodilians, the two types of blood is completely separated, and nearly complete in other reptiles, but some mixing does occur in other parts of the circulatory system. The embryonic conus arteriosus splits into three instead of two vessels:



(i) Pulmonary arch carrying blood to the lungs from right side of the ventricle.
(ii) Right systemic aorta carrying blood from left side of the ventricle to the body by way of right fourth aortic arch.

(iii) Left systemic comes from the right ventricle to the left fourth aortic arch. At the point of contact with the systemic aorta from the left ventricle, even in crocodilians, an opening between the two is present, called the foramen of Panizzae where there may be some mixing of the two types of blood. Thus, reptilian heart represents the transitional heart against amphibian heart-2 complete auricles and 2 incomplete ventricles with a little mixing of blood in right and left systemic.

1. **Four-Chambered Heart:** Aves and Mammalia: In birds, the ventricle is completely divided into two, so that the heart is four chambered (2 auricles and 2 ventricles). There is complete separation of venous and arterial blood. The systemic aorta leaves the left ventricle and carries blood to the head and body. While the pulmonary artery leaves the right ventricle and carries blood to the lungs for oxygenation. Thus, there is double circulation in which there is no mixing of blood at any place. The sinus venosus is completely incorporated into right auricle, which receives two precavals and a postcaval. The left auricle receives oxygenated blood through pulmonary veins, conus arteriosus is absent, arises from the left ventricle, and both have valves at their bases.



BIRDS AND MAMMALS

Birds and mammals have a completely divided ventricle, so that their heart is completely 4-chambered (2-auricles, 2 ventricles). Circulatory System in Vertebrates Left auricle receives aerated blood from lungs, pours into left ventricle which pumps it to entire body through systemic circulation. Right auricle receives deoxygenated blood returning from body, passes it to right ventricle which pumps it to lungs fot' reoxygenation. Thus there is double circulation in which there is no mixing of oxygenated and non-oxygenated blood at all. Such a heart is known as a pulmonary heart. Sinus venosus is absent being completely incorporated into right auricle which directly receives two precavals, postcaval. The union of sinus with right auricle in some cases is marked externally by a groove called sulcus terminalis and internally by a muscular ridge, crista terminalis which separates right auricular chamber (sinus venerum) from smaller ventral chamber (appendix auricular). Similarly, the left auricle receives blood directly through pulmonary veins. Primitive conus arteriosus is completely replaced by a pulmonary aorta leaving the right ventricle for lungs, and a single systemic aorta leaving the left ventricle for body. All major vessels have valves basally at the point of exit from or entry into heart. Blood from the walls of the heart is brought to the auricle by means of coronary sinus in right atrium. The opening of the sinus is guarded by valves called coronary valve (= Thebsian valve). The inner surface of right auricle wall is marked by small depressions of Thebesian foramina in which fine veins directly pass the blood from atrial walls to right atrium. Although, interauricular septum is complete in adults but a fine depression, fossa ovalis is present which marks the site of foramen ova Ie. The fossa ovalis is surrounded by a prominent ridge annulus ovalis.

The pulmonary aorta arises from the right ventricle, and single systemic aort

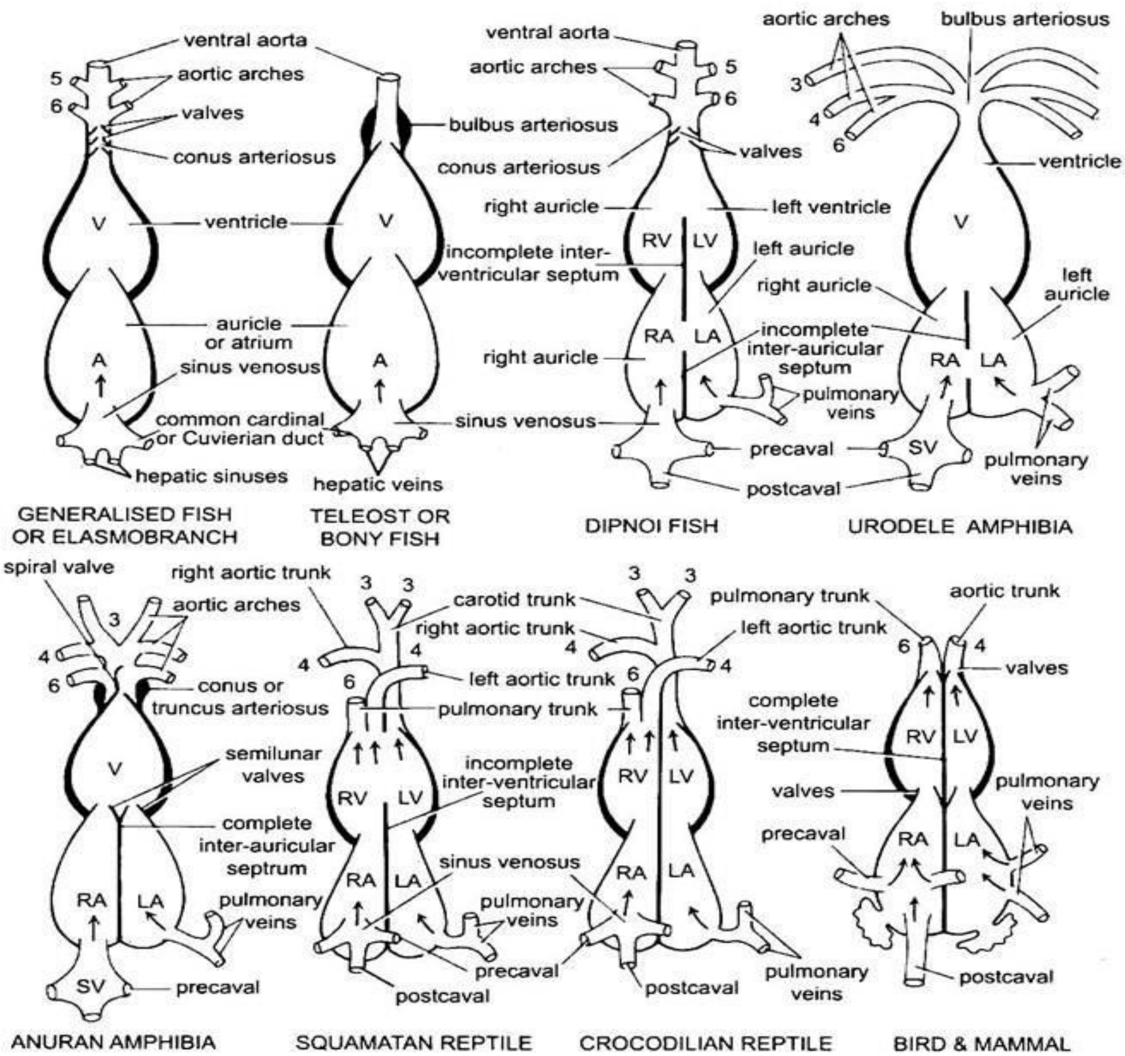


Fig. 45.4. Evolution of heart in different classes of vertebrates.

Prof. M. Jagadish Naik

LESSON - 16
EVOLUTION OF AORTIC ARCHES AND PORTAL SYSTEM AMONG VERTEBRATES

OBJECTIVES

16.1 BASIC EMBRYONIC PLAN

In typical vertebrate embryo, major arterial channels: –Ventral aorta—Dorsal aorta 6 pairs of Aortic Arches: connecting Ventral & Dorsal aorta Blood leaves heart through ventral aorta ◊ runs forward, midventrally, beneath the pharynx ◊ branches anteriorly into a pair of External Carotid Arteries into head. In between, the Ventral aorta gives off 6 pairs of aortic arches running through visceral arches Each aortic arch consists of a Ventral Afferent Branchial Artery carrying venous blood to capillaries in a gill Dorsal Efferent Branchial Artery taking arterial blood from the gill.

All efferent branchial arteries of the same side join dorsally to form a Lateral DorsalAorta/ Radix Radix extend into head as Internal Carotid Artery. The two lateral dorsal aortae unite just behind the pharynx to form a single Median Dorsal Aorta which continues behind into tail region as Caudal artery. Branches from these main arterial channels supply all parts of the vertebrate body.Although arterial system of different adult vertebrates shows major differences, but it is actually built according to the same basic architectural plan as seen in the vertebrate embryo. The differences are due to increasing complexity of heart on account of a shift from gill respiration to lung respiration.The modifications mainly concern the aortic arches which undergo a progressive reduction in number from lower to higher vertebrates

16.2 MODIFICATIONS IN AORTIC ACHES IN VERTEBRATE ADULTS PRIMITIVE VERTEBRATES

Branchiostoma (Amphioxus): Nearly 60 pairs of aortic arches are present, connecting the ventral and dorsal aortae

Petromyzon: 7 pairs of aortic arches are found

Other cyclostomes: varies from 6 (Myxine) to 15 pairs (Eptatretus) fishes • **Embryos:**primitive plan with 6 or more pairs of aortic arches, each passing through a gill.

Adults:the number is reduced to 4 or 5 Elasmobranchs., Sharks: only 5 pairs (II, III, IV, V, and VI) are functional.

1st gill slit forms the spiracle (a non-functional gill) 1st arch (mandibular) is absent or represented by an efferent pseudobranchial artery.

Heptanchus:7 pairs of aortic arches

Each arch forms one afferent and two efferent arteries (by splitting) in each gill.
Bony fishes

Teleosts:I and II arches disappear, so that only 4 pairs (III, IV, V and VI) remain functional.
Each gill has one afferent and one efferent artery Lungfishes • Polypterus and lungfishes

(Dipnoi): Gills are poorly developed, so that a pulmonary artery arises from the efferent part of the VI arch on both sides and supplies blood to the developing air bladder or lung.

Protopterus: III and IV embryonic arches are uninterrupted by gill capillaries Each arch forms one afferent and two efferent arteries (by splitting) in each gill.

Tetrapods: No true internal gills◊ so aortic arches do not break up into afferent and efferent arteries I and II arches totally disappear in all tetrapods.

Amphibians: Transition from gills to lungs urodeles live in water and retain external gills + lungs. So, aortic system shows only partial shift w.r.t. fishes. 4 pairs of arches (III to VI). Except Necturus, Siren, Amphiuma – V arch = incomplete, reduced or absent only 3 pairs of aortic arches. III arch forms the carotid arches, IV the systemic arches. The radix or lateral aorta between III & IV arches may persist as a vascular connection: ductus caroticus. VI arch on either side becomes the pulmocutaneous artery or arch, supplying blood to skin and lungs. It also retains connection with radix aorta called ductus Botaili or ductus arteriosus.

Anurans: larvae- arrangement of aortic arches = adult urodele (gill respiration). At metamorphosis, with loss of gills, aortic arches I, II and V disappear.Ductus caroticus disappears so that the III or carotid arch takes oxygenated blood only to head region. IV or systemic arch on each side continues to dorsal aorta to distribute blood elsewhere except head and lungs. Ductus arteriosus disappears so that VI or pulmocutaneous arch supplies venous blood exclusively to lungs and skin for purification. Adults exhibit only 3 functional arches, (III, IV and VI) similar to amniotes.

Reptiles: Fully terrestrial vertebrates, gills disappear altogether & are replaced by lungs. Only 3 functional arches (in, IV and VI) present. Elongation of neck, posterior shifting of heart and partial division of ventricle brings about certain innovations in the aortic system 1. 2. 3. 4. 5. Entire ventral aorta and Conus split: forming only 3 trunks-two aortic/systemic + one pulmonary Right systemic arch (IV): arises from left ventricle carrying oxygenated blood to the carotid arch (III) to be sent into head Left systemic arch (IV) leads from right ventricle carrying deoxygenated or mixed blood to the body through dorsal aorta Pulmonary trunk (VI) also emerges from right ventricle carrying deoxygenated blood to the lungs for purification Ductus caroticus and ductus arteriosus are absent. But, ductus caroticus is present in certain snakes and lizards (Uromasitx), ductus arteriosus in some turtles, and both in Sphenodon. Reptiles also remain cold-blooded, like amphibians and fishes, due to mixing of blood.

