PREFACE

In a bid to standardize higher education in the country, the University Grants Commission (UGC) has introduced Choice Based Credit System (CBCS) based on five types of courses viz. *core, generic, discipline specific elective, ability and skill enhancement* for graduate students of all programmes at Honours level. This brings in the semester pattern which finds efficacy in sync with credit system, credit transfer, comprehensive continuous assessments and a graded pattern of evaluation. The objective is to offer learners ample flexibility to choose from a wide gamut of courses, as also to provide them lateral mobility between various educational institutions in the country where they can carry their acquired credits. I am happy to note that the university has been recently accredited by National Assessment and Accreditation Council of India (NAAC) with grade "A".

UGC (Open and Distance Learning Programmes and Online Programmes) Regulations, 2020 have mandated compliance with CBCS for U.G. programmes for all the HEIs in this mode. Welcoming this paradigm shift in higher education, Netaji Subhas Open University (NSOU) has resolved to adopt CBCS from the academic session 2021-22 at the Under Graduate Degree Programme level. The present syllabus, framed in the spirit of syllabi recommended by UGC, lays due stress on all aspects envisaged in the curricular framework of the apex body on higher education. It will be imparted to learners over the six semesters of the Programme.

Self Learning Material (SLMs) are the mainstay of Student Support Services (SSS) of an Open University. From a logistic point of view, NSOU has embarked upon CBCS presently with SLMs in English / Bengali. Eventually, the English version SLMs will be translated into Bengali too, for the benefit of learners. As always, all of our teaching faculties contributed in this process. In addition to this we have also requitioned the services of best academics in each domain in preparation of the new SLMs. I am sure they will be of commendable academic support. We look forward to proactive feedback from all stakeholders who will participate in the teaching-learning based on these study materials. It has been a very challenging task well executed, and I congratulate all concerned in the preparation of these SLMs.

I wish the venture a grand success.

Professor (Dr.) Subha Sankar Sarkar
Vice-Chancellor

Netaji Subhas Open University
Under Graduate Degree Programme
Choice Based Credit System (CBCS)
Subject : Honours in Zoology (HZO)
Course : Animal Diversity
Course Code : GE-ZO-11

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: Course Writer :
Dr. S. K. Raut
Retd. Professor of Zoology
University of Calcutta

: Course Editor :
Dr. K. K. Mishra
Retd. Associate Professor of Zoology
Rishi Bankim Chandra College

: Format Editor :
Dr. Bibhas Guha
Associate Professor of Zoology
Netaji Subhas Open University

NETAJI SUBHAS OPEN UNIVERSITY

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Unit 1 ❑ Protista : General Character of Protozoa; Life Cycle of *Plasmodium*

Structure

1.1 Objectives

By studying this unit, the students will be able to understant about the general idea on protista and the life cycle of the malarial parasite, *Plasmodium.*

1.2 Introduction

R.H. Whittaker (1969) introduced five kingdom system of classification of organisms. That is, he divided all the organisms into five kingdoms *viz*, Kingdom : Monera, Kingdom: Protista, Kingdom: Fungi, Kingdom: Plantae and Kingdom: Animalia. All unicellular organisms are grouped under Protista.

1.3 Salient features of protista

1. Microscopic, unicellular and eukaryotic organisms.
2. Most have mitrochondria and other cellular organelles. Nucleus may be one, two or many.

3. Aquatic or terrestrial but in moist enviorment.
4. Free living and parasitic.

Protista is represented by several groups of organism, namely, **Chrysophytes, Dinoflagellates, Euglenoids, Slime moulds** and **Protozoa.** Chrysophytes include diatoms and golden algae. Dinoflagellates are pigmented marine organisms and Euglenoids are mostly freshwater organisms and are autotrophs. On the other hand slime moulds are terrestrial and heterotrophs and thereby they adapted to live as parasites or predators.

1.4 General characters of protozoa

Shape : Single-celled organisms represent various shapes and some group is habituated to change the shape constantly (i.e., *Amoeba*) while some could be seen with definite shape just like a slipper (i.e., *Paramoecium*).

Size : Microscopic, usually ranges from 1 micrometre to several milimetre. But, the largest forms i.e., the deep-sea dwelling xenophyophores—the foraminiferans may bear a shell upto 20 cm in diameter.

Habitat : Aquatic as well as terrestial; but the terrestrial inhabit moist soil and damp places. Aquatic forms are equally adapted to live in freshwater and marine enviorment. However, many of them may be seen in air in the form of cyst. The parasitic forms are found in the body of the hosts. They may be found singly or in colony.

Structure : The unicellular organism's body is composed of cytoplasm and nucleus. Also, various organelles could be seen inside the cytoplasm. The cytoplasmic mass is enclosed by the plasma membrane. The nucleus is also enclosed by a membrane. Outside the plasma membrane variously projecting fine structures like cilia, flagella as well as pscudopodia could be seen as the extended part of the plasma membrane. In shelled forms tread like pseudopodia make their way outside through the minute pores of the shell.

Locomotion : Pseudopodia, cilia and fleglla are the locomotory organelles or protozoans. But, some parasitic groups are nonmotile. Pseudopodia are temporary whereas cilia and flagella are permanent locomotory organelles.

Nutrition : (i) Holozoic or Zootrophic or Heterotrophic, (ii) Saprozoic or Saprophytic and (iii) Parasitic, mode of nutrition. In holozoic nutrition protozoans

used organism smaller that their body size as food. This mode of nutrituion is associated with ingestion, digestion, assimilation and egestion. In case of saprophytic nutrition nourshing substances enter into the body by diffusion through body surface or protozoa. Bacteria produced simpler compounds, dead or decomposed bodies of animals or plants are the nourshing substances in this type of nutrition. Mostly, flagellate protozoans exercise this type of nutrition. Parasitic protozoans derive nutrients from the host. In case of *Monocystic* the digested or decomposed materials of the host are drawn into the body on way of diffusion. *Entamoeba* being gut parasitice holozoic nutrition.

Respiration : Free molecular oxygen from the surrounding media enter the body by diffusion. Some parasitic protozoans get oxygen from the body of the host while many such protozoans are able to survive without oxygen and they, thus termed as anaerobic protozoa. However, the chicken intestinal parasitic flagellate *Histomonas meleagridis* is able to grow in presence or absence of oxygen, and thus, is known as 'facultative aerobe'.

Excretion : Excretory products are water, carbon dioxide and nitrogenous compounds. These remain in soluble from. These are, in due course of time, removed from the body either by diffusion or by contractile vacuole in protozoans occurring in hypertonic water media, while marine or parasitic protozoans inhabiting isotonic media lack contractile vacuole.

Response to stimuli : The reaction to stimulus is ascertained by observing the movements of protozoans in changing direction in response to the stimulus. These movements are to two types—taxis and kinesis.

Reproduction : Reproduction is effected both by asexual and sexual means. Fission, budding and schizogony are the modes of asexual reproduction. In fission one cell (individual) splits into two (binary fission) to give rise two daughter individuals while in other cases the said individual may spilt into several small fragents (multiple fission) to produce a daughter individual from each of such fragments. In case of multiple fission (also known as schizogony) daughter cells are produced due to multiple fission of the nucleus followed by segmentation of cytoplasm to form separate mass around each smaller nucleus, as in *Amoeba.* In budding, buds form around a nucleus and pinch off of the cell to give a new individual. Sexual reproduction is effected through (i) Syngamy and (ii) Conjugation. In syngamy complete fusion of two cells or gametes, resulting in the formation of zygote. In case of conjugation temporary union of two organisms for the exchange of genetic material takes place as in *Paramoecium.*

Economic importance : Protozoans help to maintain the food-chain and thereby play significant role to maintain the food-chain to regulate biodiversity. As certain protozoans are parasitic in nature, they, on way of their survival strategy cause serious dieases in animals and humans and thus, malaria, trypanosomiasis, leishmaniasis (Kala azar), amoebiasis, giardiasis are of serious concerned. Study of the shells of shelled protozoa like Foraminifera embedded in the rock is an important indicator for geologists who are involved in oil exploration.

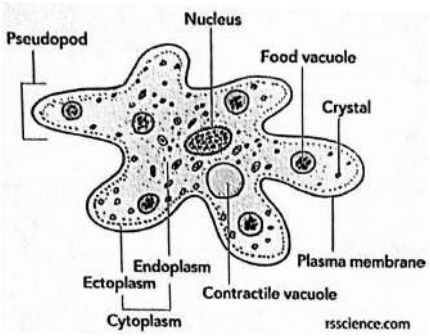


Fig. 1 *Amoeba*

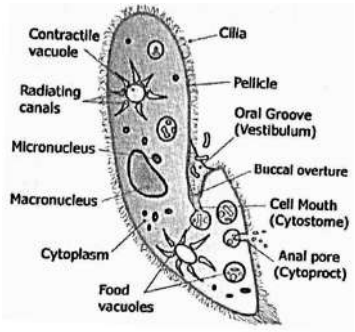


Fig. 2 *Paramoecium*

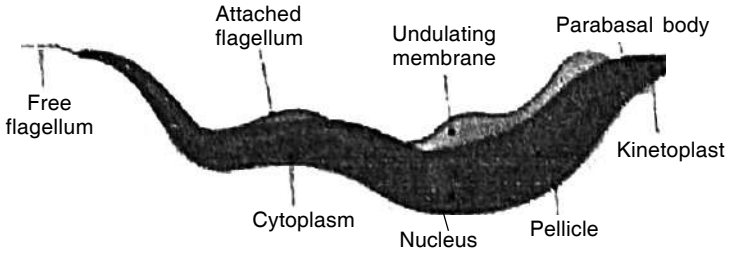


Fig. 3 *Trypanosoma*

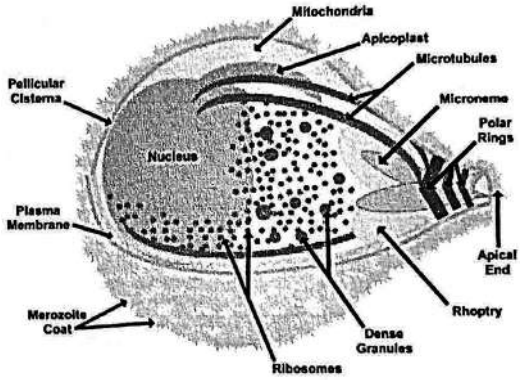


Fig. 4 *Plasmodium*

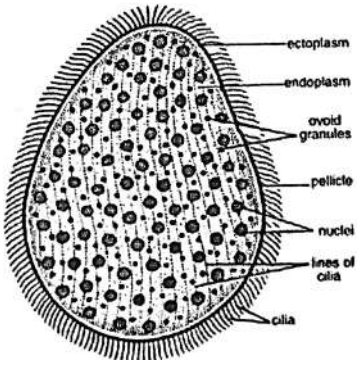


Fig. 5 *Opalina*

Examples : *Amoeba* (Fig:1), *Paramoecium* (Fig:2), *Trypanosoma* (Fig:3), *Plasmodium* (Fig:4) and *Opalina* (Fig:5)

1.5 Life cycle of *Plasmodium*

Members of the genus *Plasmodium* belong to sporozoan protozoa. They are parasitic organisms and depend on two different species as hosts to complete their life cycle. *Plasmodium* species are very important because of their involvement in causing serious disease—malaria, in humans. There are five *Plasmodium* species viz. *P. falciparum, P. malariae, P. vivax, P. ovale* and *P. knowlesi* known to cause malaria in humans. Of these *P. Knowlesi* is a zoonotic malaria parasite, transmitted between non-human primate hosts by the *Anopheles* mosquito, and causing spill-over infections in humans where the parasite, vector, hosts and human converge [Abeyasinghe, 2016 (WHO)]. Thus all these *Plasmodium* species can infect humans and cause illness i.e. malaria. As regards to human malaria, *Plasmodium* complete the life cycle in two host human host (intermediate host) and the mosquito host (definitive host). In all cases mosquito belongs to the genus *Anopheles* acts as definitive host.

The life cycle of *Plasmodium* is completed through the following events :

(i) Infection of human with sporozoite.

(ii) Asexual reproduction

(iii) Sexual reproducation

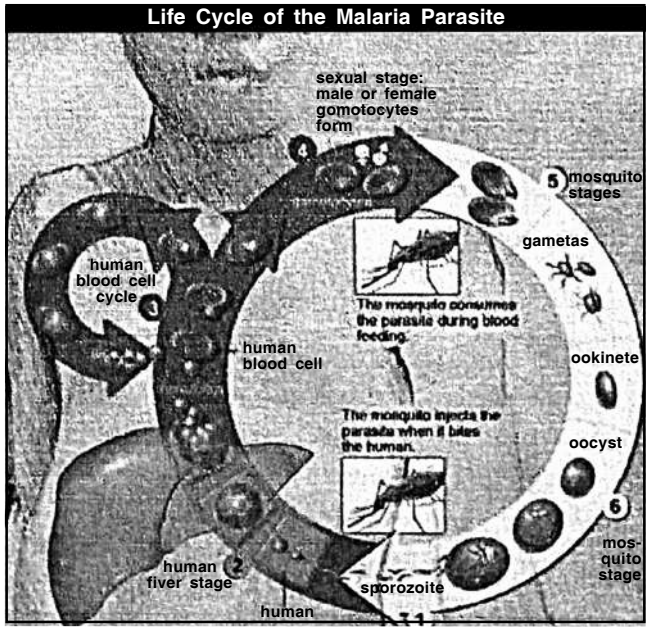


Fig. 6 Life cycle of malarial parasite

The events (i) and (ii) take place exclusively in human body while the event (iii) though starts in human body is completed in the mosquito host. The female *Anopheles* mosquito, to satisfy its nutritional requirement for the development of the eggs, takes blood by biting the intermediate host (human) and also other animals (for malaria in other animals). During a blood meal the malaria infected female *Anopheles* mosquito injects saliva, infected with *sporozoites* of *Plasmodium,* into the blood stream of human host (Fig:6).

Human cycle :

Human cycle of *Plasmodium* initiates with the inoculation of sprozoites into the blood circulation. In the next state of life cycle asexual reproduction takes place. This stage is divided into exoerythrocytic phase and erythrocytic phase. Following inoculation the sprozoites find their way to the first target, the liver within 30-60 minutes. The sprozoites penetrate the liver cells and start dividing to produce schizonts in 6-7 days. From a single schizont thousands of merozoites are produced. This is known as exoerythrocytic schizogony. These merozoites then are released into the blood stream indicating the end of the exoerythrocytic phase of asexual reproduction stage of *Plasmodium.* It is to be mentioned here that sprozoites of *P. vivax* and *P. ovale* may not follow the reproduction path and stay dormatic (hypnozoites) in the liver. They may be activated after a long time leading to relapses entering the blood stream (as merozoites) after weeks, months or even year.

The exoerythrocytic phase is not pathogenic. Thereafter, no sign or symptoms of the disease could be seen at this phase. The duration of this phase varied with the species of *Plasmodium.*

Merozoites in the blood stream move towards the second target, the red blood cells (RBCs). They penetrate into the RBC and initiate the erythrocytic phase. After invasion a ring stage appears first inside their RBCs which ultimately turned into trophozoite. The trophozoite resemble a ring and is called signet ring stage. The trophozoites are unable to digest the haem from haemoglobin, so they convert the same into haemozoine and then digest the globin which is used as a source of aminoacids for their reproduction. The next stage is the erythrocytic schizont. Each mature schizont gives birth to new generation—the merozoites. The merozoites assembled themselves in the form of petals of a rose-flower called rosette stage. The merozoites are either microgametocytes (males) or microgametocytes (females). The rupture of red blood cells by merozoites releases certain factors and toxins which could directly induce the release of cytokinins such as TNF and interleukin-1 from macrophages resulting in chills and high grade fever. The time needed for the gametocytes to attain mature state differs for each *Plasmodium* species :3-4 days for *P. vivax* and *P. ovale,* 6-8 days for *P. malariae* and 8-10 days for *P. falciparum.*

Mosquito cycle :

The female *Anopheles* Mosquito, in course of sucking blood from the body of a malaria infected persons ingest both a sexual and sexual forms *Plasmodium* but only

the sexual forms survive and subsequent stages are developed inside the gut. The nucleus of microgametocyte divides three times producing 8 nuclei. Ultimately 8 filamentous motile appendages emerge and each nucleus with each flagellum is called microgamete or malegamete. Each such nucleus fertilizes a macrogamete (developing from macrogametocyte) forming a zygote. This is completed in 20 minutes to 2 hours time period. The zygote moves actively and becomes so-called 'ookinete'. Then, the ookinete penetrates the midgut wall of the mosquito and comes to rest under the outer lining epithelium of the gut wall. There, it, then transformed into a spherical mass or oocyst surrounded by cyst wall. Inside the oocyst, the ookinete nucleus divides to produce thousands of sporozoites (Sporogony). Thus, the parasite completes the third stage (stage of sexual reproduction) or the sprogony.

Thereafter, the nucleus of the sporozoite divides repeatedly and a large number of sickle-shaped sporozoites are formed from one oocyst. The oocysts rupture and the sporozoites are released into the haemocoel of the body cavity of mosquito. Subsequently, the sporozoites find their way to salivary glands though only few hundreds of sporozoites could manage to accommodate themselves there. The said mosquito, at the onset of blood meal injects its infected saliva into the next victim and thus making the beginning of a new cycle (Fig-6; Table-1).

Table-1: Duration of each different phase in the life cycle of different species of *Plasmodium.*

		P. vivax	*P. malariae*	*P. ovale*	*P. falciparum*
1.	Pre-erythrocytic phase (days)	6-8	14-16	9	5-7
2.	Erythrocytic cycle (hours)	48	72	50	48
3.	Incubation period (days)	12-17 or even 6-12 months	18-40 or more	16-18 or more	9-14
4.	Sporogony (days)	8-10	14-16	12-14	9-10

1.6 Conclusion

Kingdom Protista, contains simple eukaryotic organisms, usually composed of a single cell or a colony of similar cells. Of the differnt groups of Protista, except Protozoa, all are autotrophs. Protozoans being heterotrophs lead a life either as predators or parasites. Of the parasitic protozoans the species belongs to *Plasmodium* are the causative agents of human malaria and the female *Anopheles* mosquito is very much involved not only to ensure the completion of life-cycle of these parasites but also to spread the malaria disease from man to man.

1.7 Summary

i) Protista are single-celled eukaryotic organisms.

ii) Protozoans are protista but heterotrophic in nature.

iii) Free living protozoans are predacious in habit while parasitic protozoans derive their nourishment from host.

iv) *Plasmodium* being sporozoan protozoa are very much involved with creation of malaria disease in humans.

v) *Plasmodium vivax, P. ovale, P. falciparum* are notable human-malaria-causing agents while *P. knowlesi* creates malaria in monkeys and apes but sometimes in humans also. Thus, *P. knowlesi* is involved with zootonic malaria.

1.8 Glossary

Protist : Any member of a group of diverse eukaryotic, unicellular, microscopic organisms which may share certain characters with plants and animals.

Eukaryotic : An organism whose cells have nucleus enclosed with membrane and with membrane bound organelles.

Pseudopodium : A temporary protrusion of the surface of an amoeba for movement and feeding.

Cilium : It is a slender protuberance of the cell body of the eukaryotic ciliate organisms which is known as locomotory organalle.

Fagellum : It is a long whip-like structure that helps flagellated protozoans in locomotion.

Malaria : An intermitent and remittent fever caused by a protozoan parasite which invades the red blood cells and is transmitted by *Anopheles* mosquitoes in many tropical and subtropical regions.

Intermediate host : An organism (host) that supports the immature or non-reproductive forms of a parasite.

Definitive host : An organism (host) which supports the adult or sexually reproductive forms of a parasite.

Sporozoite : A motile spore-like stage of *Plasmodium* which is the infective agent introduced into the host (man).

Signet ring stage : Due to a large food vacuole and the peripherally situated nucleus young spherical trophozoites of *Plasmodium* species inside the red blood cells look like a signet ring.

Ookinete : The elongated motile zygote of a parasite of the malaria mosquito that forms an oocyst in the mosquito gut.

Conjugation : The process of temporary union of two organisms (*Paramoecium)* for the exchange of genetic material.

1.9 Questions

1. State the characteristic features of Protista.
2. Mention different groups of Protist organisms with examples.
3. State the general characters of Protozan organisms.
4. Mention the type of locomotory organelles of protozoans with example.
5. Name the *Plasmodium* species known to cause malaria in humans. What in zoonotic malaria?
6. Describe the human cycle of *Plasmodium* parasite.
7. Describe the mosquito cycle of *Plasmodium* parasite.
8. By the help of a flow chart show the sequential events in the life cycle of *Plasmodium* parasite.
9. Explain the following :

   (a) Schizont (b) Sprogony (c) Oocyst (d) Gamogony

   (e) Contractile vacuole (f) Conjugation (g) Budding (h) Sprozoite.

1.10 Suggested readings

1. Medical parasitology by D. R. Arora, CBS Publishers and distributors Ltd, Amazon, 2018.
2. Handbook of the protists by John M. A., Alastair G. B. Simpson, C. H. Slamovits. etds. springer, Cham, Switzerland, 2017.

3. Kingdon of Life—Protista (enhanced ebook) by Gina Hamilton. Lorenz Educational Press, Rediff Books.
4. Textbook of Medical Parasitology by S. C. Parija. Amazon India, 2013.
5. Parasitology by K. D. Chatterjee. Sree Saraswaty Press, 1967.
6. Protozoa and other protists by Michael A. Sleigh L 978071312943-Amazon Com, 1989.
7. Malaria according to the new researches, by Angelo Celli, Franklin Classics, Trade Press, 2018.

Unit 2 ❑ Porifera : General Characters and Canal System in Porifera

Structure

2.1 Objectives

By studying this unit, students will be able to understand—

i) about the characteristic features of poriferan animals.

ii) To study the types and significance of canal systems developed by the poriferan organisms.

2.2 Introduction

Commonly poriferans are known as sponges. This animal group was separated from other metazoans very early in the history of evolution. Fossil sponges are among the oldest known animal fossils, dating from the late Pre-Cambrian. The member of fossil genera of sponges recorded so far, exceeds 900. At present

appoximately 5000 living species of sponges are grouped, in respect to their characteristic features, into Hexactinellida, Demospongiae and Calcarea. The animals belong to the Phylum Porifera are characterized by having pores all over the body—as the name implied (Latin "porous" means pore and "ferre" means to bear/carry).

2.3 General characters of porifera

Habitat : Aquatic animals mostly found in marine enviornment while few species belongs to Fam. Spongillidae live in freshwater.

Size and shape : Some sponges are only a few centimeters in size. Many sponges are shapeless and are less than a centimeter, while some sponges are with a definite shape—either vase-like or tube or like branches to tree and may be 1-2 meters in height. Also some species are broad rounded in shape and up to 2 meters in diameter.

Body organisation : Mostly with asymmetrical body while some are radially symmetrical. Multicelluar with cellular level of organisation without true tissues. Cells are arranged in outer layer as well as in inner layer. Pinacocyte cells are known as skin cells. They lined the exterior of the body wall of the sponges. They are tightly packed together. Choanocyte cells (Fig. 1) line the interior body wall of sponges. Choanocyte cell has a central flagellum which is surrounded by a collar of microvilli. Between the two cell layers, a space known as mesenchyme or mesohyl could be seen. Mesenchyme contains some loose cells and spicules (Fig. 2) in a proteinaceous matrix. Of these, archaeocyte cells (Fig. 3) are totipotent, that is, they are able to change into other types of sponge cells. Also, sclerocytes, myocytes and porocytes are found in sponges. Sclerocytes secrete spicules while the other cells, called spongocytes secrete spongin fibres. Myocytes and porocytes have the power to contract themselves. In sponges a continuous single cavity called paragastric cavity or spongocoel is present within the body. In most cases the cavity is thrown into folders to form a complex canal system. *Canal system* in sponges is meant for water transport. Water enters through minute pores known as ostia in the body wall into a central cavity known as spongocoel, from where it goes out through the comparatively larger pore—the osculum. Myocytes and porocytes which surround canal openings and pores can contract to regulate water flow through the sponge. Choanocytes or

collar cells regulate the direction of movement of water in the canals by the beating of flagellae.

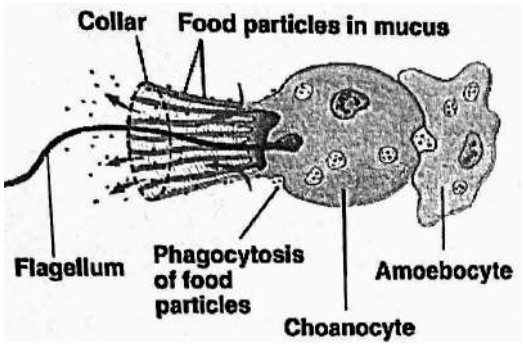


Fig. 1: Choanocyte

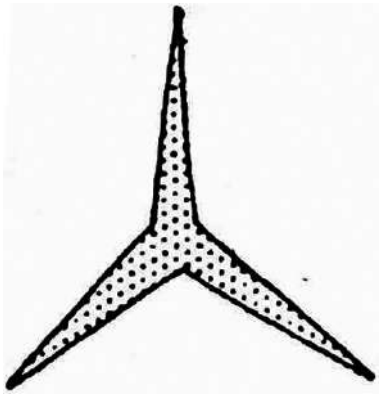


Fig. 2: Spicule

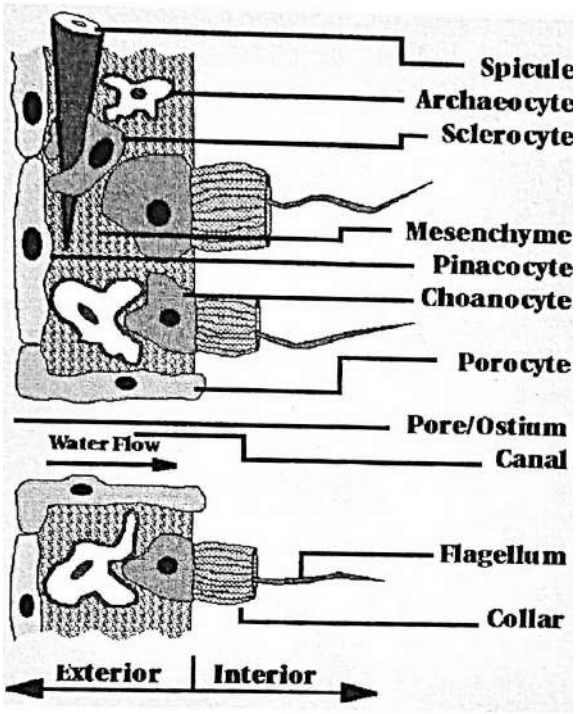


Fig. 3: Archaeocyte and other cells

Food and feeding : Sponges feed on detritous particles, plankton, bacteria etc. that is brought close by water currents created by the choanocytes. Food items are taken into individual cells by phagocytosis and digestion occurs within individual cells.

Respiration and excretion : Water moves through the canal system. Oxygen present in incoming water diffuses into the sorrounding cells. Carbon-dioxide and other wastes diffuse into the water and are carried out.

Reproduction : Sponges are mostly hermaphrodites. They have no reproductive organs as well as gonads. Sponges are able to reproduce both by asexual and sexual means. Fragmentation, gemmeule formation, budding, both external and internal, are the mode of asexual reproduction. In sexual reproduction, being hermaphrodite,

individuals produce eggs and sperms at different times. The sperm is released in water frequently. The sperm travels in water and enters into the respective site of the other sponge individual waiting for fertilization of the eggs produced by the same, the so-called female one. After fertilization a larva is released into the water. Within a short period the larva settle and develop into juvenile sponges.

Economic importance : Commercially sponges play a vital role in our economy. The bath sponges are beneficial to man because of their skeleton which has many commercial uses.