16.3 BIRDS AND MAMMALS

Warm-blooded: ventricle is completely divided, no mixing of O2 and deO2 bloods as usual, 6 arches develop in the embryo, but only 3 (III, IV, VI) persist in the adult Other modifications include

1. Ventral aorta is replaced by two independent aortae or trunks-systemic & pulmonary
2. IV arch is represented by a single systemic aorta, right in birds and left in mammals, emerging from left ventricle and carrying oxygenated blood. Uniting with the radix aorta of its side it forms the dorsal aorta.
3. The only remaining part of the other lost systemic arch is represented by a subclavian artery, on left side in birds and on right side in mammals.
4. Arch III with remnants of lateral and ventral aortae represents carotid arteries, which arise from systemic aorta.
5. Arch VI forms a single pulmonary trunk taking deoxygenated blood from right ventricle to the lungs.
6. Embryonic ductus caroticus and ductus arteriosus also disappear. The latter closes but persists until hatching or birth in some cases as a thin ligament of Botalli or ligamentum arteriosu.

Renal Portal system: Amphibians & some reptiles - acquires a tributary (external iliac vein; not homologous to mammalian external iliac) which carries some blood from the hind limbs to the renal portal vein. This channel provides an alternate route from the hind limbs to the heart. o Crocodilians & birds - some blood passing from hind limbs to the renal portal by-passes kidney capillaries, going straight through the kidneys to the postcava (see diagram above) o Mammals - renal portal system not present in adults

Hepatic Portal system - similar in all vertebrates; drains stomach, pancreas, intestine, & spleen & terminates in capillaries of liver

Pulmonary veins - carry blood from lungs to left atrium in lungfish &tetrapods.

16.4 SUMMARY

Students should be able to describe the

- Salient features and morphology of vertebrates
- Comparative account of respiratory organs; evolution of heart, aortic arches and portal systems among vertebrates
- Student will get complete knowledge about comparative accounts of vertebrates.

16.5 KEY WORDS

Ectoderm: The ectoderm is one of the three primary germ layers formed in early embryonic development.

Endoderm: Endoderm is the innermost of the three primary germ layers in the very early embryo.

Mesoderm: Mesoderm is the middle developmental layer between the ectoderm and endoderm, which gives rise to the skeleton, muscle, heart and bones.

Diploblastic: Diploblastic animals develop from two germ layers (ectoderm and endoderm)
Triploblastic: triploblastic animals develop from three germ layers (ectoderm, mesoderm, and endoderm).

16.6 QUESTION AND ANSWERS

1. Write about the general characteristics of vertebrates?
2. Explain the comparative account of respiratory organs of invertebrates?
3. Give the detail account on morphology of vertebrates?
4. Write about evolution of hearts among vertebrates?
5. Describe the evolution of aortic arches and portal systems of vertebrates?

16.7 REFERENCES

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Prof. M. Jagadish Naik

LESSON - 17
NERVOUS SYSTEM OF VERTEBRATES

COMPARATIVE ACCOUNT OF BRAIN IN VERTEBRATES

Brain of all vertebrates, from fish to man, is built in accordance with the same basic architectural plan. However, form of brain differs in different vertebrates in accordance with the habits and behaviour of the animals.

1. Cephalochordates

In amphioxus, brain does not consist of forebrain, midbrain and hindbrain. Instead, the so-called brain is made of an anterior prosencephalon or cerebral vesicle with a single enlarged ventricle. It is lined with cilia and long filamentous processes of ependymal cells as revealed by electron microscope. Anterior extension of notochord may suggest absence of a forebrain.

2. Cyclostomes

Brain is very primitive. Subdivisions are not well marked. Two olfactory lobes are prominent, but cerebral hemispheres are quite small. Cavities of cerebral hemispheres or lateral ventricles are rudimentary. Pineal apparatus and parapineal (parietal) body are very well developed in Petromyzon, though they are vestigial in Eptatretus (Bdellostoma) and absent in Myxine. Connected to pineal apparatus is epithalamus made of two habinulae ganglia. The two optic lobes are imperfectly differentiated. Medulla oblongata is very well developed while cerebellum is a small transverse dorsal band. A welldefined infundibulum from hypothalamus of diencephalon bears a hypophysis or pituitary body.

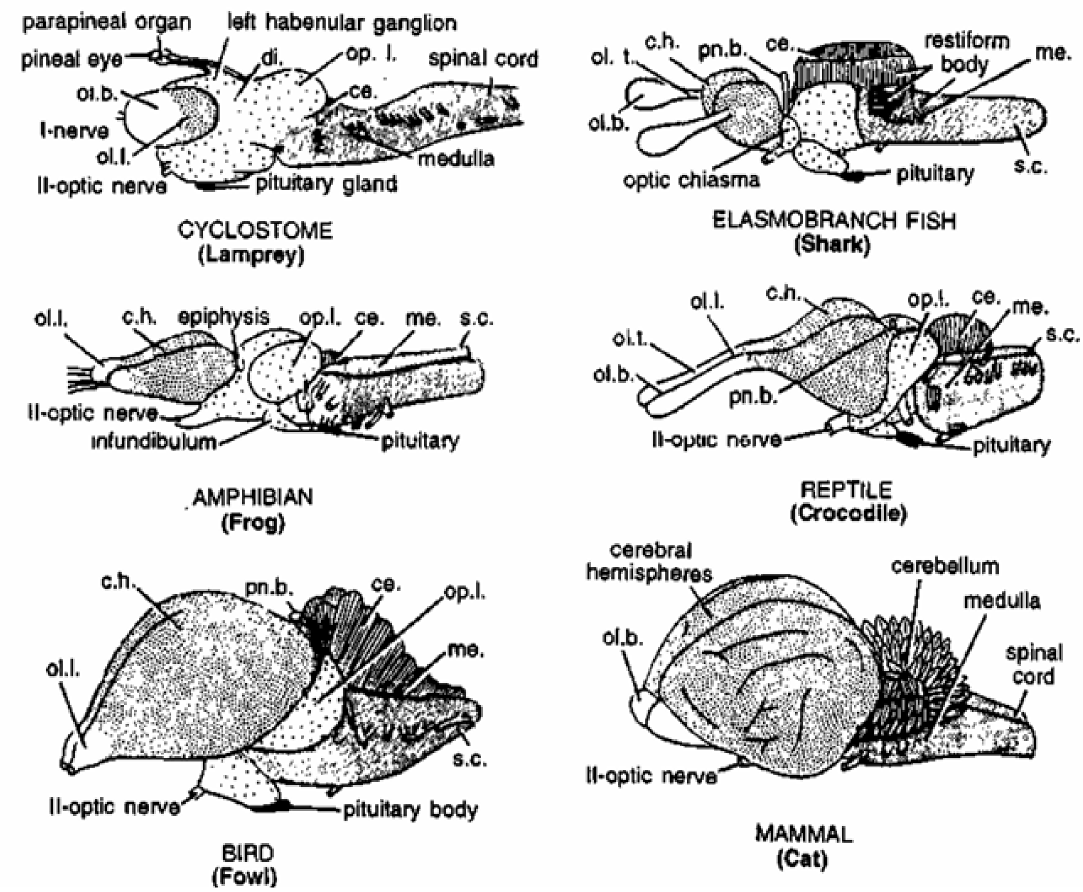
3. Fishes

Brain of fishes is more advanced than that of cyclostomes. However. subdivisions of brain are seen in their primitive relations.

(a) Elasmobranchs. In elasmobranch fishes (shark or dogfish), olfactory organs are enormous so that olfactory lobes of brain are correspondingly large, attached to cerebrum by short but stout olfactory tracts or peduncles. Optic lobes and pallium are relatively moderate in size. Midbrain cavity (III ventricle) is quite large and extends into optic lobes. A thin-walled vascular sensory organ, called saccusvasculosus, is attached to pituitary and connected by fibre-tracts with cerebellum. Pineal apparatus is well developed. Topographical features of hindbrain are least pronounced. Cerebellum is especially large due to active swimming habit. To assist cerebellum in the maintenance of equilibrium, ruffle-like restifoml bodies are present at the antero-Iateral angles of medulla.

(b) Osteichthyes. In bony fishes, brain is more specialized than. In elasmobranchs. In perch, olfactory lobes, cerebral hemispheres and diencephalon are smaller while optic lobes and cerebellum larger than in a shark. Some bony fishes have restiform bodies. In bottom-feeders, having scattered taste buds on body surface, the antero-Iateral sides of medulla show unusual bulgings or vagal lobes. Parapineal body is absent in modern teleosts.

Nervous System in Vertebrates



4. AMPHIBIANS

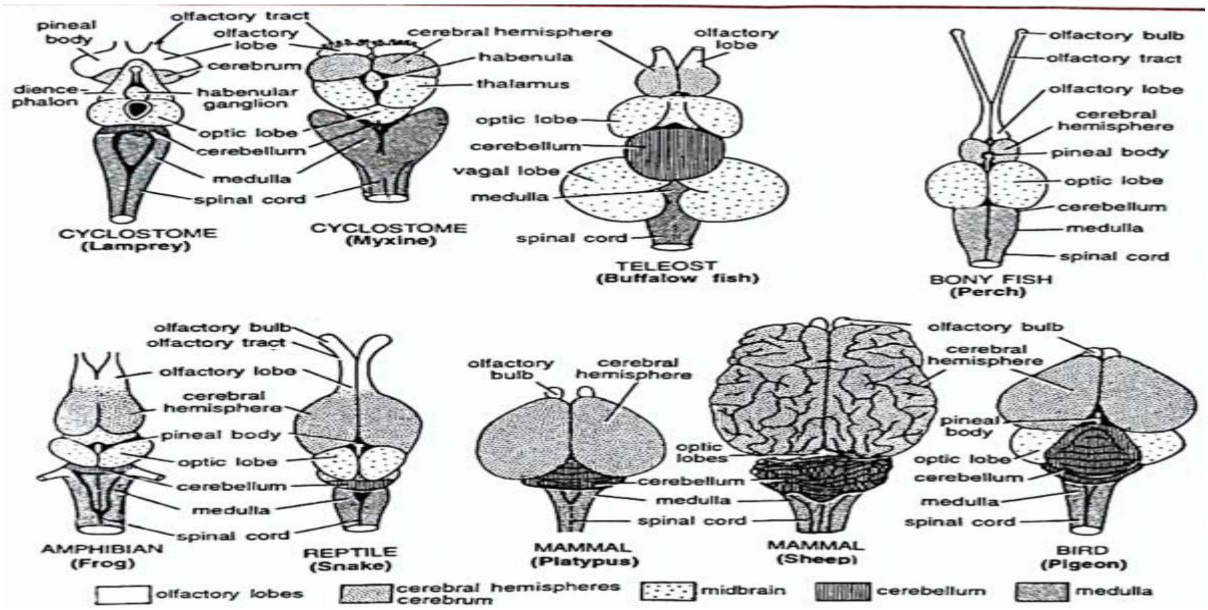
Brain of frog shows many contrasts from that of dogfish. Smaller olfactory lobes and larger optic lobes indicate a greater reliance on sight rather than smell. Corpus striatum or paleostriatum (floor of cerebrum) receives greater number of sensory fibres projected forward from thalamus than In fishes. Two cerebral hemispheres show greater development in accordance with more complex activIties of locomotion. hibernation. breeding. etc. However. optic lobes are probably the dominant coordinating centres in amphibian brain. The walls of mid brain are thickened and reduce the lumen into a narrow passage called. aqueduct. Poor development of cerebellum. a mere transverse band. shows relative decrease in muscular activity. Medulla is also small. A small pineal body is present in all the modern amphibians.

5. Reptilians: Reptilians brain shows advancement in size and proportions over that of amphibians because of complete terrestrial mode of life. Telencephalon increases to become the largest region of brain. Two long olfactory lobes are connected to cerebral hemispheres which are larger than in amphibians because of greater thickness and enlargement of corpora striata. A fine vomeronasal nerve from the organ of Jacobson goes to the olfactory bulbs. Parapineal body. more often called the parietal eye, is still found in Sphenodon and some modern lizards. but is vestigial or absent in other reptiles. A pair of auditory lobes are found posterior to optic lobes which are not hollow. The III ventricle is reduced to a narrowcerebral somewhat pear-shaped amphibian. aqueduct. Cerebellum IS and larger than In

6. Birds: Avian brain is proportionately larger than that of a reptile, and is short and broad. Olfactory lobes are small due to poor sense of smell. Two cerebral hemispheres are larger, smooth and project posteriorly over the diencephalon to meet the cerebellum. Pallium is thin but corpus striatum is greatly enlarged making lateral ventricle small and vertical. Third ventricle is also narrow due to great development of thalami. Optic lobes on mid-brain are conspicuously developed in correlation with keen sight, but they are somewhat laterally displaced. The cerebellum is greatly enlarged with several superficial folds (flocculi) due to many activities involving muscular coordination and equilibrium such as flight and perching.

7. Mammals: Parts of vertebrate's brain in linear arrangement become progressively enlarged from fishes onwards until they reach their peak in mammals. Brain is proportionately larger than in other vertebrates. Cerebral hemispheres of Prototheria are smaller and smooth, like those of reptiles. They are larger but smooth in Metatheria. In most higher mammals (Eutherian), cerebral hemispheres become greatly enlarged and divided into lobes, with thick cerebral cortex of gray matter. In mammals such as rabbit, the surface of cerebral hemispheres is relatively smooth with few fissures. In others, such as man and sheep, surface is immensely convoluted with a number of elevations (gyri) separated by furrows (sulci). TI1is folding increases the surface cortex or gray matter contains nerve cells, resulting in greater intelligence without adding to the size of brain. The two hemispheres are joined internally by a transverse band of fibers, the corpus callosum, not found in other vertebrates or even in Prototheria and Metatheria. Olfactory lobes are relatively small but clearly defined and covered by the hemispheres. Diencephalon and midbrain are also completely covered by the cerebral hemispheres. Characteristic of mammals are 4 almost solid optic lobes, called corpora quadrigemina, on the roof of midbrain. The III ventricle or iter of midbrain is a laterally compressed vertical passage, called cerebral aqueduct.

Cerebellum is also large, conspicuously folded and may overlie both midbrain and medulla. Usual folds are a median vermis, two lateral floccule and their mushroom - like projections, the para floccule. The other chief topographical features of mammalian hindbrain include the pyramids carrying voluntary motor impulses from higher centers, the pons varoli with crossing or decussating fibers connecting opposite sides of cerebrum and cerebellum, and the trapezoid body of transverse fibers relaying impulses for sound: Hindbrain contains centers for the regulation of digestion, respiration and circulation.



Cranial Nerves

The peripheral nervous system includes cranial and spinal nerves. All the nerves arise in pairs. Cranial nerves have both afferent and efferent fibers, arise from brain and emerge through skull foramina. There are 10 pairs of cranial nerves in anamniotes (cyclostomes, fishes, amphibians) and 12 pairs in amniotes (reptiles, birds, mammals). Their sequence and distribution are essentially the same in all vertebrates. Table 2 provides a summary of the serial number, names, origin from brain, distribution, nature and functions of cranial nerves in vertebrates.

Tenninal nerves

An additional pair of anterior-most terminal nerves are found in all vertebrates including man. They emerge from rhinencephalon close to olfactory roots through neuropore of cerebrum. They are numbered zero (0) because of their discovery after all other cranial nerves were already numbered.

Autonomic Nervous System

Cranial and spinal nerves (somatic nerves) mainly innervate the skeletal or voluntary muscles and direct the adjustment of the vertebrate to its surroundings. On the other hand, autonomic nerves and ganglia innervate the involuntary or smooth· muscles of viscera, heart and glands and control the internal body environment. Readers may refer to the note on autonomic nervous system described in the end of nervous system of rabbit.

	Name	Origin	Distribution	Nature	Functions
I.	**Olfactory**	Olfactory lobe or bulb	Olfactory epithelium in nasal cavity	*Sensory*	Smell
II.	**Optic**	Optic lobe on midbrain	Retina of eye	*Sensory*	Sight
III.	**Oculomotor**	Floor of midbrain	Eye, 4 muscles of eyeball	Motor	Movements of eyeball, iris, lens, eyelid
IV.	**Trochlear**	Floor of midbrain	Eye, superior oblique muscles of eyeball	Motor	Rotation of eyeball
V.	**Trigeminal**	Side of medulla	Head, face, jaws, teeth	*Sensory* Motor	Forehead, scalp, upper eyelid, side of nose, teeth Movement of tongue, jaw muscles for chewing
VI.	**Abducens**	Side of medulla	External rectus muscle of eyeball	Motor	Rotation of eyeball
VII.	**Facial**	Side and floor of medulla	Anterior 2/3 tongue. Muscles of face, neck and chewing	*Sensory* Motor	Taste Facial expression, chewing, movement of neck
VIII.	**Auditory (acoustic)**	Side of medulla	Organ of Corti in cochlea Semicircular canals	*Sensory*	Hearing Equilibrium
IX.	**Glossopharyng eal**	Side of medulla	Posterior 1/3 tongue, mucous membrane and muscles of pharynx	*Sensory* Motor	Taste & touch Movements (swallowing) of pharynx
X.	**Vagus (pneumogastric)**	Side and floor of medulla	Muscles of pharynx, vocal cords, lungs, heart, oesophagus, stomach, intestine	*Sensory* Motor	Vocal cords, lungs Respiratory reflexes, peristaltic movements, speech, swallowing, secretion of gastric glands, inhibition of heart beat
XI.	**Spinal accessary**	Floor of medulla	Muscles of palate, larynx, vocal cords, neck, shoulder	Motor	Muscles of pharynx, larynx, neck, shoulder movements
XII.	**Hypoglossal**	Floor of medulla	Muscles of tongue, neck	Motor	Movements of tongue

Prof. G. Simhachalam

LESSON - 18

COMPARATIVE ANATOMY OF SPINAL CORD, SPINAL NERVES, AND AUTONOMOUS NERVOUS SYSTEM

OBJECTIVES

18.1 SPINAL CORD

Nerve cord or spinal cord is formed from the neural tube behind the brain. The nerve cord is a cylindrical tube somewhat flattened dorso ventrally. Its anterior end is wide where it is continuous with medulla, the posterior end generally tapers to a fine thread, the filum terminale. In fishes it extends to the posterior end of the tail. It extends the full length of the vertebral column in amphibians, reptiles and birds, but in mammals it is short and does not extend into the tail. In cyclostomes, fishes and limbless amphibians the nerve cord has a uniform diameter, but in tetrapoda it has two enlargements called cervical (brachial) and lumbar enlargements. They are formed due to a larger number of nerve cell bodies whose fibres form nerves going to limbs. The spinal cord remains as a comparatively slightly differentiated tube. The primary lumen is secondarily reduced by the fusion of the side walls into a narrow central canal.

18.2 SPINAL NERVES

The spinal ganglia are formed from the neural crest, which grows out like a continuous sheet from the dorsal margin of the neural tube and is secondarily split up into cell groups (the ganglia) by a segmentating influence from the somites. Fibers grow out from the ganglionic cells and form the sensory fibers of the spinal nerves. Motor nerve fibers emerge from cells situated in the ventral horns of the spinal cord. The ventral motor fibers and the dorsal sensory fibers fuse to form a common stem, which is again laterally divided into branches, innervating the corresponding segment of the body.Spinal Nerves: The spinal nerves arise from the spinal cord. They are also paired segmental structures emerging through intervertebral foramina of the vertebral column. Their number corresponds approximately to the number of vertebrae present. Each spinal nerve is formed by two roots: (i) A dorsal root (sensory) attached to the dorsal horn of the gray matter. The dorsal root has always a ganglion containing nerve cell bodies of sensory fibres. (ii) A ventral root (motor) arising from the ventral horn of the gray matter. The nerve cell bodies of motor fibres are always located in the brain or spinal cord. Cranial Nerves of Vertebrates The roots have different embryonic origin- the dorsal roots arise from neural crests, while the ventral roots arise from the gray matter of the spinal cord. In an amniota, the dorsal roots contain somatic sensory, visceral sensory and visceral motor fibres. In amniota the dorsal roots have only somatic sensory and visceral sensory fibres. The ventral roots have visceral motor and somatic motor fibres in all. Except in some cyclostomes, a dorsal and a ventral root of each side unite to form a spinal nerve. In cyclostomes, the sensory and motor roots do not join together to form a common trunk. In lampreys, they remain separate 283 and emerge alternately from the spinal cord, whereas in hagfishes there may be an incomplete union. In all other fishes the dorsal sensory root and ventral motor root unite with each other outside the vertebral column to form a common trunk. In amphibians dorsal and ventral roots of the spinal nerves unite in their passage through the intervertebral foramen rather than outside as in most fishes or within the neural canal as in amniotes (reptiles, birds and mammals). In mammals, complicated plexuses, resulting from the intermixing of fibres from the ventral branches of spinal nerves are found. These are differentiated into cervical, brachial, lumbar and sacral plexuses.Each spinal nerve divides into three branches or rami, a dorsal ramus supplying the skin and muscles of the back, a ventral ramus going to body muscles and skin of ventral side, and a communicating ramus communicants or visceral ramus going to the viscera and a ganglion of the autonomic nervous system. A ramus communicans has two parts, a white ramus and a gray ramus. There are no gray rami in elasmobranchs. The white ramus has medullated visceral sensory and visceral motor fibers. The axons of visceral motor fibers go to autonomic ganglia and form synapses with non- medullated fibres of the gray ramus. The medullated visceral motor fibers are called preganglionic fibers because they terminate in autonomic ganglia where they form synapses with non-medullated postganglionic fibers of the gray ramus. These fibers enter the spinal nerves and pass into the dorsal ventral rami to supply structures under involuntary control. In brief the white ramus of ramus communicans carries medullated visceral sensory fibers and medullated preganglionic motor fibers, the gray ramus carries only non-medullated postganglionic autonomic motor fibers.

18.3 AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system functions primarily at a subconscious level. It is traditionally partitioned into the sympathetic system and the parasympathetic system. The ganglia of the sympathetic nervous system develop ventrolateral to the spinal cord as neural crest derivatives. At first, a continual column of sympathetic nerve cells is formed; it later subdivides into segmental ganglia. The parasympathetic system is made up of preganglionic fibers emanating as general visceromotor fibers from the brain and from sacral segments of the spinal cord. Cells migrate to form the peripheral ganglia along them.

18.4 PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system consists of nerves connected to or arising from the central nervous system, it has cranial and spinal nerves. All the nerves arise in pairs. Cranial nerves originate from brain and emerge through foramina of the skull. Except the first four pairs of cranial nerves, the rest arise from the medulla oblongata There are ten pairs of cranial nerves in amanita (cyclostomes, fishes and amphibians), and twelve pairs in amniota (reptiles, birds and mammals). There is a paired nervus terminalis or number zero nerve arising from the cerebral hemisphere in all vertebrates except birds, it goes to the organ of Jacobson. The cranial nerves do not show a clear metameric arrangement, yet they represent a regular series of segmental dorsal and ventral roots of the segments of the head, but the dorsal and ventral roots do not join. summarizes the cranial nerves of vertebrates showing their serial numbers, names, origin from brain, distribution, nature and functions.