Examples :

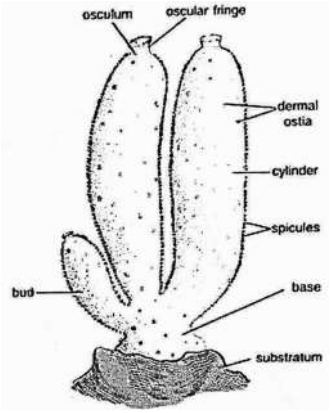


Fig. 4: *Scypha sp.*

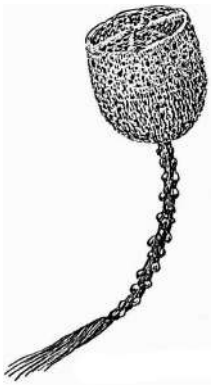


Fig. 5: *Hyalomena sp.*

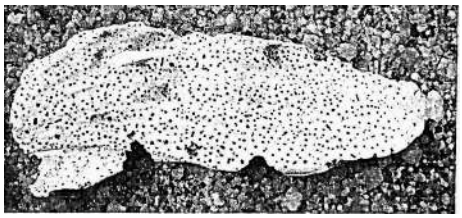


Fig. 6: *Cliona sp.*

2.4 Canal system in porifera

The perforations of the body of sponges by a large number of ostia is characteristic of phylum porifera. But in all cases these pores are nothing except the terminal point of a canal. Thus, from all the pores canals lead to a large canal, the spongocoel which opens to the extirior through a larger pore, the osculum. Depending upon body structure of sponges there may be many such openings i.e. oscula. The entire physiological activities of the sponges depend on the water current and the exchanges between the body and the exterior are maintained through the water current.

2.4.1 Components of a typical canal system

A typical canal system is composed of (i) Incurrent canal, (ii) Excurrent or radial canal and (iii) Prosopyle.

Incurrent Canal : It opens to the outside by a small pore known as incurrent pore or ostium. It ends blindly internally.

Radial canal or Excurrent Canal : It is closed externally but opens internally by minute pores or apopyles into spongocoel.

Prosopyle : It is a smaller canal or pore connecting incurrent canal with radial canal.

Incurrent canals are lined by flat squamous cells which help to form water current. The radial canals are lined by collar cells having openings at the surface. These cells are porovided with flagella. The lashing movements of flagellum help to capture and to push the food particles into the cell-mouth. The spongocoel opens to the outside by osculum.

2.4.2 Types of canal system in sponges

Depending upon the complexity in body organisations in different groups of sponges the canal systems are also divided into four distinct types : **Ascon type, Sycon type, Leucon type** and **Rhagon type (Fig. 7).**

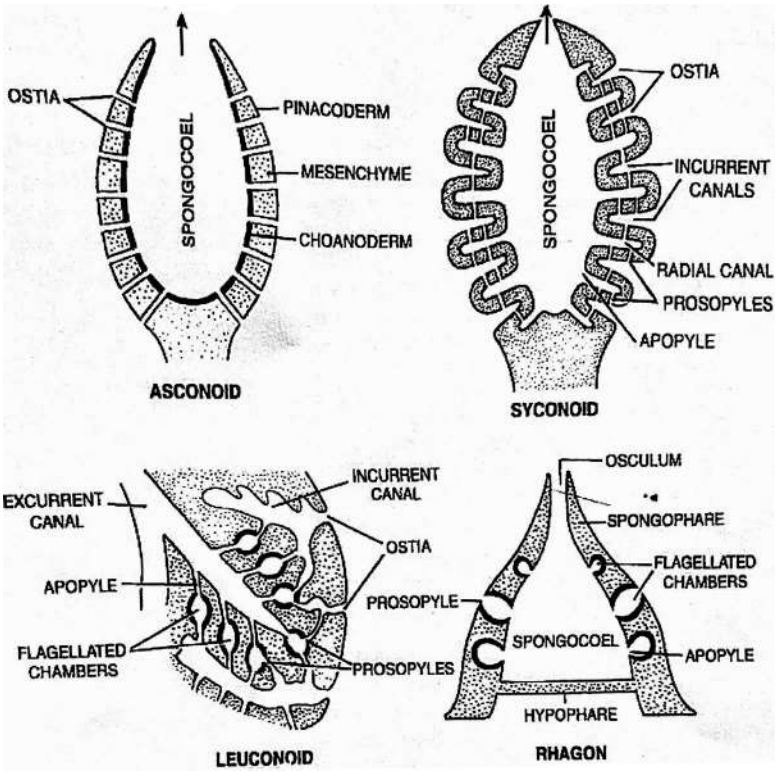


Fig. 7: Four types of canal systems in porifera

Ascon Type : Simple and primitive type of canal system. It encloses a large spongocoel which is lined by choanocytes. The wall is pierced by numerous microcopic apertures, the ostia which extend from the external surface to the spongocoel. Ostium is intracellular and disposes in a porocyte. The spongocoel is completely lined by a layer formed by choanocyte cells but interrupted only by the porocyte (Fig. 8). This type of canal system is mostly seen in calcareous sponges. (e.g. *Leucosolenia clathrina*).

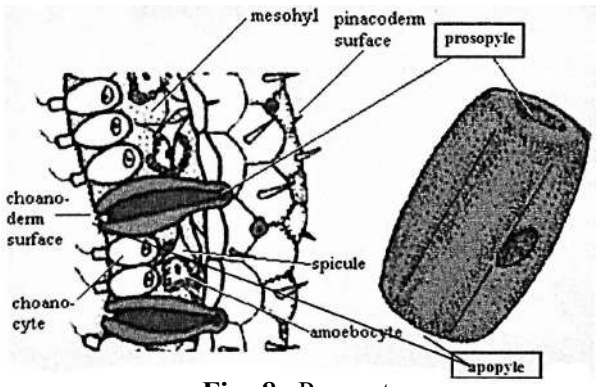


Fig. 8: Porocyte

In ascon type of canal system the course of water current is as follows :

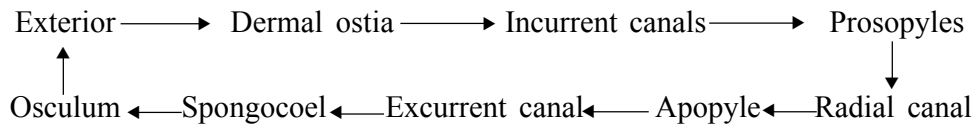
Dermal pore → Internal ostia → Spongocoel → Osculum → Exterior → Dermal pore

Sycon type : This type is little bit complex than the ascon type because, here the wall is pushing outward into finger like projections called radial canals, at regular intervals. In this system choanocytes are found only in the radial canals. It may be of (a) Simple sycon type, (found in ***Sycetta*** sponges) (b) Complex sycon type (found in ***Scypha***) and (c) Sycon type with cortax (found in ***Grantia, Grantiopsis*** sponges).

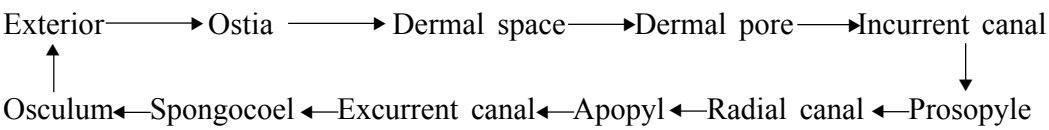
Course of water current in simple sycon type is as follows :

Exterior → Ostia → Radial canal → Apopyle → Spongocoel → Oscula → Exterior

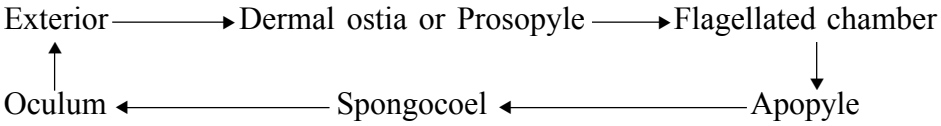
Course of water current in complex sycon type is as follows :



Course of water current in sycon type with cortex type is as follows :



Rhagon type : In this type of canal system the osculum is located at the summit of conical body. Spongocoel is bordered by oval flagellated chambers, opening into it by apopyles. The mesenchym is traversed by incurrent canals. The rhagon type is little complex than the complex syconoid type. This type of canal system is seen in the larval stages of demospongiae. The course of water current in rhagon type is as follows.



Leucon type : In this type of canal system the choanocytes lining the radial canals evaginate into many small chambers which repeat the same process to give rise to a cluster of small flagellated chambers. The incurrent canals lead to small round flagellated chambers open by apopyles into excurrent canals.

Leucon type again may be of (a) Eurypylous type (seen in *Plankina, Tetilla*), (b) Aphodal type (seen in *Geodia, Stellata*) and (c) Diplodal type (seen in *Oscarella, Spongilla*).

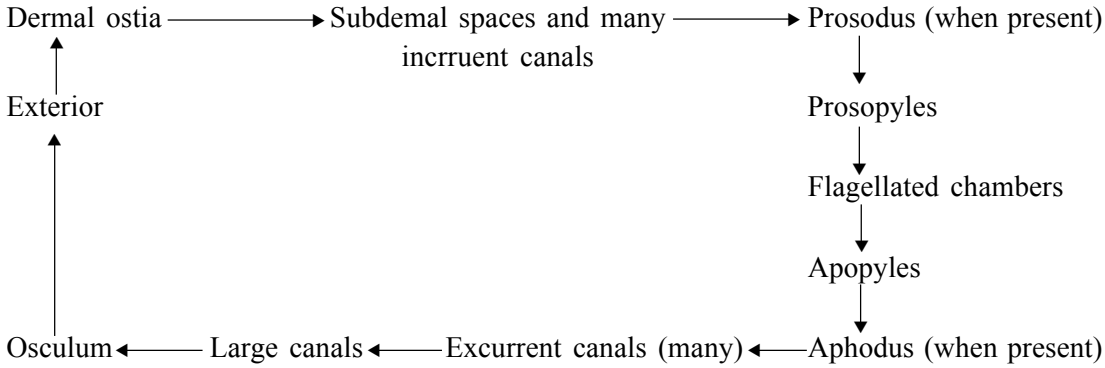
The main advancement of leuconoid canal system over syconoid type are :

(i) Choanocytes are limited to small chambers.

(ii) Development of mesenchyme in a better way.

(iii) Elaboration and complication of the incurrent and excurrent water passages.

Course of water current in leucon type of canal system :



2.4.3 Machanism of water circulation of porifera

Beating of flaglla by the choanocyte cells produces water current which draws the water inside through ostia and also forces the water to get out through the osculum (Fig: 7)

2.4.4 Functions of canal system in porifera

Canal system serves the purpose of feeding, respiration and excretion in sponges.

2.5 Conclusion

Porifera i.e. sponges are though multicellular organisms with various types of cells, no tissue level organisation could be seen in these animals. They have developed the canal system for the entry of water from the enviornment and remove the same from the body following ensuring feed, respiration and containing the excretory end/or other waste materials. Complexity in canal system in different groups of sponges indicates an evolutionary trend towards development of tissue level organisation and organ formation in the next higher groups of animals.

2.6 Summary

i) Sponges are aquatic organism. They depend on water current regulated by the flagellated cells occurring along the outer surface of the canal forming walls, from the enviornment to the exterior through the body channel.

ii) Spongocoel is the main canal while the other canals are shorter and narrower.

iii) There are many pores on the surface of the body known as ostia which allow entry of water into the body and the larger openings, the oscula are very limited in number help to remove the water from the body.

iv) Feeding, respiration and excretion are regulated by the canal systems.

v) Depending upon the complexity in body structure the canal system have been modified into ascon, sycon, rhagon and leucon types.

vi) Sponges reproduces both asexually and sexually and in sexual reproduction after fatilization, a large stage is released into the water.

2.7 Glossary

Ostia : A series of any pores all over the body of a sponge.

Osculum : A large opening to the outside through which the current of water exits after passing through the spongocoel in sponges.

Choanocyte : A flagellated cell which helps to form the choanoderm in sponges with a view to regulate the direction of water current along the canal system.

Gemmule : It is internal bud which develops in sponges to accomplish asexual reproduction.

Mesoglea : A translucent non-living jelly-like substance found between the two epithellial cell layers in the body of sponges. It acts asa hydrostatic skeleton.

Prosopyle : In sponges, a pore through which water is drawn from outside into a sac-like chamber formed by the evagination of the body.

2.8 Questions

1. What is spongocoel?
2. Define apopyle and prosopyle?
3. What is radial canal?
4. State the location and function of choanocytes in sponges.
5. What is canal system? How many types of canal systems are there in Porifera. State the significance of Porifera?
6. Describe the following :
   (a) Ascon type of canal system.

(b) Sycon type of canal system.

(c) Leucon type of canal system.

(d) Rhagon type of canal system.

7. By the help of flow chart present the course of water current through the different types of canal systems of Porifera studied by you.

2.9 Suggested readings

1. Sponges (Porifera). W.E.G. Muller (Ed) Springer, Germany 2003.
2. The cell biology of sponges. T.H. Simpson. Springer-Verlag, New York. 1984.
3. The sponges. H.V.P. Wilson. Nabu Press, 2012.
4. Invertebrate Zoology. E.I. Jordan and P.S. Verma. S. Chand and Company Limited, New Delhi (Revised Edition) 2018.

Unit 3 ❑ Radiata : General Characters of Cnidarians and Polymorphism

Structure

3.1 Objectives

By studying this unit, students will be able to gain knowledge on the characteristic features of Radiata in respect to the features of Cnidarian and the phenomenon of division of labour i.e., polymorphism.

3.2 Introduction

Depending upon the body plans from the study of histological view point certain animals were recognized as Radiata. Because, their body is radially symmertrical. Therefore, these animals belong to Radiata. These animals are with two germ layers i.e. diploblastic. Radiata contains two phyla-Cnidaria and Ctenophora. The name cnidarian comes from the Greek word "cinods" which means stinging nettle. It contains over 11,000 species and are excusively aquatic, predominantly marine. Cnidocytes are the specialized cells found in this group which help to capture the prey.

Polymorphism is an interesting aspect from the evolutionary view point of animals. Because, this refers to the occurrence of structurally and functionally more than two different types of individuals within the same organism. This may be condidered as unique

characteristic feature in cnidarian by producing verieties of zooids, especially the polyp and medusa forms, within the colony to ensure efficient functioning of the biological activities on way of division of labour among the colony forming zooids.

3.3 General characters of cnidarians

1. Mostly marine but few cnidarians are found in freshwater (e.g. *Hydra*).
2. Usually colonial though solitary forms could also be seen (e.g. *Hydra*).
3. Diploblastic with externally epidermis and internally gastrodermis. These two layers are separated by a jelly like layer called the mesoglea.
4. In each tissue layer presence of different types of cells is well marked. These are nerve cells, contractile epithelial cells enzyme secreting cells, and nutrient absorbing cells, as well as the presence of intercellular connection. But, no organ system is developed.
5. The whole surface of the body, except the pedal disc, is provided with a large numer of stinging cells or cnidoblasts (Fig:1). They are found in maximum number in tentacles which are located surrounding the hypostome. Each cnidoblast contains a capsular nematocyst inside. Cnidoblast cells help in food collection (capturing), defence and locomotion.

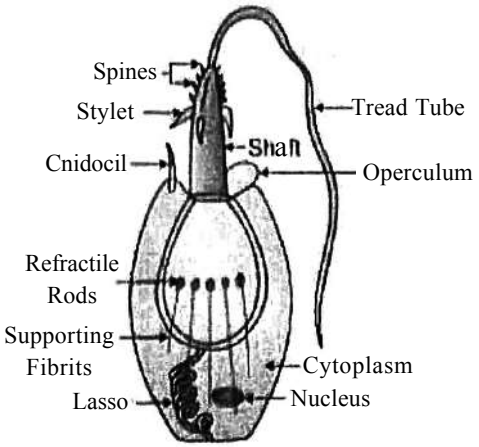


Fig. 1: Cnidoblast cell

6. The cells that produce nematocysts are called nematoblasts or cnidoblasts. There are four types of nematoblasts viz. (i) penetrant (ii) large glutinant, (iii) small glutinant and (iv) volvent.
7. Interstitial cells are undifferentiated mesenchyme cells. They are capable to convert in any type of epithlial cells. These are rather reserve and the main totipotent cells in cnidarians.
8. Gastrovascular cavity is the only internal cavity is a blind sac. Because it has only one opening— the mouth and the same is located at the centre of the hypostome. The anus is absent and the mouth also acts as anus.
9. Digestion is extracellular and intracellular.

10. Body forms are usually soft and transparent but some shows bioluminescence.
11. Gaseous exchange takes place through general body surface (no specialized respiratory, circulatory and excretory organs).
12. Circulation of various substances takes place at the cellular level. i.e. from cell to cell.
13. No nervous system but non-polar neurons are distributed irregularly in the body.
14. Statocysts or tentaculocysts are present as the organ of balance in free swimming forms.
15. The phenomenon of polymorphism i.e. occurrence of more than one kind of individuals in the same species. The two basic forms polyp and medusa are well marked in cnidarians. Polyp form is sessile (eg. sea anemone, hydra) while medusa is free swimming (e.g. *Aurelia* popularly known is jelly fish). Polyp reproduce asexually while medusa reproduces sexually. The other forms of zooids are gastrozooids, gonozooids, dactylozooids, tentaculozooids etc.
16. Metagenesis or alternation of generation, another notable biological phenomenon, is well marked in cnidarians. It is a phenomenon whereby, in the life cycle of an organism, a diploid asexual phase and a haploid sexual phase regularly alternate with each other in case of alternation of generation while in metagenesis a diploid asexual phase and a diploid sexual phase regularly alternate with each other.

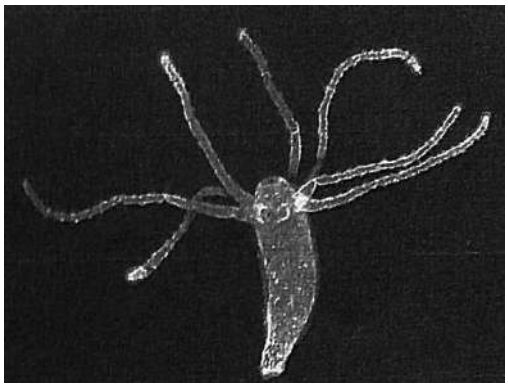


Fig. 2: *Hydra*

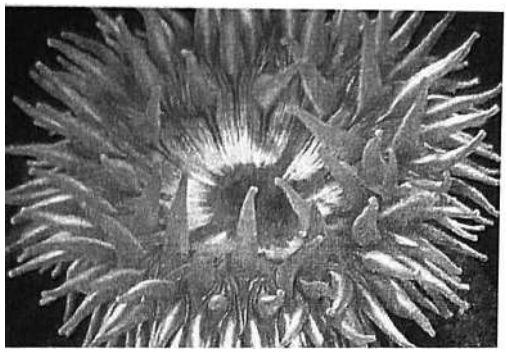


Fig. 3: *Sea anemone*

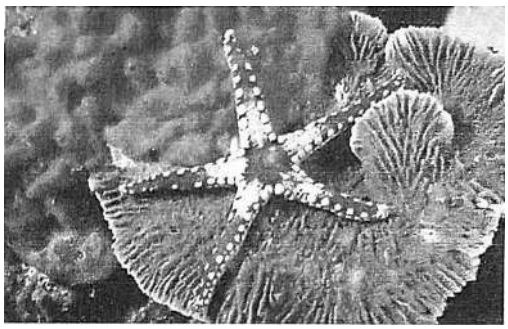


Fig. 4: Coral *(Astraea)*

17. Reproduction in polyp forms is effected due to budding, during favourable periods. Though male and female organisms are seen but there exists no sexual dimorphism.
18. Gonads simple but without ducts.

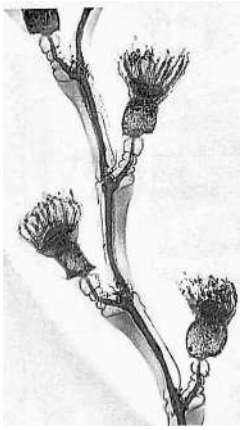


Fig. 5: *Obelia*

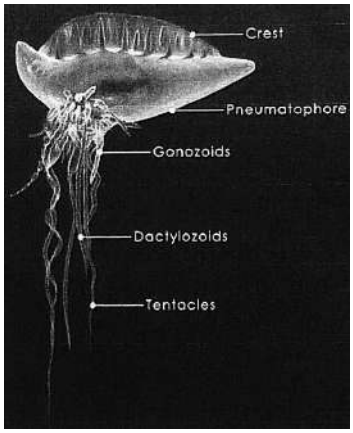


Fig. 6: *Physalia*

19. *In-situ* fertilization, holoblastic cleavage. Development may be direct or indirect. In case of indirect development, planula and ephyra larval stages are seen.

Examples : *Hydra* (Fig. 2) *Sea anemone* (Fig. 3), Coral (*Astraea*) Fig. 4), *Obelia* (Fig. 5), *Physalia* (Fig. 6)

3.4 Polymorphism in cnidaria

In Cnidaria polymorphism (Fig:7) means the occurrence of structurally and functionally more than two different kinds of individuals within the same organism. These different forms are known as zooids (gastrozooids, dactylozooids, tentaculozooids, gonozooids etc.). Of these zooids the polyp and medusa are considered as basic zooids.

3.4.1 Basic unit of polymorphism

The zooids can be divided into two fundamental forms which can be derived from each other.

(i) Polyp form (Fig. 7)

It is characterized by :

(a) Tube like body with one end closed but sedentary in habit.

(b) Preoral end is provided with hypostome, mouth and tentacles while aboral end is fixed.

(c) Mouth is round and situated at the centre of hypostome leading to coelenteron.

(d) Mouth is encircled by 6-8 elongated tentacles.

(e) It may be encased by a transparent covering- the hydrotheca.

(ii) Medusoid form (Fig. 7) :

It is characterized by :

(a) Body umbrella-shaped with convex exumbrellar surface and ventral concave subumbrellar surface.

(b) Mouth and manubrium are located in the subumbrellar surface.

(c) Radial and circular canals are prominent.

(d) The bell margins are provided with tentacles.

(e) Usually a velum is present.

(f) Gonads present.

(g) Free-swimming forms.

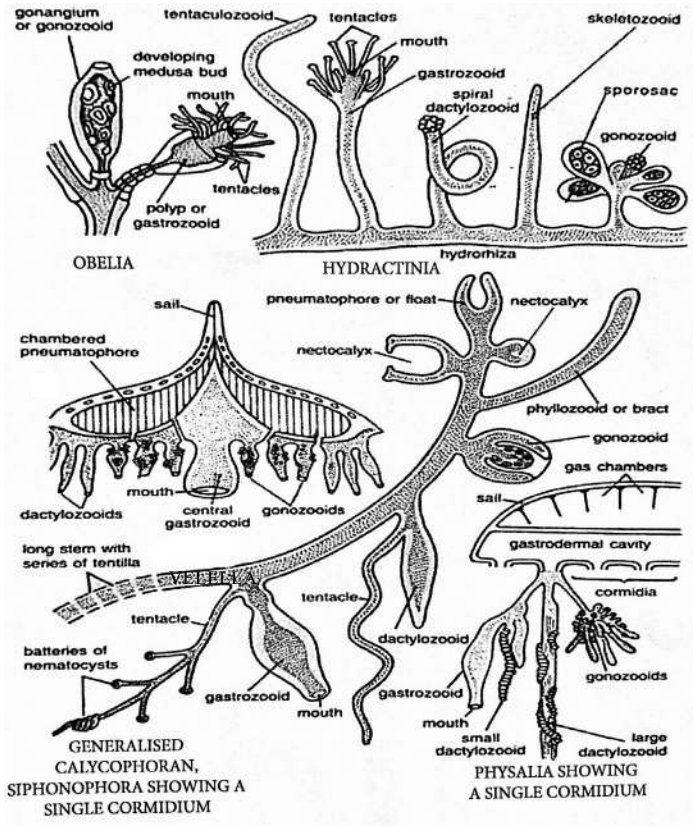


Fig. 7: Polymorphism *in Cnidaria*

3.4.2 Origin of polymorphism

There are different theories viz. poly-organ theory, poly-person theory, medusa theory, etc. but the main purpose of polymorphism is to assign different functions to different forms with a view to divide the labour to achieve the resultant effects of different functions.

3.4.3 Significance of polymorphism

Polymorphism assigned different form of zooids to perform different functions, such as gastrozooids for feeding, dactylozooids for protection, tentaculozooids for sensory function, gonozooids for reproduction etc. Theerefore, the aim is to establish a fact for the division of labour. Of these form—polyp forms are associated with the feeding, protection, testing and asexual reproduction while medusa is concerned with sexual reproduction.

3.5 Conclusion

Cnidarians are characterized by the presence of cnidoblast cells which help to capture the prey. Diploblastic organisms but with various forms of individuals in the form of zooids are seen with a view to perform definite function. These zooids are grouped into two forms viz. polyp and medusa. Polypoid forms are sedentary while medusoid forms are free-swimming. Due to the presence of diffenent forms of zooids in respect to accomplishment of specific function the phenomenon of polymorphism have been developed in cnidarians.

3.6 Summary

i) Cnidarians are aquatic, mostly marine diploblastic, colonial or solitary animals.

ii) The outer layer epidermis and the inner layer gastrodermis are separated by a jelly like layer called mesoglea.

iii) Presence of specialized cells viz. nerve cells, contractile epithelial cells, enzyme secreting cells, untrient absorbing cells and the intercellular connections is well marked.

iv) Except basal disc the body surface is provided with cnidoblast cells which are abundant in tentacles and hypostome. It helps to capture food, in defence and swimming.

v) The interstitial cells are able to produce different types of cells on way of conversion.

vi) A sac-like gastrovascular cavity which has only one opening which serves as mouth and anus.

vii) Bioluminesence is observed.

viii) Circulation of substance takes from cell to cell.

ix) Non-polar neurons are seen in the body.

x) Different zooids are produced to perform differnt functions. Of these, polypoid forms are sessile and medusoid forms are free-swimming.

xi) Metagenesis or alternation of generation is well marked and larval stages are developed following fertilization and development of zygote.

xii) Essentially polymorphism is nothing but a colonial mode of living style by producing different forms in the body of a single organism.

3.7 Glossary

Cnidocyte : In Cnidaria cnidocyte is a special type of cell which contains one giant secretory organelle or cnida that defines the phylum Cnidaria. Cnida is used to capture prey and for protection from predators and/or enemies.

Polyp : Polyp is a sessile organism of cnidarian species (sea anemone, hydra).

Medusa : Medusa is a free-swimming form of cnidarian species (jelly fish).

Polymorphism : Occurrence of stracturally and functionally more than two types of individuals within the same individual. That is, occurrence of polyp, medusa and other types of zooids in a cnidarian species.

Zooid : Zooid is a single individual that is of course, a part of a colonial animal.

Mesoglea : Translucent, non-living jelly-like substance found between the two epithelial cell layers in the body of a cnidaria.

3.8 Questions

1. Define Zooid. Name any two types of zooids studied by you in cnidarian animals and explain any one type of such zooid.
2. Draw, label and describe the structure of a cnidoblast cell and add a note on its functions.
3. State the differences between polyp and medusa.

4. Define polymorphism. Give an account of polymorphism in Cnidaria.
5. Write notes on : (a) Asexual reproduction in hydra and (b) Gastrodermis in Cnidaria.
6. State any five distinguishing features of Cnidaria. Mention the types of gametes and larvae are found in Cnidaria.
7. What are the basic components that enable Cnidaria to develop the ground for polymorphism? State the significance of polymorphism.

3.9 Suggested readings

1. Introduction to general Zoology, K.K. Chaki, G. Kundu and S. Sarkar. New Central Book Agency (p) limited, 2008.
2. Invertcbrate Zoology-E.I. Jordan and P.S. Verma. S. Chand, 2009.
3. Siphonophora (Cnidaria : Hydrozoa) of Canadian Pacific waters. G.M. Mapstone and M.N. Arai. NRC Research press 2009.

Unit 4 ❑ Acelomates : General Characters of Helminthes; Life cycle of *Taenia solium*

Structure

4.1 Objectives

By studying this unit, students will be able to gain knowledge on— (i) acoelomate animals like flatworms; and (ii) the life cycle of *Taenia solium.*

4.2 Introduction

Invertebrate animals lacking a coelom are known as acoelomates. These animals are grouped into flatworms and nemerteans.