18.5 AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system is so called because it is partly independent and not under voluntary control, though it is involuntarily controlled by the nerve centers located in the central nervous system. It is also connected to spinal nerves and some pre-vertebral ganglion ramus, cranial nerves. Cranial and spinal somatic nerves mainly innervate the voluntary (skeletal) muscles of the animal. While the autonomic nerves and ganglia innervate the smooth or involuntary muscles of the viscera (alimentary canal, heart, etc.) and glands, and, thus, control the internal environment of the body. Little is known about the autonomic nervous system in cyclostomes although sympathetic ganglia are present. The digestive system and heart are supplied by the vagus nerve. In elasmobranchs, an irregular series of sympathetic ganglia lies along the body wall. Fibers from these ganglia connect both to the spinal cord and to the smooth muscles of the digestive and circulatory systems. In bony 285 fishes autonomic nervous system is more advanced i.e., the sympathetic ganglia are arranged in a chain extending forward to the trigeminal nerve

TABLE 46.2. CRANIAL NERVES (PAIRED) OF VERTEBRATES.

S.No.	Name	Origin	Distribution	Nature	Functions
I.	**Olfactory**	Olfactory lobe or bulb	Olfactory epithelium in nasal cavity	*Sensory*	Smell
II.	**Optic**	Optic lobe on midbrain	Retina of eye	*Sensory*	Sight
III.	**Oculomotor**	Floor of midbrain	Eye, 4 muscles of eyeball	Motor	Movement of eyeball, iris, lens, eyelid
IV.	**Trochlear**	Floor of midbrain	Eye, superior oblique muscles of eyeball	Motor	Rotation of eyeball
V.	**Trigeminal**	Side of medulla	Head, face, jaws, teeth	*Sensory* Motor	Forehead, scalp, upper eyelid, side of nose, teeth, Movement of tongue, jaw muscles for chewing
VI.	**Abducens**	Side of medulla	External rectus muscle of eyeball	Motor	Rotation of eyeball
VII.	**Facial**	Side and floor of medulla	Anterior 2/3 tongue. Muscles of face, neck and chewing.	*Sensory* Motor	Taste. Facial expression, chewing, movement of neck
VIII.	**Auditory (acoustic)**	Side of medulla	Organ of Corti in cochlea Semicircular canals	*Sensory*	Hearing Equilibrium
IX.	**Glossopha-ryngeal**	Side of medulla	Posterior 1/3 tongue, mucous membrane and muscles of pharynx	*Sensory* Motor	Taste & touch, Movements (swallowing) of pharynx
X.	**Vagus (pneumo-gastric)**	Side and floor of medulla	Muscles of pharynx, vocal cords, lungs, heart, oesophagus, stomach, intestine	*Sensory* Motor	Vocal cords, lungs Respiratory reflexes, peristaltic movements, speech, swallowing, secretion of gastric glands, inhibition of heart beat.
XI.	**Spinal accessory**	Floor of medulla	Muscles of palate, larynx, vocal cords, neck, shoulder	Motor	Muscles of pharynx, larynx, neck, shoulder movements
XII.	**Hypoglossal**	Floor of medulla	Muscles of tongue, neck	Motor	Movements of tongue.

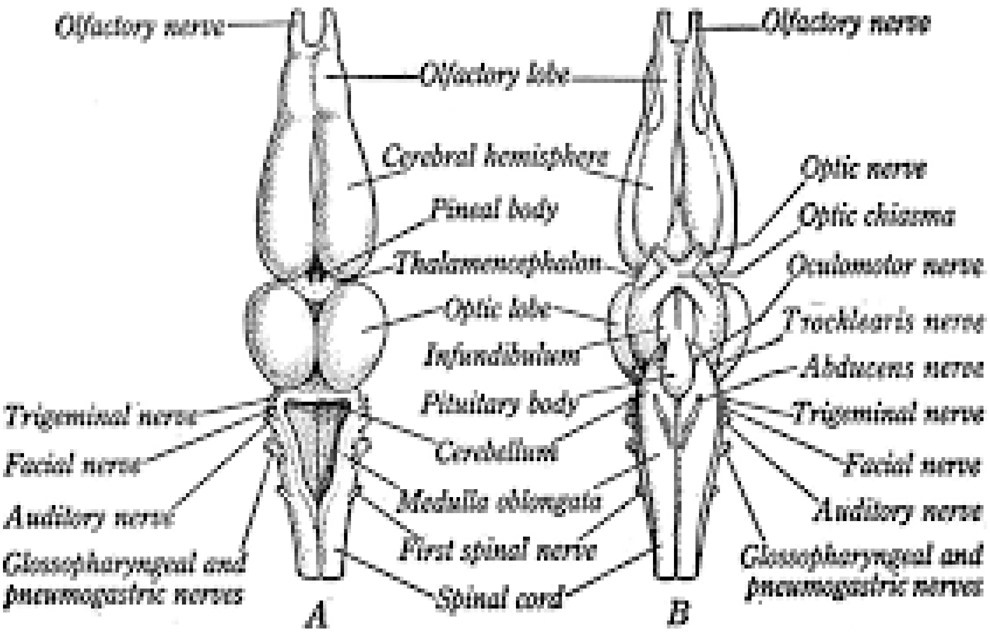


FIG. 409. *Brain of Frog*
A, dorsal view; *B*, ventral view

Prof. G. Simhachalam

LESSON 19
URINOGENITAL SYSTEM

Irlc\udes kidneys and their ducts, while reproductive system includes male and female gonads and their ducts. Kidneys excrete harmful metabolic nitrogenous wastes and regulate the composition of body fluids, while reproductive organs perpetuate the species. Thus, kidneys and gonads remain functionally unrelated. However, the two systems are intimately related ducts morphologically in vertebrates because the male urinary are also used for discharging gametes. For this reason, it is more convenient to treat and describe the two systems together as the urogenital or urinogenital system. Vertebrate Kidneys and Ducts a

1. BASIC STRUCTURE AND ORIGIN

Vertebrate kidneys are pair of compact organs, lying dorsal to coelom in trunk region, one on either side of dorsal aorta. They are all built in accordance with a basic pattern. Each kidney is comp0sed of alarge number of units called uriniferous tubules or nephrons. Their arrangement differ number, in complexity different groups and of vertebrates. Kidney tubules arise in the embryo in a linear series from a special part of mesoderm called mesomere or nephrotome. It is the ribbon-like intermediate mesoderm, running between segmental mesoderm (epimere) and lateral plate mesoderm (hypomere) on either side along the entire trunk from heart to cloaca. A uriniferous tubule is differentiated into three parts: peritoneal funnel, tubule and Malpighian body.

(a) PERITONEAL FUNNEL

Near the free end of a uriniferous tubule is a funnel-like ciliated structure called peritoneal funnel. It opens into coelom (splanchnocoel) by a wide aperture, the coelomostome or nephrostome, for draining wastes from coelomic fluid. Nephrostomes are usually confined to embryos and larvae and considered vestiges of a hypothetical primitive kidney.

(b) MALPIGHIAN BODY

A tubule begins as a blind, cup-like, hollow, double-walled Bowman s capsule. It encloses a tuft of blood capillaries, called glomerulus. It is supplied blood by a branch of renal artery, called afferent glomercular arteriole. An efferent glomerular arteriole emerges out of glomerulus to join the capillary network surrounding the tubule. Bowman's capsule and enclosed glomerulus together form a renal corpuscle or Malpighian body. Encapsulated glomeruli are termed internal glomeruli which are common. Those without a capsule and suspended freely in coelomic cavity are called external glomeruli (embryos and larvae). Capsules without (c) glomeruli termed aglomerular, such as found in embryos, larvae and some fishes. Tubule. Malpighian bodies filter water, salts and other substances from blood. During passage through- tubules more substances are secreted into filtrate, while some are reabsorbed. All the a tubules of embryonic kidney are convoluted ductules that conduct the final filtrate to longitudinal duct which opens behind into embryonic cloaca. 2. Archinephros. Archinephros is the name ,given to the .hypothetical primitive kidney of ancestral vertebrates. It may be regardedas are a complete kidney or holonephros as it extended the entire length of coelom. Its tubules were segmentally arranged, one nephron for each body segment. Each tubule opened by a peritoneal funnel or nephrostome into coelom. Near each nephrostome was suspended in coelom an external glomerulus (without capsule). All the tubules were drained by a common longitudinal Wolffian or archinephric duct opening behind into cloaca. Such a hypothetical archinephros is found today in the larVae of certain cyclostomes (Myxine), but not in any adult vertebrate. It is supposed to have given rise to all the kidneys of later vertebrates during the course of evolution. Modern vertebrates exhibit three different kinds of adult kidneys : pronephros, mesonephros and metanephros. It is supposed that these represent the sequence or three successive stages ofdevelopment of the ancestral archinephros, and all the three are never functional at the same time.

1. PRONEPHROS

In the embryos of all vertebrates, the first kidney tubules appear dorsal to the anterior end of coelom, on either side. These are called pronephros as they are first to appear (Fig. 3). Pronephros is also termed head kidney due to its anterior position immediately behind the ht:ad. A pronephros consists of 3 to 15 tubules segmentally arranged, one opposite each of the anterior mesodermal somites. There are only 3 pronephric tubules in frog embryo, 7 in human embryo and about a dozen in chick embryo. Each tubule opens into coelom by a funnel or nephrostome. Also projecting into coelom near each tubule and not connected with it is an external or naked glomerulus without capsule. In some cases, glomeruli unite to form a single compound glomerulus, called glomus. Glomus and tubules become surrounded by a large pronephric.

Urinogenital System in Vertebrates

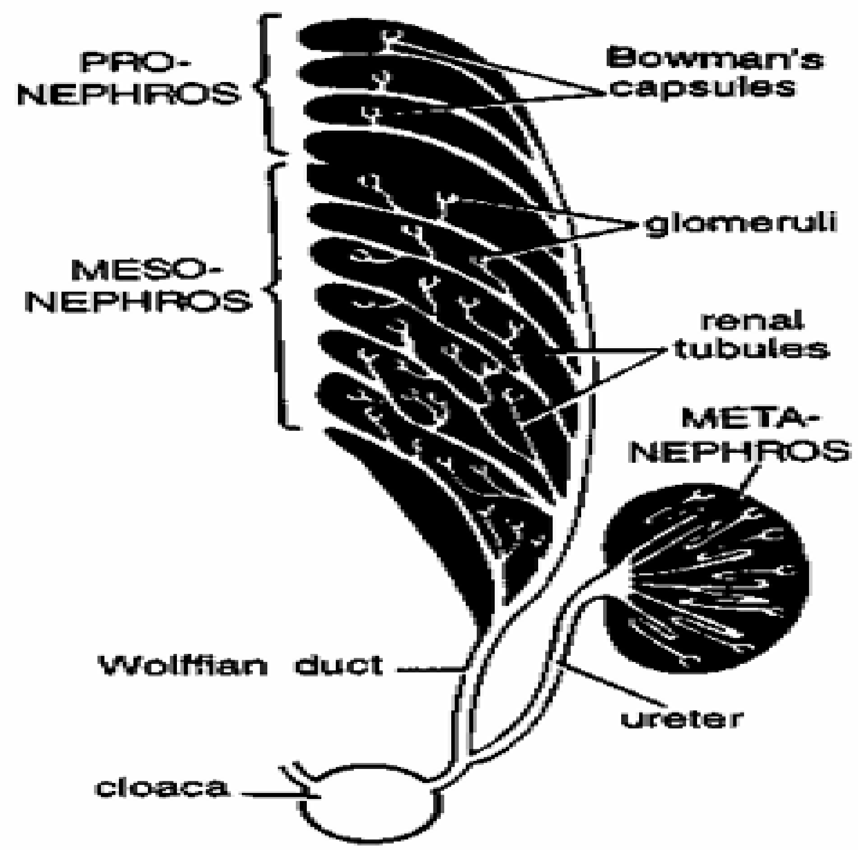


Fig. 4. Diagrammatic plan of pronephros, mesonephros and metanephros in vertebrates.

Chamber derived from pericardial or pleura peritoneal cavity. Originally each tubule has its individual external aperture, but secondarily, all tubules of a pronephros open into a common pronephric duct, leading posteriorly into the embryonic cloaca. Pronephros is functional, if at all, only in embryonic or larval stage. It is mostly transitory and soon replaced by, the next stage or mesonephros. However, a pronephros is retained throughout life in adult cyclostomes and a few teleost fishes, but it is non urinary and mostly lymphoidal in function.

2. MESONEPHROS

In the embryo, a mesonephros develops from the middle part of intermediate mesoderm, posterior to each pronephros soon after its degeneration. At first, the new mesonephric tubules join the existing pronephric duct and are segmentally disposed. Later on the tubules multiply by budding so that their segmental arrangement is disturbed due to increased number of tubules per segment. Tubules of pronephros and mesonephros develop similarlyand are homologous. However, mesonephros is functionally better than pronephros because mesonephric tubules are more numerous, longer and develop internal glomeruli enclosed in capsules forming Malpighian bodies. Thus, they remove liquid wastes directly from glomerular blood rather than indirectly from coelomic fluid as in case of a pronephros. The mesonephros is also termed Wolffian body. With disappearance of pronephros, the old pronephric duct becomes the Wolffian or mesonephric duct.

In cloaca amniotes (reptiles, birds and mammals), mesonephros is functional only in the embryos, replaced by metanephros in the adults. In fishes and amphibians, mesonephros is functional both in embryos as well as adults. In sharks and caecilians, tubules extend posteriorly throughout the length of coelom. Such a kidney is sometimes called posterior kidney or opisthonephrosWhereas in adult anurans, urodeles and embryonic amniotes, the mesonephros does not extend posteriorly. Mesonephric kidney is not metameric,but in myxinoids it is segmental and sometimes called a holonephros. Nephrostomes are generally lacking in mesonephros of embryonic amniotes.

3. Metanephros

The functional kidney of higher vertebrates or amniotes is a metanephros. It is nephro~enic formed from the posterior end of the mesoderm which somewhat anteriorly and is laterally. displaced When metanephric tubules develop, all the mesonephric tubules disappear except those associated with the testis in male and forming vasa efferentia. The adult kidney (metanephros) of amniotes differs from that (1) of anamniotes opisthonephros) chiefly in:
Its origin from only caudal end of nephrogenic mesoderm.

In greater multiplication and posterior concentration of nephrons or tubules. They are particularly very large in number and highly convoluted in birds and mammals, hence the large size of kidney. It is estimated that each kidney of man is composed of about 1 million nephrons. The high rate of metabolism yields a large amount of wastes to be excreted.

In developing a new urinary duct, called metanephric duct or ureter. It is budded off from the base . of the Wolffian duct (mesonephric duct). It grows anteriorly and dorSally, and eventually the metanephric tubules open into it. Its dilated distal tip forms pelvis which forks several times to become the collecting tubules. Its proximal portion becomes the metanephric duct or ureter that empties into cloaca or urinary bladder in mammals.

The mammalian metanephros shows greatest organization of all, with several additional features. A thin, U-shaped loop of Henle forms between proximal and distal convolutions of a metanephric tubule. Such loops are absent in reptiles and rudimentary in birds. Kidney shows an outer cortex with concentration of renal corpuscles, and an inner medulla having collecting tubules and loops of Henle, which are aggregated intoone or several pyramids tapering into pelvis. Mammalian kidneys do not receive afferent venous blood supply as there is no renal portal system.

4. URINARY BLADDERS

Most vertebrates have a urinary bladder to store urine before it is discharged. However, it is lacking in cyclostomes, elasmobranchs, some lizards, snakes, crocodilians and most birds. In most fishes it is simply a terminal enlargement of mesonephric ducts and called a tubal bladder. In Dipnoi, it evaginates from dorsal wall of cloaca and is probably homologous to the rectal gland of elasmobranchs. In tetrapods, it evaginates from the ventral wall of cloaca. In amphibians, it is termed a cloacal bladder. In amniotes, the adult bladder is derived from the proximal part of embryonic allantois, hence called an allantoic bladder. Kidney ducts or ureters generally open dorsally into cloaca. But in mammals, except monotremes, the ureters lead directly into the urinary bladder which opens to outside through a short tube, the urethra. Mammals lack a cloaca as the dorsal part of embryonic cloaca forms the rectum and the ventral part becomes the urethra.

5. GONADS AND THEIR DUCTS

Reproduction is sexual in vertebrates, and the sexes are separate (dioecious) with the exception of hagfishes and a few bony fishes having a hermaphrodite gonad. Reproductive glands or gonads of males are called testes which produce the male gametes called sperm. Female gonads are called ovaries which produce ova. In the embryo, gonads originate as a pair of thick elevated folds or genital ridges of coelomic epithelium from the roof of coelom, one on either side of the dorsal mesentery. Genital ridges are much longer than the functional adult gonads, suggesting that in the ancestral vertebrates the gonads extended the whole length of the pleuroperitoneal cavity. The functional adult gonad is derived from the middle or gonal part of genital ridge, while its anterior progonal and posterior epigonal parts remainsterile. Gonads remain suspended in coelom from dorsal body wall by a fold of dorsal mesentery, called mesorchium in males and mesovarium in females. Generally, one pair of gonads is present. But, some vertebrates have a single gonad only because of either fusion of both embryonic genital ridges (most cyclostomes, perch and some other. fishes), or degeneration of one juvenile gonad (hagfishes, some elasmobranchs and lizards,alligators and most birds). Associated with the gonads are special gonoducts or genital ducts. vasa deferentia in males and oviducts in females, to transport gametes to cloaca or to outside body. However, cyclostomes and a few elasmobranchslack genital ducts. Their eggs and sperm escape body cavity via abdominal pores.

1. Testes and male genital ducts

Testes of vertebrates are paired organs of moderate size, usually found attached to kidneys. Each testis is a compact gland, covered by coelomic epithelium and seminiferous tubules composed of numerous highly coiled embedded in connective tissue. Tubules are lined by germinal epithelium which gives rise to billions of sperm. On maturity the sperm are set free in the lumen of tubules and move towards the genital ducts. Some Cyclostomes have a single median testis without a genital duct. Sperms are released in the coelom from where they pass through abdominal pore, located at posterior part of coelom. In dogfish, the two testes are elongated bodies. In most anamniotes, the opisthonephros (or mesonephros) is differentiated into anterior genital and posterior renal portions. In the anterior genital portion in males, some uriniferous tubules lose excretory function, form slender vasa efferentia, and become continuous with seminiferous tubules of the adjacent testis. They serve to convey sperm of testis to the mesonephric duct of kidney. Thus, in male anamniotes, mesonephric or wolffian duct forms a urinogenital duct. serving both as a vas deferens for sperm as well as a ureter for urine. However. in many elasmobranchs (e.g. dogfish). accessory urinary ducts drain urine from kidney to cloaca so that the mesonephric duct serves entirely or mainly as a vas deferens. The anterior genital part of kidney along with the part of mesonephric duct forms an epididymis. In the embryos of Anura. each testis is made of two portions. In male frog. the anterior portion disappear and the posterior portion becomes the adult functional testis. In adult male toad. the anterior portion also persists as the Bidder's organ, containing large cells similar to immature ova. In male amniotes, a metanephros develops as the adult functional kidney with its own urinary duct or ureter to transport urine. Thus, mesonephric or Wolffian duct becomes solely a genital duct or vas deferens. The remnants of embryonic mesonephros and a coiled portion ofmesonephric duct become the epididymis of the adult kidney. From each testis sperms pass first through epididymis, then through vas deferens to reach urethra. In most mammals testes descend permanently into extra-abdor.unal skin bags called scrotal sacs. In rabbits, bats and rodents, they are lowered into sacs and retracted at will. Passage between abdominal cavity and scrotal sac, through which testis descends, is called inguinal canal. However some mammals such as monotremes, insectivores, elephants, whales. etc., lack scrotal sacs so that their testes remain permanently intra-abdominal like ovaries.

2. Copulatory organs

Copulatory organs are absent in anamniotes, since they have usually external fertilization. But, in amniotes, fertilization is internal, and preceded by copUlation or mating. Male amniotes usually develop intromittant or copulatory organs for transferring sperm into the genital tract of females, during copulation. They are particularly mammals. In characteristic of reptiles and elasmobranchs (e.g. dogfish), bases of pelvic fins are modified as intromittant organs called claspers. These are grooved, cylindrical structures that are inserted into the female cloaca to inject sperm. In dog fishes and some allied forms there is blind muscular sac called siphon, located at the base of claspers. This sac gets filled with sea water which is used to force the spermatic fluid into the cloacae of female. In several teleosts, the anal fin is modified as a gonopodium for sperm transport. It is modification of anal fin. Snakes and lizards have a pair of retractile, grooved and sac-like hemipenes which can be everted through cloaca. Their retraction is controlled by modified body wall musculature. Turtles, crocodilians, some birds (drakes, ganders, ostriches) and prototherian mammals have an unpaired, grooved and erectile penis formed as a thickening of cloacal floor. Only higher mammals have a true external, erectile penis with a tubular groove continuous with a spongy urethra. A series of accessory sex glands associated with penis secrete a fluid in which sperm are carried.

3. Ovaries and female genital ducts

In female anamniotes, ovaries are large, occupying much of the body cavity and produce thousands of eggs as fertilization is external. In amniotes, ovaries produce fewer eggs because fertilization is internal. Ovaries of reptiles and birds are still large and the eggs produced contain much yolk. However, mammalian eggs contain very little yolk so that their ovaries also remain quite small. Ovaries are generally paired structures, but only a single median ovary occurs in cyclostomes, as also in some teleosts (e.g. perch). They are not attached to kidneys like testes in the males. Only the right ovary elasmobranchs, is functional whereas only the left ovary becomes mature in birds and some primitive mammals (e.g. Ornithorhynchus). Histologically, an ovary is of connective tissue Wi~!l an outer layer of germinal epithelium showing' ova in various stages of development. Ovaries are hollow and saccular in fishes and amphibians but compact in amniotes, especially in mammals, in which each ovum is surrounded by a follicle. Mature eggs are released either internally into the central ovarian cavity (teleosts) which is continuous with the lumen of the oviduct, or extruded externally into the surrounding coelom or bodycavity (Tetrapoda). This process is termed ovulation. In all vertebrate embryos, except cyclostomes, the coe~omic epithelium on the outside of mesonephric duct develops a groove which becomes closed to form a tube called Mullerian duct. In adult males, Mullerian duct becomes vestigial and functionless. In adult females, itgrows larger and becomes the female genital duct or oviduct. It opens anteriorly into coelom, in the region of degenerating pronephros, by a coelomic funnel or ostium, and terminates posteriorly into cloaca. In female elasmobranchs, the Mullerian duct is formed differently by the longitudinal splitting of the pronephric duct. Thus, in adult female anamniotes, both the Mullerian duct (oviduct) and the Wolffian duct (mesonephric or urinary duct) are present. But, in adult female amniotes, with the. development of adult metanephros and its metanephric duct or ureter, mesonephros anddegenerate provarium. leaving its only duct (Wolffian vestiges duct) known as In viviparous mammals, posterior ends of both the Mullerian ducts become fused and are modified into a uterus in which the embryos develop, and a vagina which receives the male intromittant organ during copulation. The remaining anterior parts or oviducts are relatively short, narrow and convoluted and called the fallopian tubes. Condition of uteri varies in different mammals. When uteri remain double without fusion, it is called duplex uterus (marsupials). When uteri partially fuse so as to form two horns and two separate lumens inside, it is called bipartite uterus (hamster, rabbit). When there are two horns but a single internal cavity it is termed bicornuate uterus (ungulates). When uterine horns are absent and both uteri fuse completely with a single internal cavity, it is termed simplex uterus (Primates, some bats, armadillos).