4.3 General characters of helminthes

1. Eukaryotic, multicellular, free-living or parasitic animals.
2. Worm-like body with bilateral symmetry.
3. Distinct head and tail region.
4. Well marked tissue differentiation with distinct ectoderm, mesoderm and endoderm.

5. Body shape may be round (round worm), flat or tape-like (flat worm or tape-worm), or hook-like (hook-worm) and the length of the body may be ranged from less than one millimetre to over one metre.
6. Digestive, circulatory, nervous, excretory (presence of flame cells) and reproductive systems are well marked in most cases.
7. Parasitic forms spend either live completely in the host body or sometimes depend partially on the host to complete their life cycle.
8. Many parasitic helminthes lack a digestive system and thereby, they are adapted to absorb nutrients from host's body fluids and/or tissues.
9. In some cases nervous system is in reduced form.
10. Becasue of parasitic nature in most cases locomotion is absent or is reduced to a great extent.
11. Reproductive system is very complex. They may be unisexual or bisexual. Eggs when released outside may infect another host.

Fig. 1 *Fasciola hepatica*

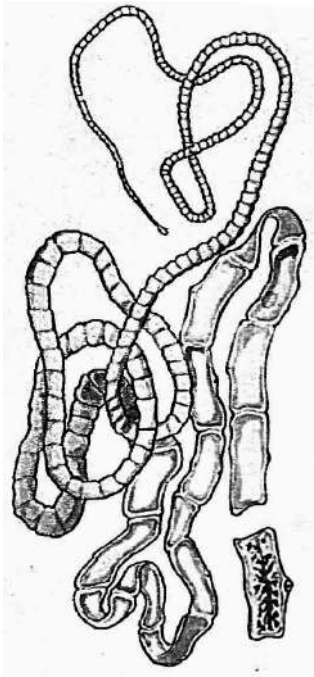


Fig. 2 *Taenia solium*

Examples : *Fasciolo hepatica* (Fig:1), *Taenia solium* (Fig:2)

4.4 Life cycle of *Taenia solium*

Taenia solium also known as pork tapeworm, is a tapeworm belongs to the class Cestoidea, phylum Platyhelminthes. It is an intestinal, mainly zoonotic, paraste found throughout the world and is most common in the geographical areas where pork is eaten. Man is its definitive host while pig is the intermediate or larval host.

4.4.1 Structure

(i) Ribbon-like body, two-three meters long having about 800-900 segments or proglottids (Fig: 3).

(ii) Head or scolex (Fig: 4) is pear-shaped with 28 curved chitinoid hooks arraged in two rows. There are four adhesive suckers.

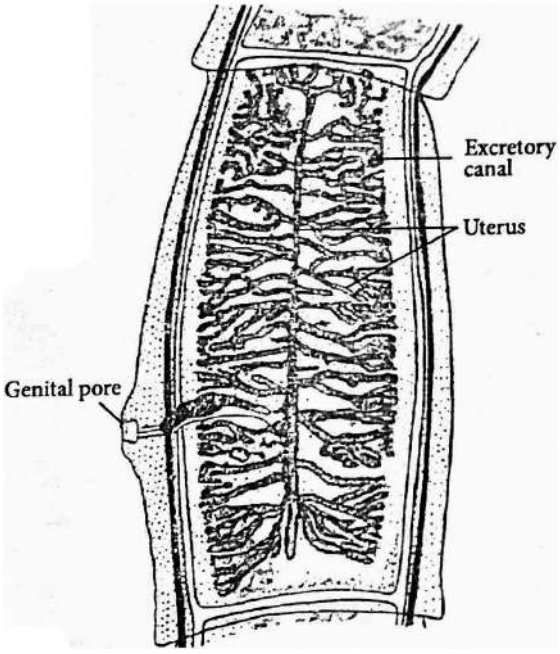


Fig. 3 Proglottid of *Taenia*

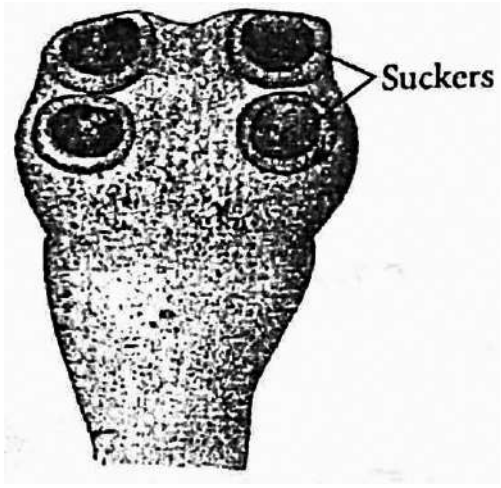


Fig. 4 Head of *Taenia*

(iii) Following head an elongated but unsegmented region is well marked, known as neck.

(iv) The rest of the body after neck is known as strobila. The strobila is segmented and contains 800-900 segments called proglottids.

(v) Each proglottid represents a complete hermaphrodite sexual unit.

4.4.2 Reproductive organs

1. Reproductive organ appears first in most cases at the 200th segment. The male reproductive organ appears first and then female organs develop. The worm grows and subsequent segments were added gradually. The male part of the said reproductive organ attained maturity at about 400th segment. The segments following 400th segment are filled with highly developed uterus fully loaded with developing embryos. The male reproductive organ consists of a many lobed testis with ducts, vas-deferens and cirrus. The cirrus open into the atrium in the male genital aperture (Fig: 5)

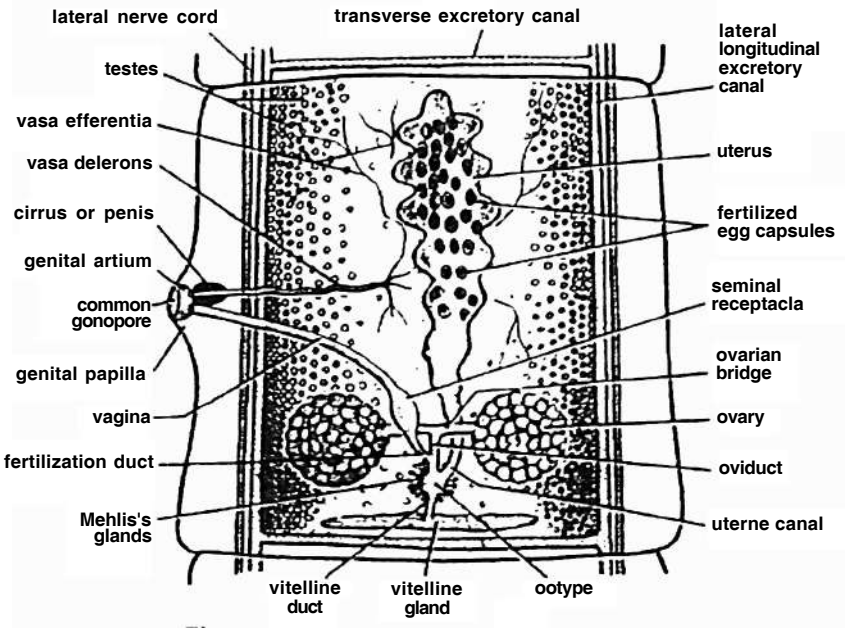


Fig. 5: Reproductive organs of *Taenia*

2. The female reproductive organ consists of a paired ovary with their ducts, uterus, yolk glands, shell gland, ootype, receptacolum seminalis and the vaginal opening in the atrium through the female genital aperture. The gravid uterus looks like long stem with 5-10 lateral branches (Fig: 5).
3. Fertilization internal. In *Taenia* self-fertilization occurs. Eggs are fertilized by sperms of same proglottid or may be fertilized by the sperms of proglottid situated anterior to it. Zygote coated with yolk and surrounded by egg shell passes to the uterus.

4. The ripe proglottids detached in chains of 5-6 and and removed from the body with the faeces of the host.
5. Proglottids are now eaten by the pigs and the six-hooked or hexacanth embryos are liberated following digestion of the segments.

4.4.3 Life cycle (Fig: 6)

1. The eggs of *T. solium* following removal with the faeces of human host remian alive for days to months in the environment. The pigs become infected by ingesting vegetation contaminated with eggs/gravid proglottids.

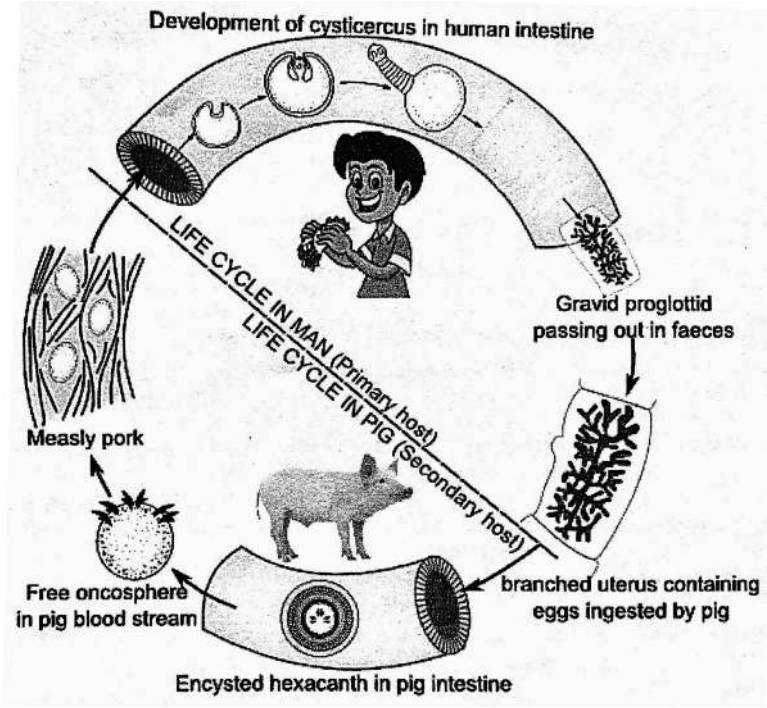


Fig. 6: Life cycle of *Taenia*

2. Inside pig's intestine the egg hatches and the onchosphere or hexacanth embryo is produced. Onchosphere is round in shape and covered by two membranes. Six curved chitinous hooks are present at one end.
3. The embryo invades the intestinal wall with the help of hooks and reaches the voluntary or striated muscle where the hooks are lost.
4. Then, the embryo through the portal vein enters the general circulation and reaches at the liver and thereafter to the right side of the heart, then to the lungs,

then to the left side of the heart and finally enters into the systemic circulation. Finally, it migrates to the striated muscle.

5. In the muscle the embryo grows to a ball like structure containing fluid inside and assumes the shape of a bladder.
6. At one point of the bladder an invagination takes place. In the inner surface of this invagination 28 hooks and 4 suckers, characteristics of the scolex (head) of adult *Taenia,* are developed.
7. The invagination bocomes everted and the suckers and hooks come to the surface.
8. Now the embryo looks like a bladder with a head and neck. This is known bladder worm or cysticercus stage. The pig's flesh infested with cysticercus cellulosae (Cysticercus of *T. solium* is also known as cysticercus cellulosa (pl. cellulsae) due to the presence of cellulose layer on the wall of cysticercus larva.) is known as measly pork.
9. When a piece of imperfectly cooked measly pork is eaten by man the bladder i.e. cysticercus is dissolved in the gastric juice.
10. The swelling of albuminous materials due to the action of gastric juice, inside the cysticercus causes the fluid to come out into the cavity and thus enables the head to come out through the pore.
11. The head attaches itself with the wall of the intestine by the help of hooks and suckers. With time the worm grows and a series of proglottids developed to attain the adult stage to the worm.
12. The worm attains sexual maturity within 2-3 months.
13. Inside the host the worm may survive up to 24 years or sometimes more.
14. Next cycle begins when a piece of under cooked measly pork is consumed by man.

4.5 Conclusion

Helminthes are eukaryotic multicellular animals. They are causative agents of different kinds of worm diseases of man and animal. Of these parasitic worms, the flatworms *Taenia solium* is responsible for the disease taeniasis in humans. *T. solium* passes its life cycle in two host—pig is the intermediate host (larval host) while man is the definitive host (adult's host). The worm finds its entry into human's body through the measly pork. The main-way to get rid of such a disease is to avoid eating pork-meat having cysticercus infestation.

4.6 Summary

i) Helminthes are commonly known as worms, most of them are parasitic in nature.

ii) They may be round, flat or hook like in shape.

iii) Body could be differentiated distinctly into the head and tail regions.

iv) Though many kinds of organs to perform various types of biological activities are well marked, of them presence of flame cells to ensure excretion effectively and the reproductive organs to ensure maximum rate of production of young individuals are noteworthy.

v) *Taenia solium* is also known as pork tapeworm, depends on two hosts—pig (the intermediate host) and the man (the definitive host) to complete the life cycle.

vi) The man is infected by consuming pork meat infected with the cysticercus stage of *Taenia* (measly pork).

vii) Cysticercus develops into the adult worm inside the human host.

viii) The mature worm releases gravid proglottids, few in number, in the form of chain through the faeces of human host.

ix) The eggs (hexacanth embryos) are released into the environment following disintegration of uterine membrane and remain in water or in contact of vegetations. The pigs on way of swallowing vegetations ingest these larval stages of the worm.

x) The larval stage or onchosphere develops inside the pig's gut and the scolex emerged out to be hooked with the gut wall.

xi) The embryo after proper development enters into the circulation and comes in contact with the liver, heart, lungs and then enters into the systemic circulation.

xii) The embryo is filtered out and finally finds its position in the muscle of the pig. Consumption of such a pork-meat intiates human infestation by *Taenia.*

4.7 Glossary

Cestoda : Cestoda is a class of parasitic worms in the flatworm phylum Platyhelminthes.

Proglottid : Any segment in the strobili of tape worm containing a complete sexually mature reproductive stystem.

Hermaphrodite : Organisms bearing both the male and female reproductive organs together in the same body.

Primary host : Host which harbours the adult stage of a parasite. It is also known as definitive host.

Intermediate host : Host in which larval stages of a parasite find their shelter and nutrition.

Onchosphere : It is the larval form of the tapeworm which subsequently develops into a cysticercus.

Flame cell : It is the specialized excretory cell found in tapeworm.

Measly pork : Pork-meat infected with the cysticercus larval form of *T. solium.*

4.8 Questions

1. State any 5 characteristic features of helminthes. What are host and parasite?
2. What is hexacanth embryo? State its characteristic features. What is measly pork?
3. What is scolex? Describe the structure of a scolex.
4. What is onchosphere? State its significance in respect to spreading of taeniasis disease.
5. Describe the life cycle of tapeworm *Taenia solium.*
6. Describe the structure of a gravid proglottid. Explain how pigs are involved to regulate the life cycle of *Taenia solium.*
7. Write notes on:
   (a) Flame cell
   (b) Hexacanth embryo
   (c) Cysticercus
   (d) Measly pork

4.9 Suggested readings

1. The tapeworm. Nicholas A. Price. Demy publshing, 2008
2. Parasitology. K.D. Chatterjee. CBS, 2009
3. Invertebrate Zoology. E.L. Jordan and P.S. Chand. S. Chand, 2009
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Unit 5 ❑ Pseudocoelomate : General Characters of Nemathelminthes; Parasitic Adaptations

Structure

5.1 Objectives

By studying the unit, students will be able to learn about pseudocoelomate animals with special emphasis on the general characters of nemathelminthes and the parasitic adaptations in nematodes.

5.2 Introduction

A pesudocoelomate is an organism with body cavity which is not lined by mesoderm as it is not derived from the mesoderm, as in a true coelome or body cavity. A pseudocoelomate is also known as a blastocoelomate, as the body cavity is derived from the blastocoel, or cavity within the embryo. Nematodes or round worms, rotifers, acanthocephalans and nematomorphs or horse hair worms are pseudocoelomate animals.

5.3 General characters of nemathelminthes

Nemathelminthes (or Aschelminthes) [Nematos—thread, Askos—bladder, Helminthes—worm]

1. Narrow, elongated, light-yellowish brown colour, round, worm like body.
2. Body is covered by tough and resistant cuticle.
3. Four longitudinal streaks, one dorsal one ventral and two lateral, are present on the body surface.
4. Various pores are present on the body surface.
5. Organ system level of organization.
6. Body cavity is filled with muscles and as these are pseudocoelomates the body cavity is not lined by mesodermal layer.
7. Internal cephalization is distinct. External differentiation between the anterior and posterior region is faint.
8. Mouth is anterior, terminal and well marked with constrictions. It is bounded by three lips—one median and dorsal while two ventro-lateral.
9. Complete but straight tube like digestive canal could be recognized into three regions—the club-shaped foregut or oesophagus, the voluminous mid gut (endodermal in origin) and the hind gut or rectum which is lined by cuticle.
10. Sense organs poorly developed in the form of papillae termed as amphids, found in association with anus.
11. Respiratory and circulatory systems are absent.
12. Respiration is aerobic in free-living form and anaerobic in parasitic form. Respiration is effected through body surface.
13. Excretory system consists of longitudinal canals or lateral excretory ducts. Protonephridia having renette cells help in excretion also. Excretory pore is ventral and near the anterior end.
14. Nervous system though not well developed, the circumpharyngeal nerve ring and longutudinal dorsal and ventral nerve cords are prominent. The ventral nerve forms a ganglion just in front of the anus (Fig: 1).

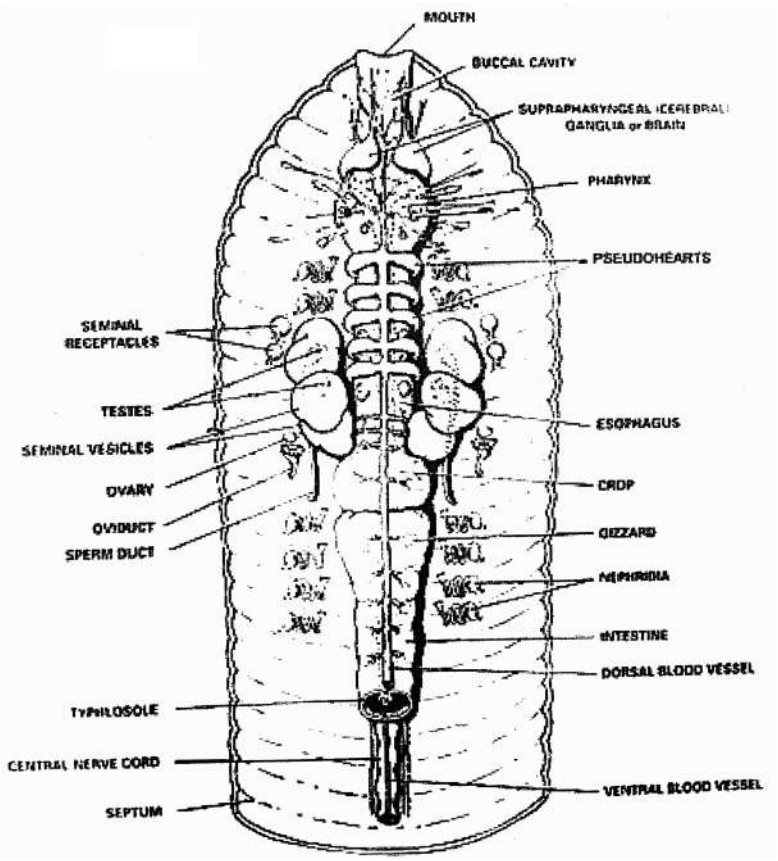

Fig. 1: Anatomy of nematode

15. Unisexual and with distinct sexual dimorphism. In male the tail end is curved ventrally in the form of a hook with a conical tip where anus opens. Thus the said aperture serves a common passage for rectum and genital duct. Two copulatory setae protrude from the said aperture. The genitalia consists of a single coiled tubule differentiating into testes, vas deference, vesicular seminiferous and ejaculating duct opening in the anus. In female the posterior extremity is conical and straight. The anus is located slightly anterior to the posterior extremity on the ventral side, guarded by one pair of post anal papillae. In female about one third of the entire anterior end, the body is narrower gradually. This region is marked as vulvar waist. The valva is located on the ventral surface of the vulvar waist. Ovaries are paired tubes which pass gradually into oviducts, seminal receptacles and uteri. The uteri join to form an unpaired, conical vagina which opens into the female gonophore.

16. Fertilization may be self or cross but internal. A female usually produces 20,000 eggs daily which pass out of the host with its faeces.
17. Development is direct or indirect. In case of indirect development Rhabditiform, Filariform and Microfilariaform larvae may be seen. Moulting takes place at certain intervals and after fourth moulting beween 25th and 29th day, the young continues to grow to attain the normal size. Sexual maturity attains within 6-10 weeks.

Examples :

Freeliving nematods : *Caenorhabditis elegans, Prochromadora helenae, Pelodera strongyloides* (Fig: 2)

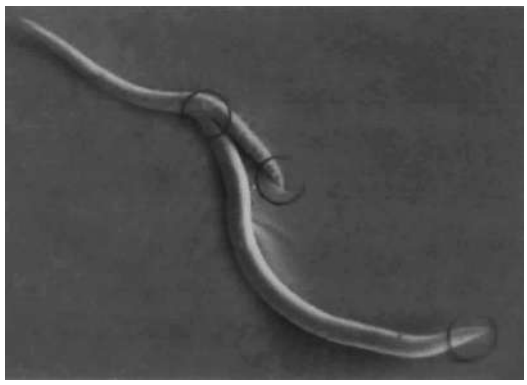

Fig. 2: *Pelodera strongyloides* in copulation

These nematodes are beneficial as they are very much involved to unlock nutrients from the detritus. Thus they play important role in the cycling of nutrients and providing energy in a variety of environment. Also many of them are used as food in aquaculture of some edible species.

5.4 Parasitic nematodes

Nematodes are found as parasities in plants and animals. Therefore, they cause certain dreadful diseases in the concerned host-species. The species like *Trichinella spiralis* (causes trichinosis disease in some vertebrates), *Dirofilaria immitis* [Heartworm] (attack the lung, heart of dog, cat and ferrets), *Agamermis decaudata* (parasite of grasshopper), *Heterodera rostochiensis* (plant parasite, forms galls implants), *Dracunculus medinensis* (cause dracunculiasi disease in humans, mostly in Africa, residing just beneath the skin), **Wuchereria bancrofti** (cause elephantasis disease in man) (Fig: 3), *Loa loa* (cause loa loa in man), *Onchocerca volvulus* (cause river blindness in man), *Ascaris*

Fig. 3: *Wuchereria bancrofti*

lumbricoides (cause ascariasis disease in humans and domestic animals), *Ancylostoma duodenale* (cause ancylostomiasis in humans) (Fig: 4).

Fig. 4: *Ancylostoma duodenale*

5.5 Parasitic adaptations in nematodes

Parasitic nematodes have undergone remarkable physical and biochemical adaptations to ensure their survival and propagation. Of these adaptive features (i) Cylindrical reduced body size with pointed ends (ii) development of invasion apparatus such as hooks and suckers and (iii) body wall is covered with cuticle formed of albuminous proteins. The reduced body size helps them to occupy the niche in the internal or external surface of the host. The albuminous proteins in the cuticle of the body-wall is resistant to the digestive enzymes of the host. (iv) produce enzyme inhibitors that protect from the host's digestive enzymes. (v) locomotory organs are absent as they are protected from enemies being with the host body and also being ensured of supply of nutrients from the host, (vi) alimentary canal is poorly developed because of availability of semidigested food material from the intestine of the host, (vii) mostly anaerobic and required energy at the first step is available to them from the anaerobic glycolysis of glycogen because of accumulation of fatty acids by the parasite. In some cases presence of cytochrome enables them aerobic respiration. Thus, they are facultative anaerobes, (viii) sense organs are confined to lips in the form of papillae (ix) hypotonic or hypoosmotic to intestinal fluid thus ensures the stability of body-volume, (x) eggs are numerous in nature and are covered with thick warty chitinous shell. This protect them from the adverse effect of the digestive enzyme of the host, prolonged dryness and cold weather for several days.

5.6 Conclusion

Nemathelminthes are worm-like pseudocoelomate animals. Most organ system are poorly develped. No respiratory and circulatory system while excretion is effected by protonephridia with active participation of renette cells. Nervous system though not well developed but presence of circumpharyngeal nerve ring, longitudinal dorsal and ventral nerve cords are prominent. A ganglion is located just in front of the anus. Unisexual with distinct sexual dimorphism. Development may be direct or indirect. In case of indirect development Rhabditiform, Filariform and Microfilariaform larvae are seen. Both free living and parasitic forms found under varied ecological conditions. Parasitic form have undergone a remarkable physical propagation. Some parasitic nematodes cause serious diseases in man and animals. With these adaptive features nematodes are highly adapted animals to maintain their existence.

5.7 Summary

i) Nemathelminthes are pesudocoelomate worm-like, free-living or parasitic animals.

ii) Ogan system level of body organization though some system viz. respiratory and circulatory systems are absent.

iii) Complete tube-like digestive canal.

iv) Amphids are found in association with mouth and phasmids are found in association with anus.

v) No respiratory and circulatory system.

vi) Respiration is aerobic in free-living forms and anaerobic in parasitic forms.

vii) Protonephridia having renette cells help in excretion.

viii) Nerve ring dorsal and ventral nerve cord and ganglion could be seen in nervous system.

ix) Unisexual with distinct sexual dimorphism. Male and female reproductive systems are well developed. Development is direct or indirect development passes through larval stages viz. Rhabditiform, filariform and microfilariaforms.

x) Sexual maturity takes place within 6-10 weeks.

xi) Parasitic forms are reduced in body size, cylindrical body with pointed ends.

xii) Invasion appaatus like hooks and suckers are well developed.

xiii) Body wall is covered with cuticle.

xiv) Enzyme produces by the parasitic forms helps them to protect from the host's defence mechanism.

xv) Eggs are numerous and are protected from adverse conditions by the help of thick warty chitinous shell.

5.8 Glossary

Pseudocoelomates : Animals in which body cavity is not derived form the mesoderm and thus not lined by mesoderm.

Amphids : Poorly developed sense organs in the form of labial papillae.

Phasmids : Caudal papillae in some nematodes which are chemosensory in nature.

Renette cells : Cells those help in excretion in nematodes.

Sexual dimorphism : It refers to morphologically different two sexes due to the presence of distinct characters for identification of males and females of the same species.

Elephantasis : A disease of man caused by the nematode *Wuchereria bancrofti.*

Suckers : The organs for attachment with the host's body.

5.9 Questions

1. What do you mean by pseudocoelomates?
2. Cite example of two pseudocoelomate animals. State any five characteristic features of a pseudocoelomate animal studied by you.
3. State the salient features of male and female reproductive organs of a nematode.
4. How many types of larvae could be seen in nematodes? What type of fertilization is effective in nematodes? How eggs of a nematode come out of the host body to the exterior? When does fourth moulting take place in a developing nematode? How many weeks are needed to attain sexual maturity following attainment of adult stage after final moulting?

5. Name any 4 diseases of man caused by nematodes. Mention any five types of morphological adaptations of nematodes to lead a parasitic life.
6. Enumerate the parasitic adaptations in nematodes.
7. Write notes on :
   (a) Economic importance of nematodes.
   (b) Loa loa and river blindness.
   (c) Amphids and phasmids.

5.10 Suggested readings

1. K.C. Ghose and B. Manna (2015). A textbook of Zoology. New Central Book Agency, Kolkata.
2. K.K. Chaki, G. Kundu and S. Sarkar (2014). Introduction to General Zoology, Vol. 1. New Central Book Agency, Kolkata.
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Unit 6 ❑ Coelomate Protostomes : General Characters of Annelida, Metamerism

Structure

6.1 Objectives

By studying this unit, students will be able to- (i) gain knowledge on the coelomate protostomes; (ii) study the characteristic features of different groups of annelid animals and the phenomenon of metamerism.