EVOLUTION OF UROGENITAL DUCTS

MALE URINOGENITAL DUCTS

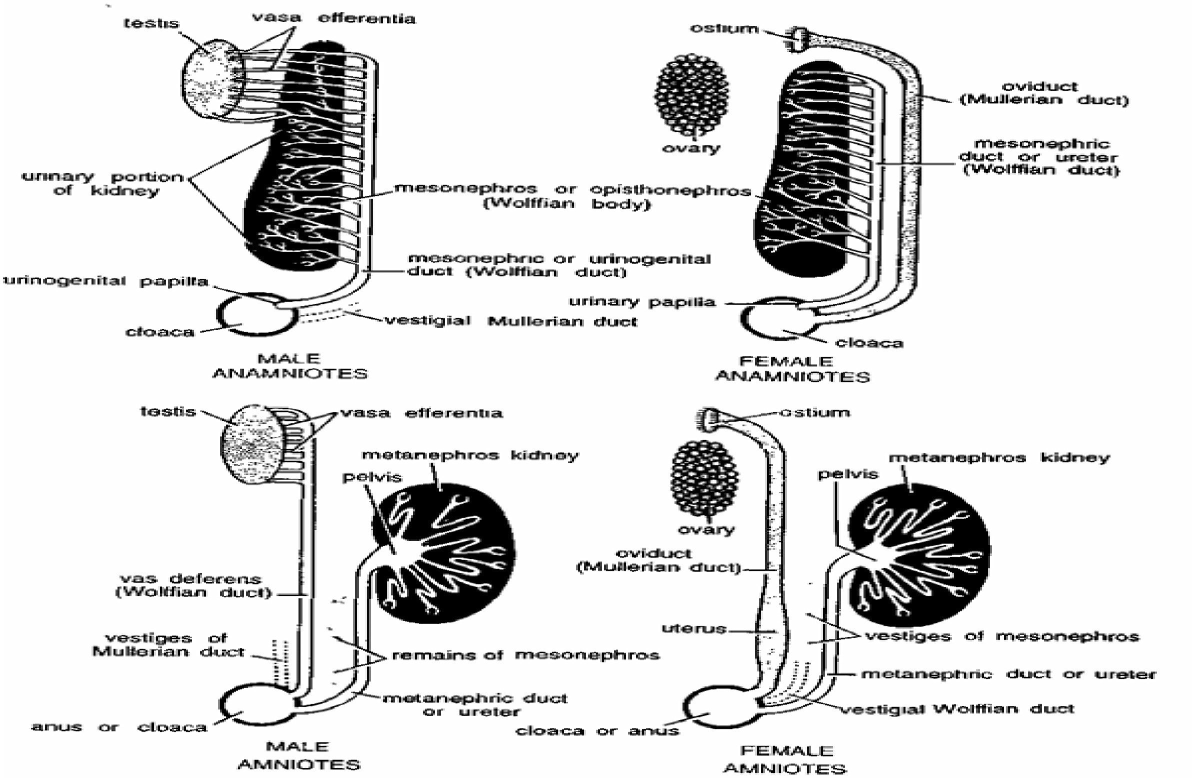
CYCLOSTOMES

- No genital ducts present. Sperm are shed into the coelom and exit via abdominal pore.
- The Archi nephric ducts drain the kidneys exclusively.

Anamniotes

- The opisthonephros (or mesonephros) is differentiated into Anterior GENITAL and Posterior RENAL portions.
- In the anterior genital portion in males, some uriniferous tubules lose excretory function, forms lender Vasa efferentia, and become continuous with seminiferous tubules of the adjacent testis. They serve to convey sperm of testis to the mesonephric duct of kidney.
- Thus, in male anamniotes, mesonephric or wolffian duct forms a urinogenital duct, serving both as a vas deferens for sperm as well as a ureter for urine.

• However, in many elasmobranchs (e.g. dogfish), accessory urinary ducts drain urine from kidney to cloaca so that the mesonephric duct serves entirely or mainly as a vas deferens.
• The anterior genital part of kidney along with the part of mesonephric duct forms an epididymis. In the embryos of Anura, each testis is made of two portions - the anterior portion disappear and theposterior portion becomes the adult functional testis. In adult male toad, the anterior portion also persists as the Bidder's organ, containing large cells similar to immature ova.



AMNIOTES

A metanephros develops as the adult functional kidney with its own urinary duct or ureter to transport urine. Thus, mesonephric or Wolffian duct becomes solely agential duct or vas deferens. The remnants of embryonic mesonephros and a coiled portion of mesonephric duct become the epididymis of the adult kidney. From each testis sperms pass first through epididymis, then through vas deferens to reach urethra.

FEMALE OVIDUCTS

• Branchiostegal: No genital ducts.
• Cyclostomes: No genital ducts.
• In all vertebrate embryos, except cyclostomes, the coelomic epithelium on the outside of mesonephric duct develops a groove which becomes closed to forma tube called Mullerian duct.
• In adult males, Mullerian duct becomes vestigial and functionless.
• In adult females, the Mullerian duct grows larger and becomes the female genital duct or oviduct.
• It opens anteriorly into coelom, in the region of degenerating pronephros, by a coelomic funnel or ostium, and terminates posteriorly into cloaca.

Fishes: In Elasmobranchs and lungfishes, the Mullerian duct is formed differently by the longitudinal splitting of the pronephric duct. It differentiates into four regions: funnel, shell gland, isthmus, and uterus. Funnel receives the ova from ovary, shell gland secretes albumen and mucus or egg shell around it. The isthmus connects the shell gland to the uterus. The uterus nutritionally supports embryos if they are held in the oviduct for an extended period. Oviducts may join before they enter the cloaca, or they may enter separately.

Teleost fishes have a short oviduct that starts directly from the ovaries. They are not Mullerian ducts and are often called Egg Ducts. There is no cloaca in telosts.

• **Amphibians:** Mullerian ducts function as oviducts. They are long and convoluted. Posteriorly each oviduct dilates to form uterus/ovisac that open independently into cloaca.

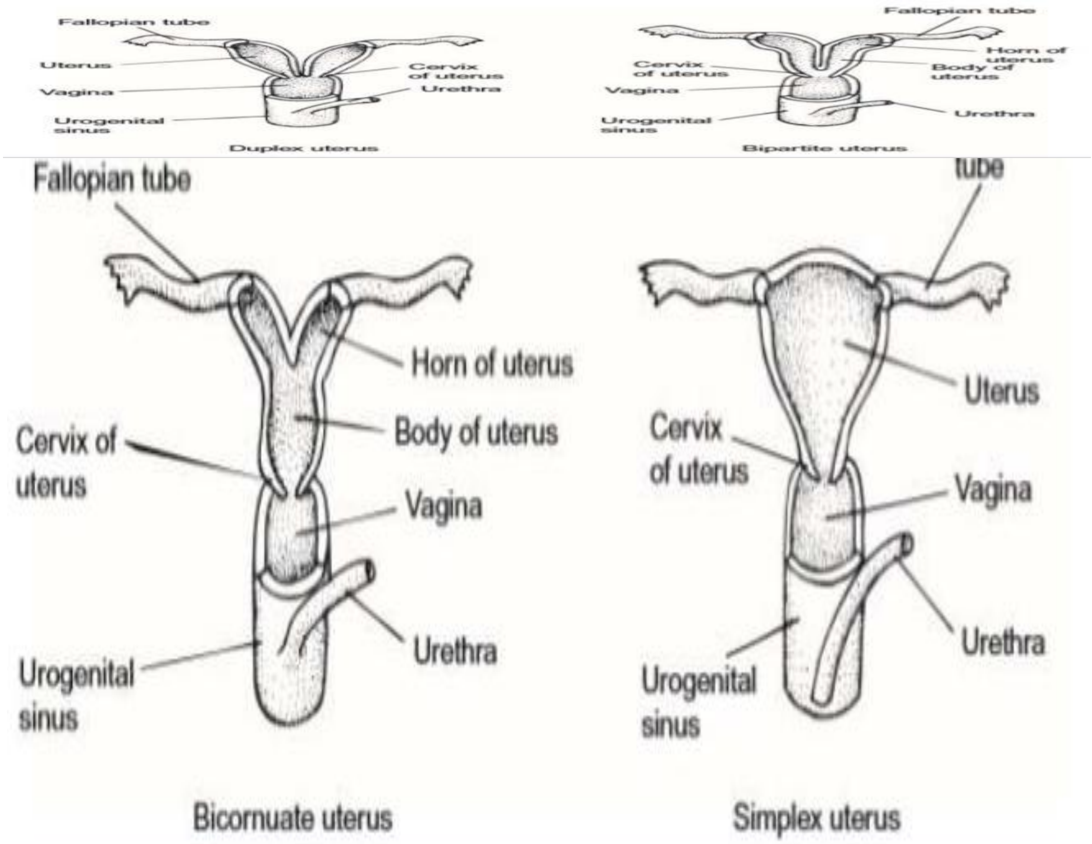
• **Amniotes:** Remnants of the mesonephros may persist in larval stages as PROVARIUM, but adults have metanephric kidneys drained exclusively by new paired ducts, the ureters (metanephric ducts). The oviducts (Müllerian ducts) persist in their roles of transporting ova from the ovaries and supporting the embryo while it is in transit.

Reptiles: The oviducts are long and open into the coelom by large, slit-like ostia. The right oviduct is shorter than the left in snakes. Posteriorly, the oviducts dilatatorforms the shell gland or ovisac, and open independently into the cloaca. Upperparts of oviduct have glandular lining in crocodilians, chelonians and Sphenodon that secrete albumen over the egg. Many reptiles have cloacal glands also, which release a secretion with nauseating odor and a defensive role.
• Aves: Both the oviducts (Mullerian ducts) appear in the embryo but only the left grows and becomes functional in the adult. A vestige of the right persists attached to the cloaca. The left oviduct is a long, muscular, convoluted tubule. – The anterior end widens to form the oviducal funnel/infundibulum that serves to receive the ova released from the ovary. Next is the glandular part Magnum, where albumen is laid down around the egg. Then comes the isthmus which secretesthe shell membranes around the egg. The terminal part is known as vagina, it secretes mucus to facilitate laying of eggs. Both oviducts are functional in certain birds of prey.
• Mammals: mammals have paired oviducts (Mullerian ducts). Each oviduct consists of anterior narrow Fallopian tube and a posterior wide uterus. The former opens into coelom by an Ostium bordered by fringed margins called fimbria/ fallopian funnel/ infundibulum. The uteri terminate in vagina through cervix. However, in monotremes, only the left oviduct is functional.

TYPES OF UTERI IN MAMMALS

Eutherian mammals possess one of the four types of uteruses on the basis of degree of fusion of uterus with vagina at the distal end:
1. Duplex uterus: uteri distinct and open separately into the vagina (elephants, many rodents and some bats. There may even be two separate vaginas for each uterus that
2. Bipartite uterus: uteri partly fused and open by a single aperture into the vagina (most carnivores, pigs, cattle, some rodents, few bats)
3. Bicornuate uterus: uteri over half fused (rabbit, whales, sheep, insectivores, most bats, some carnivores, hoofed mammals). The uterus has two horns/cornua in which the young develop. A uterus with two horns may have two totally separate passageways within the body of the uterus, although this is not discernible from the external view. One horn may be larger and longerthan the other, the blastocysts implant in that horn, even though both ovariesproduce viable eggs.