6.2 Introduction

Annelids are true coelomate animals. Coelom is the fluid-filled body cavity which is completely lined by tissue created from the mesoderm, the middle layer of the primary cells found in an embryo. The majority of coelomate invertebrates develop as protostomes ("first mouth") in which the oral end of the animal develops from the first developmental opening, the blastopore i.e. blastopore becomes the mouth. (Fig: 1). Thus, the animals bearing these characters in respect to their history

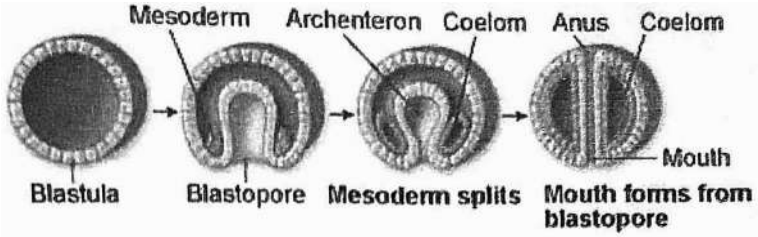

Fig. 1: Protostome

of development are termed as coelomate protostomes. These animals are primitive invertebrates such as annelids, arthropods and molluscs.

6.3 General characters of annelida

Annelida (from Latin anellus, "little ring") a group of segmented or ringed worms are found worldwide from deepest marine sediments to the soils in our yards. The extant species belong to ragworms, earthworms and leeches. The characteristic features of the phylum Annelida are as follows.

1. Elongated, triploblastic, bilaterally symmetrical vermiform body.
2. Aquatic (marine and freshwater), terrestrial, burrowing or sedimentary and free living or commensal or parasitic.
3. Metamerically segmented body: externally by transverse grooves and internally by septa into a number of division. Each division is known as a segment or metamere or somite.
4. Organ grade system body organization.
5. Single layer epidermis which is made of columnar epithelial cells. It is covered by a thin non-chitinous cuticle.
6. Dermo-muscular body wall is contractile. It consists of outer circular and inner longitudinal muscle fibers.
7. Appendages when present are paired.
8. Chitinous setae or fleshy appendages i.e. parapodia are locomotory organs. These locomotory organs are repeated segmentally.
9. Schizocoelous coelom usually divided into compartments by transverse septa. It is well developed in leeches. Cells or corpuscles are present in coelomic fuid.
10. Complete and straight alimentary canal extends form mouth to anus. Extracellular digestion.
11. Moist skin or gills of parapodia and head help in respiration. Respiratory pigments are red haemoglobin or green chlorocruoins.
12. Closed blood vascular system with dorsal and ventral longitudinal vessels connected with each other by small vessels.
13. Excretion is effected through the coiled tubes; the nephridia which communicate the coelom to the exterior.

14. Nervous system is made of a pair of cerebral ganglia (the so-called brain) and double ventral nerve cord having segmentally arranged ganglia and lateral nerves in each segment.
15. Tactile organs, buccal receptors, statocysts, photoreceptor cells and sometimes eyes with lenses act as receptor organs.
16. Hermaphroditic or unisexual; cleavage spiral. Reproduction though mostly sexual but in some species asexual reproduction is also in practice.
17. In monoecious forms development is direct but indirect in dioecious form.
18. Indirect development takes place through the trochophore larval stage.
19. Regeneration is a common event.

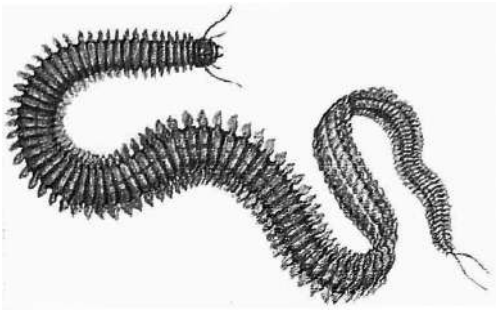

Fig. 2: *Nereis*

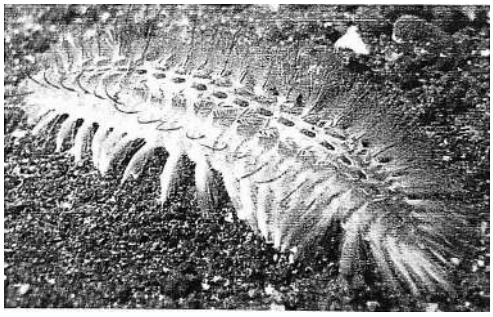

Fig. 3: *Aphrodite*

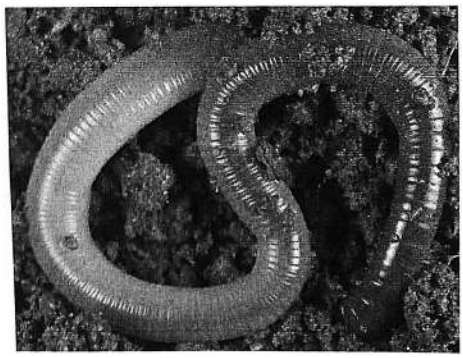

Fig. 4: *Earthworm*

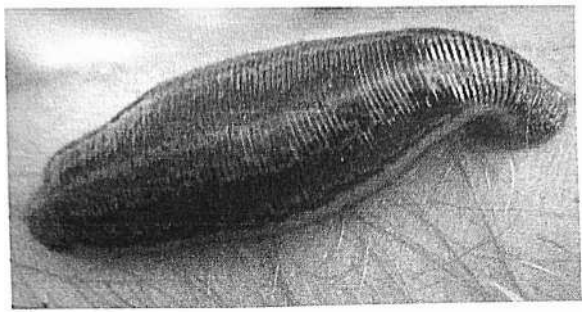

Fig. 5: *Leech*

Examples :

Nereis (Nereis dumerilii) (Fig: 2), *Aphrodite* [sea mouse] (Aphrodita aculeata) Fig : 3), *Chaetopterus* [parchment worm] (*Chaetopterus variopedatus*), *Sabella* [Fanworm] (*Sabella spallanzanii*), *Tubifex* [sludge worm] (*Tubifex*), *Pheritima* (Earthworm) (Fig: 4), (*Pheretima posthuma*), *Hirudo* (leech) (Fig: 5), (*Hirudo medicinalis*).

6.4. Metamerism

Metamerism is the phenomenon of having a linear series of body segments fundamentally similar in structure though not all such structures are entirely alike in many single life form because some of them perform special function. This is clearly visible in an earthworm. A close look to the outer surface of the earthworm's body would reveal the fact that, the tube like elongated body is made of a number of ring-like segments joining with each other. Thus, these serial repetition of segments and organ systems (skin, musculature, nervous system, circulatory system, reproductive system and excretory system) is known as metameric segmentation (Fig: 6) or mentamerism. That is, each metamere is provided with a part of almost all the organ systems. In annelids some anterior segments look different in nature. Therefore, typical homonomous segmentation is absent. In embryonic stages the metamerism is complete and uniform. But in adult condition it will change due to cephalization. The origin of mentamerism is not clearly known. Several theories have been proposed to explain the development of matamerism viz. (1) Fission theory, (2) Pseduometamerism theory, (3) Embryolgical theory and (4) Locomotory theory.

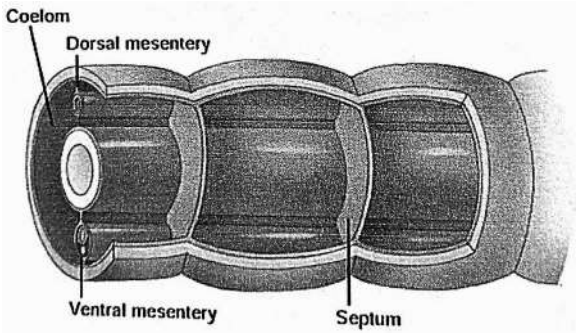

Fig. 6: Metameric segmentation

R.B. Clark (1964) proposed the locomotion theory to explain the origin of metamerism in annelids. According to this theory metamerism evolved in annelids as an adaptation to peristaltic locomotion and for burrowing.

Peristaltic locomotion is effected due to shortening and lengthening of body by circular and lognitudinal muscles. As the coelom is filled with coelomic fluid peristaltic locomotion will not be possible unless the coelom is divided by septa, so that high presure produced by contraction of muscles can be confined to a particular region and it does not affect the whole body. Metamerism helps annelids to save energy as well as to control and regulate locomotory movement in different directions. It also offers division of labour. It is noteworthy to mention that metamerism not only occurs in annelids but occurs also in arthropods and in many chordates.

6.5 Conclusion

Annelids are ringed worms triploblastic and bilaterally symmetrical commonly found in marine, freshwater and terrestrial environments. Well organized body with various organs. Closed circulatory system and nervous system presents a pair of cerebral ganglia. Bisexual or unisexual. Development takes place through the trochophore larval stage. The most interesting feature in this group is metamerism i.e. body consists of a series of ring-like body segments. Though the exact cause of metamerism is not known it is assumed that the same is associated with the locomotion of organism concerned. Thus annelids are adapted in such a way which triggered the appearance of highly developed animal groups even vertabrates.

6.6 Summary

i) Annelids are true coelomate animals.

ii) The oral end of these animals develops from the blastopore. Therefore, they are protostomes.

iii) Elongated body, segmented and each segment is ring-like.

iv) Dermo-muscular body wall is contractile.

v) Satae or parapodia serve as locomotory organs.

vi) Alimentary canal is straight and complete. Extracellular digestion.

vii) Closed type vascular system. Blood is red.

viii) The coiled tubes i.e. nephridia help in excretion.

ix) Nervous system with cerebral ganglia and ventral nerve cord.

x) Bi-sexual or unisexual. Cleavage spiral. Indirect development takes place through the trochophore larval stage.

xi) Regeneration takes place.

xii) Typical homonomous segmentation is absent.

13. The origin of metamerism is not clearly known but locomotion theory suggests that metamerism evolved in annelids as an adaptation to peristalic locomotion and burrowing.

6.7 Glossary

Seta : Locomotory organ in earthworm.

Ragworms : The worms belong to the family Nereididae of class Polychaeta are commonly called ragworms or clam (*Nereis*).

Schizocoelom : Develops due to mesodermal split. This body cavity is formed blocks of mesoderm around the gut that enlarge and hollow out.

Metameric : Consisting of several similar segments or somites.

Hermaphrodite : Organism contains both the male and female reproductive organs.

Nephridium : Excretory as well as osmaregulatory organ.

Statocyst : A small organ helps in balance.

Fan worm : *Sabella*

Sea mouse : *Aphrodite*

6.8 Questions

1. Define protostome. State the locomotory organs of annelids. What do you mean by metameric segmentation?
2. State six salient features of Annelida. Explain why annelids belong to coelomate protostome?
3. Why the blood of earthworm is red? What is nephidium? State its function. State the function of statocyst.
4. Explain the term 'hermaphrodite'. What type of cleavage is seen in Annelida? Which type of digestion takes place on annelids?
5. Define metamerism. Add a note on its origin and significance in annelids.

6.9 Suggested readings

1. K.C. Ghose and B. Manna (2015). A textbook of Zoology. New Central Book Agency, Kolkata.

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5. D.H. Shain (2009). Annelids in modern Biology. Wiley online library. Wiley-blackwell.

Unit 7 ❑ Arthropoda : General Characters; Social Life in Insects

Structure

7.1 Objectives

By studying this unit, students will be able to have an idea on the characteristics of the diverse animal groups belong to the phylum Arthropoda and to gain knowledge on the social life of some insects.

7.2 Introduction

The phylum Arthropoda (Arthro=jointed, pods-feet) contains the animals that have jointed appendages. Todate of the described animal species at least 75% belongs to Arthropoda.

7.3 General characters of arthropoda

1. Bilaterally symmetrical, triploblastic and coelomate animals.
2. The body is covered by chitinous exoskeleton.
3. The three regions, that is, head, throax and abdomen of the body are distinct.

4. Exhibits organ system level of organization.
5. Appendages are jointed and locomotion is effected by the help of these appendages.
6. Head bears a pair of compound eyes.
7. Coelom space is filled with blood and thus acts as haemocoel.
8. Open type circulatory system.
9. Excretion is effected through malpighian tubules or green glands or coaxal glands.
10. Nervous system consists of a cerebral ganglionic mass and a ganglionated double ventral nerve cord.
11. Body surface, trachea, gills help in respiration.
12. Hairs, antennae, simple and compound eyes, auditory organ and statocysts act as sensory organs.
13. Unisexual. Fertilization is either external or internal.
14. Development is direct or indirect. In case of indirect development different kinds of larval stages are seen in many group of arthropods.

The major groups are :

Crustacea : They may be aquatic, terrestrial or parasitic. Head is fused with thorax region and therefore, the said region is known as cephalothorax. Respiration takes place through gills and body surface. Body is covered either by a single large carapace or carapace covers part of the body. Bear biramous appendages and two pairs of antennae. Excrete through green glands or antennal glands. They bear one pair of compond eyes. Sexes separate. Development passes through larval stages.

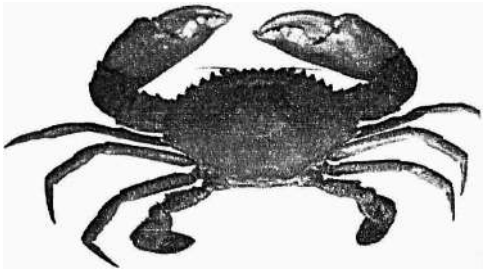

Fig. 1: *Scylla serrata*

Examples : Prawn (*Palaemon carcinus*, *Macrobrachium* rosenbergii), Daphnia (*Daphia magna*), Crab (*Scylla serrata*) (Fig: 1).

Myriapoda : Elongated, mostly terrestrial arthropods with numerious segments. Head bears antennae, two pairs of jaws and a pair of simple eyes. Legs numerous.

Mouth with upper and lower lips. Upper lip contains epistome and labrum while the lower lip contains a pair of maxilla. One pair mandible locating inside the mouth. Respire by trachea and excrete through Malpighian tubules.