4. Simplex uterus: uteri completely fused (Armadillo, Apes, Humans). Fusion commences at the ends of short oviducts and there are no uterine horns. Blastocysts implant in the body of the uterus and there is only one fetus per pregnancy. Armadillos are exceptional: they give birth to identicalquadruplets.



Points to remember

- The pronephric duct usually persists and is renamed the mesonephric(Wolffian) duct or the opisthonephric duct (if it extends till the caudal end of coelom), respectively.
- In males, this duct transports sperm and is then called the Vas deferens.
- In females, it is known embryologically as the Wolffian duct.
- The metanephric duct is commonly renamed as the ureter.
- In females, the Archi nephric (mesonephric) ducts tend to function only within the urinary system. The Müllerian duct arises embryologically nextto the Archi nephric (wolffian) duct.
- In males, the Müllerian duct regresses, but in females, the Müllerian ductsbecome the oviducts of the reproductive system.Duct Fate/other nameArchi nephric duct Pronephric duct Mesonephricduct (Wolffian duct)Vas deferens in male genital systemMullerian duct Oviduct in female genital system Metanephric duct Ureter (urinary duct).

Prof. G. Simhachalam

LESSON - 20
SENSORY ORGANS

OBJECTIVES

20.1 SENSE ORGANS IN FISHES

20.2 AMPHIBIANS

20.3 THE SENSORY ORGANS BIRD'S

20.4 MAMMAL SENSE ORGANS

20.5 SUMMARY

20.6 QUESTION AND ANSWERS

20.7 REFERENCES

20.1 SENSE ORGANS IN FISHES

The following points highlight the four main sense organs in fishes. The sense organs are: 1. Eye 2. Ear 3. Lateral-Line System 4. Hoagland.

1. Eye: The eyes of fishes are the photoreceptors to see things under water. They typically built on the principle of a photographic camera. The eye ball is composed of three layers (1) the outer is the sclera, (2) the median is the choroid layer and (3) the innermost photosensitive layer is called the retina. The lens is mostly globular and the cornea is flat.

In the elasmobranchs' and in the deep-sea holocephalans the eyes are the largest. The eyes in most elasmobranchs are held inside the orbit by a cartilaginous stalk or optic pedicel. In some sharks and rays, the pedicel is slender, elastic and helps in the protrusion of the eye ball.

The eye of elasmobranchs is the presence of cartilage in the sclera, absence of intrinsic muscles in the ciliary body, presence of a fold of conjunctiva recalling the nictitating membrane of higher forms (in a few sharks) and the presence of large rounded lens. In most elasmobranchs, a light- reflecting layer, called tapetum lucidum (composed of guanin), is exceptionally well developed. The tapetum lies in the choroid.

In Basking shark, Cetorhinus and in an abyssal shark, Lae Margus, the tapetum is wanting. In most teleost's, a silvery layer, argenteum is present between the sclerotic and the choroid layers. The cells composing the layer contain fine crystals. Absence of choroid process is a notable feature in the eyes of teleosts. A choroid gland is present which is not glandular in nature but is composed of a complicated network of vessels (rete mirabilis).

The retinal layer lacks the cones in the elasmobranchs except Mustela's, Myliobatids and a few other forms. In these forms, the cones have been derived independently from the rods. In other fishes, the eyes exhibit great variations. The cartilage in the sclera replaced by bony plates. The cones are present in teleost's. But in elasmobranchs', accommodation is brought about by the activities of the smooth muscle fibers. These fibers bring the lens towards the cornea this is called falciform process ends in a muscular knob called campanula Halleri or retractor Lentis.

The deep-sea teleost's inhabiting the total darkness possess enormous eyes. The pupil and lens are exceptionally large and rods are well-developed but the cones are totally lacking.The eye ball is tubular in some deep-sea forms. Amongst the elasmobranchs, in a deep-sea electric ray, Benthobates Moresby, the eyes are degenerated. Amongst the deep-sea teleost's, a few are blind and in others the eyes are degenerated. In Ippons Murray, the eyes disappeared. Certain cave-dwelling fishes have minute functionless eyes. In some teleost's, the eyes are adapted for vision in water as well as in air. The typical examples are Xerophthalmus and Boleophthalmus. The eyes in these two forms are prominent and each eye can be rotated in all directions. In four-eye fish, Anable's of Central America, each eye has two pupils in adults. The eye is divided into two parts by a horizontal band.

The upper half usually remains out of water and is used in aerial vision. In another fish, Dialommus two pupils are present in each eye which are actually circular transparent areas in an opaque and pigmented cornea. The fishes possess monocular vision, i.e., the two eyes cannot be focused on the same object. But certain deep-sea fishes have telescopic vision. The eyes are mostly present on the lateral sides of the head, but in flat fishes both the eyes are placed on the dorsal side.

2. Ear: The ear in fishes is represented only by the internal ear or membranous labyrinth. The internal ear is completely enclosed by the optic bones. The membranous labyrinth shows many structural peculiarities in elasmobranchs. The internal ear is composed of three semicircular canals and three other parts (the utriculus, sacculus and lagena).

The last three chambers contain otoliths (ear stones), namely the lapillus, sagitta and asteriscus. In many elasmobranchs, a small tube arising from the dorsal side of the sacculus opens to the surface of the head. It is termed the invagination canal which is homologous to the endo-lymphatic duct. The cavity of the membranous labyrinth is filled with the seawater, rather than endolymph.

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In other fishes, a new endolymphatic duct appears and the invagination canal disappears altogether. In some teleost's, the presence of Weberian ossicles correlates the function of the swim-bladder with equilibrating and auditory functions of the internal ear. In elasmobranchs, the ear may function as a vibration receptor.

1. Olfactory sense organs: In fishes, the olfactory organs are paired and show an evolutionary advancement. In many fishes these organs may be just blind pits with olfactory epithelium or Schneiderian membrane. The olfactory epithelium produces numerous Schneiderian folds to increase the area in fishes.

In bony fishes, the nostrils are generally located on the dorsal side of the head, but in elasmobranchs these are situated on the ventral side. Excepting the Channichthyids, the nasal cavities are not in communication with the mouth in other fishes, although an oronasal groove in some elasmobranchs foreshadows the condition in Channichthyids.

2. Lateral-Line System

The lateral line system is an integral part of the acousticolateralis system specially in fishes. Besides the lateral-line sense organs this system includes the ear also. The lateral-lines sense organs consist of a peculiar system of epidermal lateral-line sense organs and found in cyclostomes, fishes and a few larval amphibians. This system is best developed in fishes where the presence of lateral line has been recorded from the fossil records of Silurian strata. The whole system comprises of the following organs.

3. Lateral line proper

The lateral line lying on either side of the body of a fish consists of groups of sensory cells, the neuromasts housed in the epithelial cells of the outer layer of the epidermis. They are surrounded by many supporting cells. The sensory cells of the neuromasts bear a hair-like process. The hairs of the whole group of sensory cells remain surrounded by a gelatinous mass, called cupula, secreted by the cells.

The neuromasts are commonly placed over the paths of nerves. They usually sink down into the skin in grooves which become closed over to form the lateral-line canal. The canal becomes filled up with mucus secreted by mucous cells. In Holocephali, however, the grooves remain open. In other fishes where the groove is closed, the lateral-line canal opens to the surface of the skin through small pores.

This system arises from skin placodes on special thickening connected by strands with underlines rudiments of the cranial nerves. In embryonic and larval conditions one dorsal longitudinal, one ventral longitudinal canal and one lateral longitudinal canal extend the length of body on either side. In course of development the dorsal and ventral canals disappear in the trunk region but persist only in head region.

In full grown fishes, usually in the head region a supraorbital canal runs forward above the eyes, an infraorbital canal courses forward below the eye, one supra-temporal canal runs across the posterior part of the head and connects lateral-line canals of one side with those of the other side of the body.

Besides there may be mandibular, hyomandibular, opercular canals which are named according to their position. All the canals remain continuous with one another but this is not universal.

20.2 AMPHIBIANS

A frog lives on land and in water, a number of sensory organs that make well-suited to both environments. Most of these sensory organs are on the head, because a frog needs to be vigilant is both predator and prey. It can keep his head just above the surface of the water to take in sights, sounds, smells, tastes and other sensations, while his body remains hidden underwater.

Eyes: A tadpole's eyes are on the side of his head. As he develops into an adult frog, the eyes move to the top of head. large eyes, placed to see to the sides and behind without moving and excellent night vision and depth perception, and detect the slightest movement.

Ears: A frog does not have outer ears, but he does have an eardrum on each side of head, called a tympanum. It transfers sound vibrations to the inner ear and to maintain a sense of balance.

listens for a variety of calls from other frogs. Males listen for the calls of rival males, and females listen for the calls of potential mates and also listen for distress calls from other frogs that warn when a threat is present.

Nose: two nostrils to sample odors in the air and a second type of olfactory organ between the nostrils, called the Jacobson's organ. It is used to detect chemicals in the water. olfactory organs are on the top of head, the frog can sample air and water odors simultaneously by putting his nostrils just above the water's surface.

Taste Buds: A frog will eat just about any living thing it can fit in mouth, but also have sensitive tastebuds. occasionally spit out hastily grabbed prey if the taste is unpleasant. The taste buds are on the surface of his tongue and the inside of his mouth. Completely aquatic frogs in the Pipridae family do not have tongues, but they have taste discs in their mouth tissue to receive taste sensations.

Skin: A frog can learn a lot about environment. An aquatic frog has one additional feature, making uniquely adapted for life under water. The lateral line receptors are present on the head and around the eyes, body and neck. They detect vibrations through the water, giving the frog an idea of the shape and direction of a prey item in the water.

20.3 THE SENSORY ORGANS BIRD'S

The sensory organs receive the various stimuli from the bird's environment. Depending on the mode of action of the stimuli, special endings on the nerves will perceive that stimulus. The sensory organs include:

Eye(s) – for sight
Ear(s) – for hearing and balance
Olfactory organ – for smell
Taste buds – for taste

Eyes: The eye of the fowl is fairly large in relation to the size of the bird. There is one eye on each side of the face and only a 26° angle directly to the bird's front has binocular vision (Binocular vision occurs when both eyes see an object. This is an important aid to distance perception).

There are two main eyelids and a third very thin membrane called the nictitating membrane, which is located in the front corner of each eye. While the eye is open, this membranous "eyelid" is only partially visible. It is capable of covering the eyeball with a very fast movement to provide protection to that organ.

The fowl's eye is very similar to the mammalian eye, except that fowls have a higher threshold of light intensity at which they see than do some other birds and mammals. This makes them active during the day (diurnal) rather than at night (nocturnal). At night in nature, or in a free ranging situation, chickens seek the protection of trees to sleep Perception of the environment: The eyes play an important part in the bird's perception of the environment and it is believed they see colors in much the same way as do humans. One exception in the structure of the eye is the presence of pectin which is believed to have the function of retaining acuity, or sharpness of vision, even after long periods of fixed staring.

The eyes function by projecting the image of the "seen" object through the lens of the eye onto the retina the receptive rod and cone cells, and the image is "seen" by these cells. Then transmitted by the optic nerve as a "signal" to the optic lobes of the brain where the signal is recognized for what it is the image of the object being "seen". Special muscles associated with the lens change the shape of the lens to control the focus of the eye onto objects at different distances.

The eye is well supplied with tears that drain from the eye into a collecting sac and then into the nasal cavity via a special duct. A very fine, sensitive, transparent membrane called the conjunctiva covers the surface of the eye ball and the inside of the eye socket. This membrane can become inflamed and/or infected if the bird contract conjunctivitis. Right ear of a chicken including semicircular canals

Ear: The ears of the fowl are located on each side of the face behind the eye. While the ear is very similar to that of mammals, there are some differences. The fowl's ear does not have a pinna, ear flap or lobe and the three bones of the mammalian middle ear have been replaced by a single structure of bone and cartilage. The birds ear consists of three main segments:

The outer ear. The middle ear separated from the outer by the tympanic membrane (ear drum). The inner ear which consists of the cochlea and the three semicircular ducts. The outer ear consists of the ear canal. Unlike the mammalian ear there is no pinna to direct the sound waves into the ear canal but it is covered by a tuft of feathers to protect it from dust and other potentially harmful materials.

The middle ear is separated from the outer ear by the tympanic membrane which is stretched across the inner end of the ear canal in a similar way to that of a percussion drum topA rod of cartilage replaces the three bones of the mammalian ear connecting the tympanic membrane to the inner ear and bone called the columella.

The inner ear consists of the cochlea in which special nerve endings are located that receive the sound waves for transmission to the area of the brain associated with hearing. Also located in the inner ear are the semicircular ducts that are associated with the maintenance of balance. A special duct connects the middle ear with the roof of the mouth with the ducts from each ear joining before entering the mouth. The function of this duct is to regulate the air pressure in the middle ear to that of the outer ear (the environment) to prevent air pressure injury to the tympanic membrane.

The birds can hear by sound waves that enter the outer ear canal and apply pressure in waves on the tympanic membrane. The wave-like nature of sound causes the tympanic membrane to vibrate. This vibration is transmitted by the columella to the cochlea where special nerve endings receive it and transmit it by the auditory nerve to the brain where it is recognized as sound.

Olfactory organ

This is the organ of smell. In fowls it is not very highly developed and it is believed that smell is of secondary importance to the other senses in the location and choice of food. The loss of a chicken's ability to smell does not seem to influence either its selection of food or other behavior.

Taste buds

The taste buds in the fowl are located at the base of the tongue and on the floor of the mouth. They contain nerve endings from the glossopharyngeal nerve. Small quantities of the chemicals of taste are recognized by the taste buds and this information is transferred to the appropriate receptors of the brain. Fowls have shown that the taste of materials in the dry state is weaker than when in the liquid state and they are more likely to refuse something on the basis of taste when it is in the water than when it is in their food. This has important application when using strong tasting medications to treat disease.

The sensitivity of the fowl to the temperature of its drinking water. They are likely to reject water with a temperature above approximately 33°C and in any case the provision of cool water in hot weather is an important strategy to help reduce the effects of heat stress. They will drink water that has a very low temperature even just above freezing point.

20.4 MAMMAL SENSE ORGANS

There are five senses: sight, hearing, taste, smell and touch. There are organs connected with these sense that take in information that is sent to the brain so that the body can act on it.
Sight: The eye is the organ of the sense of sight. Eyes detect light, and convert it to electro-chemical impulses in neurons.
Parts of the eye: Cornea: The transparent window at the front of the eye which is covered in a thin layer of tears.

Aqueous humor: On the other side of the cornea is more moisture. This clear, watery fluid is the aqueous humor. It circulates throughout the front part of the eye and keeps a constant

pressure within the eye

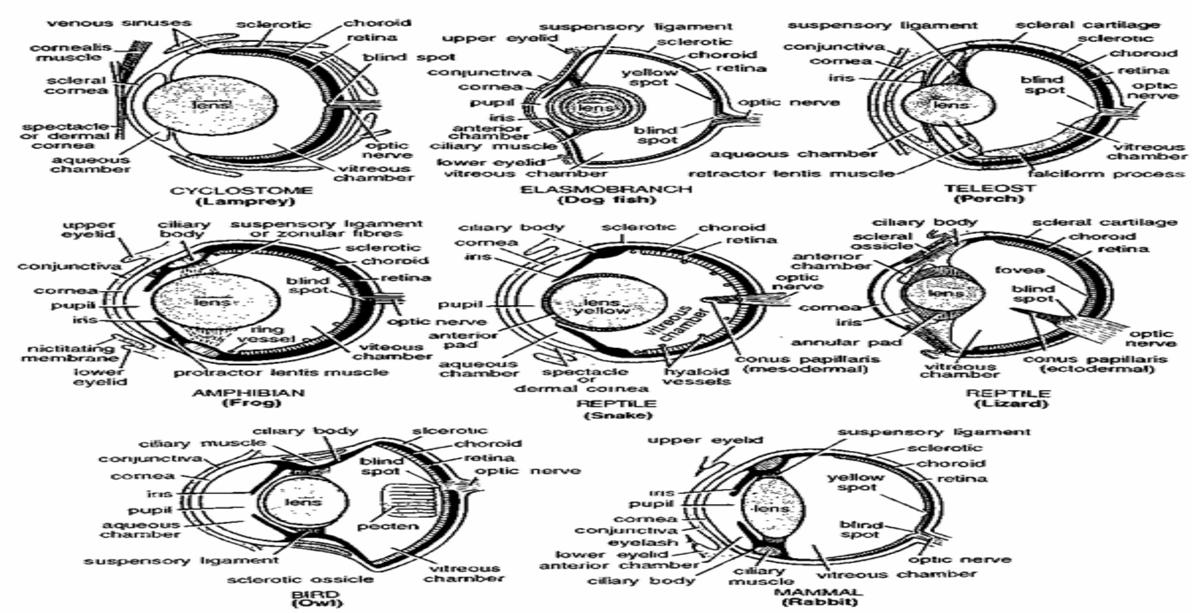

Fig. 2. Eyes of different vertebrates in sagital section.

Pupil and iris: The pupil is the circular opening in the colored part of the eye which is the iris. The iris dilates or opens and contracts to let in more or less light.

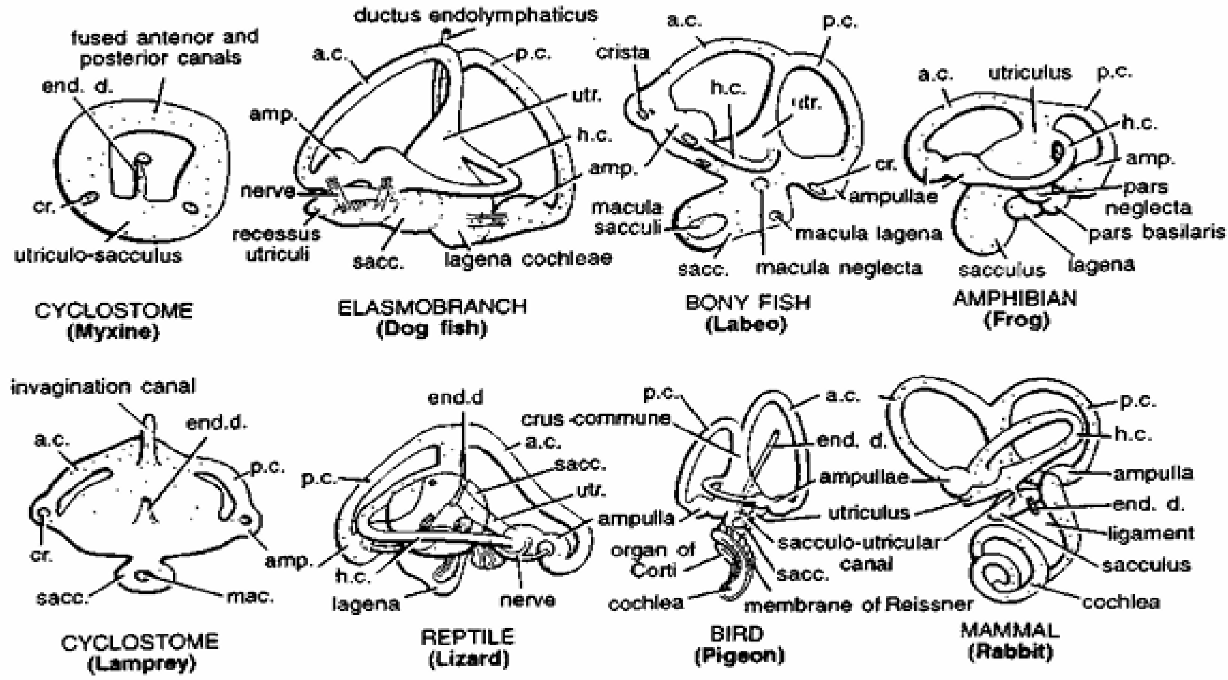

Fig. 3. Internal ears of representiative vertebrates a.c —anterior vertical semicircular canal. amp.—ampulla. cr.—crista. end.d.—endolymphatic duct. h.c.—horizontal canal. mac.—macula. p.c.—posterior vertical canal. sacc.—sacculus. utr.—utriculus.

Lens: Resembles the lens of a camera and focuses the light, changing shape as it takes in light reflected from objects near and far.

Vitreous: A clear jelly that the focused light passes through to the retina.

Retina: The inner lining at the back of the eye. It contains blood vessels which bring nutrients to the nerve cells. The macula is at the very center of the retina and contains the fovea. The photoreceptors of the retina are the rods and cones. The cones perceive color and finer elements. The retinal pigment epithelium, choroid and sclera are three more layers. The photoreceptors send light and images to a largenerve called the optic nerve. This carries the information to the occipital lobe of the brain where they are interpreted.

Eyelids and eyelashes: These protect the eye and along with tears keep the eye clear and moist. Hearing: The ear is the organ concerned with hearing. The ear has three parts: the outer ear, the middle ear and the inner ear.

Outer ear: Pinna: The outermost part of the ear made of cartilage that is connected to the outer tube called the auditory canal. This leads to the eardrum.

Middle Ear: Eardrum, stirrup, anvil and hammer: This membrane vibrates and along with the three tiny bones in the middle ear, the hammer, anvil and stirrup, and sends the stimuli to the cochlea.

Inner Ear: Cochlea: Is spiral shaped and it transforms sound into nerve impulses that travel to the brain.

Semicircular canals: This fluid filled tubes attach to the cochlea and nerves in the inner ear. They send information on balance and head position to the brain. Eustachian tube: Drains fluid from the middle ear into the throat behind the nose.

Taste: Tongue is a muscular organ in the mouth. It is covered with moist, pink tissue called mucosa and tiny bumps called papillae. Thousands of taste buds cover the surfaces of the papillae. Taste buds are collections of nerve-like cells that connect to nerves going into the brain. There are four types of taste buds: sour, sweet, bitter and salty. The tongue is vital in tasting and chewing food and in speech.

Smell: The nose, along with the mouth, lets air in and out of the body. It also helps us distinguish different smells in that air.
The nasal root is the top of the nose, forming an indentation at the suture where the nasal bones meet the frontal bone. The anterior nasal spine is the thin projection of bone at the midline on the lower nasal margin, holding the cartilaginous center of the nose. Adult humans have nasal hairs in the anterior nasal passage.

Touch: The skin is the largest organ of the body, with a total area of about 20 square feet. The skin protects us from microbes and the elements, helps regulate body temperature, and permits the sensations of touch, heat, and cold. the epidermis, the outermost layer of skin, provides a waterproof barrier and creates skin tone.

20.5 SUMMARY

Students will have knowledge on the comparative anatomy and function of nervous system, evolution of urinogenital system and sensory organs among vertebrates.

20.6 QUESTION AND ANSWERS

1. Give a detail account of circulatory system in vertebrates?
2. Explain the comparative account on urinogenital system?
3. Explain about spinal cord in vertebrates?
4. Explain about sensory organs in vertebrates?

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Prof. G. Simhachalam