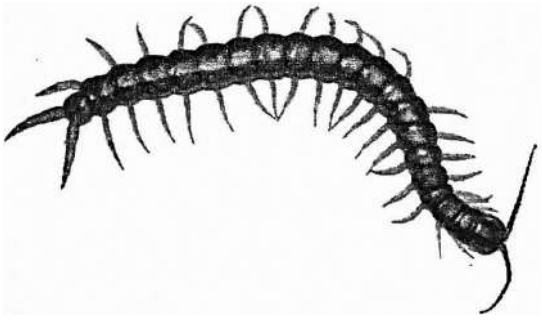

Fig. 2: *Scolopendra*

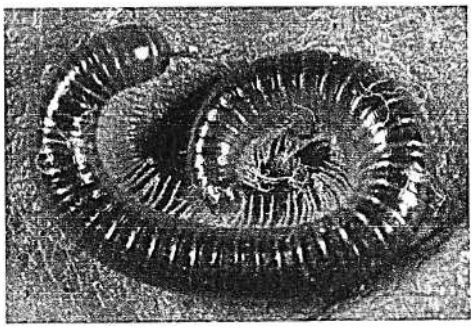

Fig. 3: *Julus*

Examples : Scolopendra (*Scolopendra subspinipes*) (Fig : 2), Julus (*Julus terrestrics*) (Fig : 3)

Hexapoda or Insecta : Mostly terrestrial, head bears a pre-segmental acron. Thorax with three segments but abdomen bears 7-11 segments. Three pairs of thoracic appendages and one pair of compound eyes. Respirae by the help of gills and trachea. Malpighian tubules serve as excretory organ. Development is indirect with larval stages.

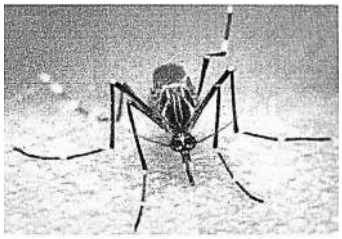

Fig. 4: Mosquito

Fig. 5: Honey Bee

Fig. 6: Butterfly

Examples : Ants (*Componotus compressus, Oecophylla smaragdyna*), Mosquitoes (*Anopheles stephensi, Culex pipiens*) (Fig : 4), Honeybee (*Apis dorsata*) (Fig : 5), Butterfly (*Papilo machaon*) (Fig : 6), Cockroach (*Periplaneta americana*).

Chelicerata : Mostly terrestrial, body is differentiated into cephalothorax and abdomen which bears 13 segments. Five pairs of anterior appendages of which 1st pair is chelicerae used in feeding. Appendages are uniramous. No mandibles or jaws.

Antennae absent. Trachea or gills serve as respiratory organ. Excretion is effected through Malpighian tubules.

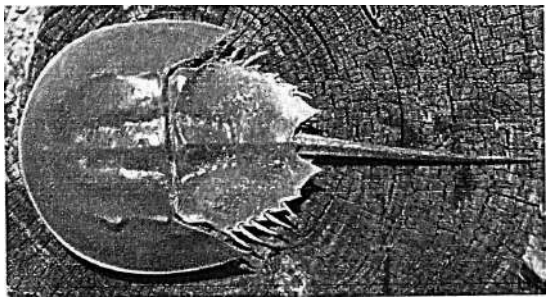

Fig. 7: *Limulus*

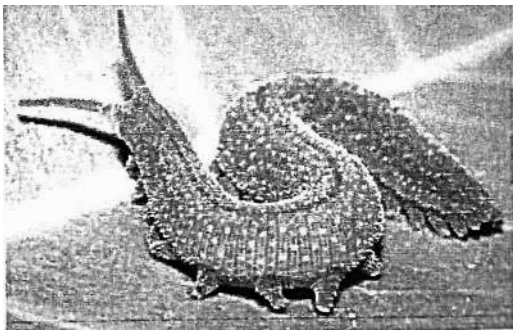

Fig. 8: *Peripatus*

Examples : Spiders (*Aranea diadema, Thiania bhamoensis*), King crab or Horse-shoe crab (*Limulus polyphemus*) (Fig: 7), Mite (*Tetranychus urticae*). Peripatus (a living fossil) (*Peripatus basilensis*, *P. capensis*) (Fig :8)

Onychophora (Recently it has been given the status of a seperate phylum) **:** Small terrestrial arthropods. Body divided into segments. Nephridia help in exertion. Trachea act respiratory organ.

Trilobitomorpha : Primitive arthropods which are now extinct.

7.4 Social life in insects

In insects social life has evolved in two groups viz. Isoptera (termits) and Hymenoptera (bees, wasps and ants). These insects construct a nest and adapted to live in colonies. Thousands of individuals may be seen in a colony and the division of labour among them is well marked in individual or individuates (castes) which is pronounced through social interactions.

In termites : Termites started to live an organized social system about 300 million years ago, much earlier than honey bees and ants.

Termite colony is composed of (1) a *queen*, (2) many *workers* and *soldiers*. (Fig : 9) The queen is an egg-laying machine. She lives for 15-20 years. She lives in a royal chamber and workers have to take care of all her daily chores. The workers and soldiers are highly devoted to the colony, working incessantly and tirelessly, demanding

nothing in return from the society. Soldiers defend their nest and workers chew the wood to feed to the queen and larvae and grow fungus gardens for lean periods.

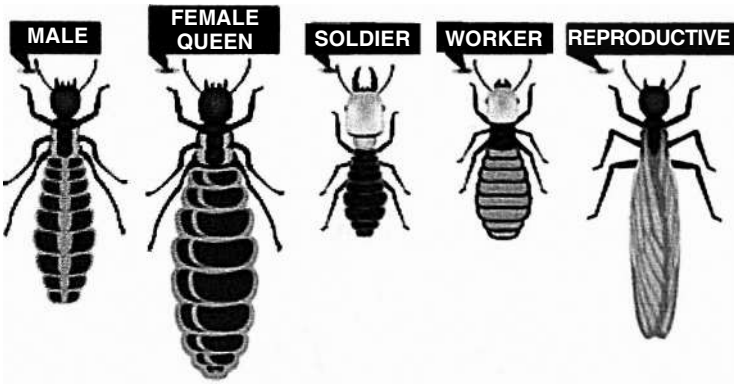

Fig. 9: Castes of termites

Nasutes are specialized soldiers. They are specialized in chemical warfare. They produce a jet of highly corrosive chemical from their bodies that can dissolve the skin of enemies and can also help in making galleries through the rocks. A termite nest which presents highest form of architecture is known as termitarium.

In bees : Honey bees construct hive and the functioning of the hive members is regulated in a disciplined way by (1) a *queen*, (2) many *drones* and (3) many *workers*.

In a bee colony only the queen is a fertile female. She keeps the colony in order by secreting a pheromone from her mandibular glands. The queen produces eggs. Drones are haploid fertile males. There may be 2-3 dozen drones in bee-hive. They take part in nuptial flight and finally one drone individual mates with the queen. Thereafter drones are driven out of the colony and finally die in starvation. In a hive workers may be 20,000 to 80,000 in number. They are genetically sterile females. They help to build, maintain and protect the hive. Cleaning and maintaining the hive, feeding the larva with honey and bee bread are their routine work. Also, a worker secretes wax from the abdominal wax glands and builds the honey comb cells. Workers act as foragers and thus collect nectar and pollen and also water for the colony members. They die in course of such services.

In wasps : In wasps society there exists a caste system consisting of one or several queens, a few drones (males) and sterile females called workers. The queen, a fertilized female, begins the colony in the

spring by building a small nest and laying eggs that hatch into workers. They construct a paper like nest, which is composed of chewed dry plant materials, woolly wood, that has been mixed with saliva and regurgitated.

In ants : Ants are cousins of honey bees and wasps but while bees and wasps are diurnal and sleep in the night ants are busy in working day and night. Ants have the highest developed social system (Fig: 10). A colony may have up to 5,00,000 individuals. The nests are built in various designs and are called formicaria. Different castes are specialized to perform specific functions.

The queen lays up to 2-3 million eggs in a year. The males fertilize her. Workers have broad, sharp mandibles for cutting and chewing and the soldiers have large head that bears sharp dagger-like mandibles for fighting. Workers and soldiers are sterile females. Ants construct nest in the ground or on wood or on trees made of earth, carton, wax or silk. They have developed a highly sophisticated chemical language for communication. Pheromones play important role in communication.

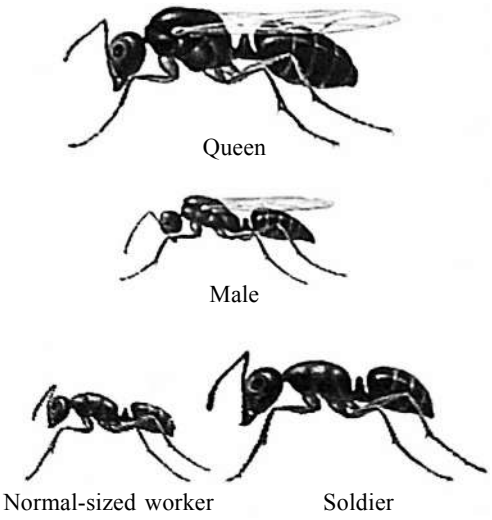

Fig. 10: Castes of Ants

The queen produces eggs while the other female workers go out for foraging food, carry the same for the queen and her brood, and also help in building, maintaining and defending the anthill. The drone has only function that is, to fertilize the queen. They die shortly after mating.

7.5 Conclusion

Arthopods are found almost in all type of habitats and thereby they have undergone distinctly different adaptations, group-wise, by modifying their body organizations morphologically, anatomically, physiologocally and behaviorally to cope up with the conditions to ensure survival and propogation. Interestingly, some of them especially those belong to insect have developed the art of living through

cooperation on way of developing a social life with a view to share the benefit among all the colony members through the execution of assigned functions.

7.6 Summary

i) Arthropods are animals with jointed appendages.
ii) Bilaterally symmetrical, body is covered by chitinous exoskeleton.
iii) Head, thorax and abdomen regions distinct.
iv) Head bears a pair of compound eye.
v) Coelomic space is filled with blood.
vi) Open type circulatory system.
vii) Malpighian tubules or green glands or coxal glands help in excretion.
viii) Unisexual, fertilization may be internal or external.
ix) Gills or trachea or body surface serve as respiratory organ.
x) Development may be direct, or iredirect through different larval stages.
xi) Termites, honeybees, wasps and ants exhibit social life by developing the strategy of living in colony.

7.7 Glossary

Compound eye : An eye consists of numerous small visual units.

Green gland : Also known as antennal gland. Acts as excretory organ in crustaceans.

Malpighian tubules : A type of excretory and osmoregulatory organ system found in some insects, myriapods, arachnids and tardigardia.

Haemocoelomic fluid : Coelomic fluid dissolved with haemoglobin.

Gonopore : Genital pore.

Hexapoda : Animals with three pairs of thoracie legs, especially the insect.

Peripatus : An arthropod belongs to onychophora. It is a living fossil.

Nasutes : Specialized soldiers of termite colony.

Drones : Haploid fertile male honeybees.

Formicaria : Nest of ant.

Royal chamber : The chamber where queen of termite lives.

Nuptial flight : Flight exhibited by drones of honey bee following queen for mating.

Wax gland : Found in the abdomen of worker bee which secretes wax to construct honey comb.

7.8 Questions

1. State any five morphological characters of Arthropoda. Name the excretory organ of cockroach and prawn.
2. Name the major groups of Arthropoda. State the characteristic features of crustaceans.
3. Cite two examples of myriapods with scientific name. An ant is an inset- justify your answer with suitable reasons.
4. Write any five distinctive characters of Chelicerata. Cite examples two such arthropods with scientific name.
5. Discuss the social life of termite.
6. Describe the castes of honeybees and state their role to maintain a social life.
7. Briefly discuss the social life of ant. What meterials are needed to constuct the nest by the wasps?

7.9 Suggested readings

1. K.C. Ghose and B. Manna (2015). A textbook of Zoology. New Central Book Agency, Kolkata.
2. K.K. Chaki, G. Kundu and S. Sarkar (2014). Introduction to General Zoology, Vol. 1. New Central Book Agency, Kolkata.
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Unit 8 ❑ Mollusca : General Characters of Mollusca; Pearl Formation

Structure

8.1 Objectives

By studing this unit, students will be able to know the characteristic features of molluscs occurring in land and water and the mechanism of pearl formation by certain groups of aquatic molluscs.

8.2 Introduction

Mollusca is one of the most diverse groups of animals having at least 50,000 living species belonging to snails, slugs, octopuses, squids, clamps, scallops, oysters and chitons. It is the second largest phylum of invertebrate animals after the Arthropoda.

8.3 General characters of mollusca

1. Soft, unsegmented (except Monoplacophora), bilaterally symmetrical, coelomate, triploblastic animal.
2. Mostly marine but freshwater and terrestrial are not uncommon.

3. Free living but some are parasitic and predacious.
4. Body size varies to a great extent—from giant octopus to small snail.
5. Mantle and radula (except pelecypods) are most notable characters in this animal group.
6. Body in most cases is protected by a calcareous shell which is secreted by the mantle.
7. Tissue-system grade of body organization.
8. Distinct head and ventral muscullar foot.
9. The soft body mass is covered with one-layered usually ciliated epidermis.
10. Except pelecypods and scaphopods head bears mouth, eyes, tentacles and sense organs.
11. The foot is modified in different forms to ensure creeping, burrowing and swimming.
12. Visceral mass contains the vital organs.
13. Body cavity is truly a hemocoel. The coelom is reduced and represented mainly by the pericardial cavity, gonadal cavity and nephridia.
14. Digestive system is well developed and digestive tract is started with mouth and terminated by anus. In gastropods, scaphopods and cephalopods the inestine becomes U-shaped and thus both mouth and anus open at the anterior part while in the remaining groups mouth is anterior and the anus is located at the posterior end.
15. Radula located in the mouth acts as rasping organs.
16. Open circulatory system (except Cephalopoda).
17. Gills or ctenidia help in respiration in aquatic forms while pulmonary sac i.e. so-called lungs help to exchange air in terrestrial forms.
18. Haemocyanins are seen as respiratory pigments in most cases.
19. Paired metanephridia (kidney) act as excretory organs.
20. Nervous system is well developed. It consists of paired cerebral, pleural, pedal and visceral ganglia joined by longitudinal and transverse nerves.
21. Eyes, statocysts and receptors act as sense organs osphradium, generally located adjacent to ctenidium, acts as chemoreceptor or tactile organ..
22. Some molluscs are unisexual while others are bisexual (hermaphroditic)

23. External as well as internal fertilization are seen in molluscs.

24. Development is direct, or indirect through the trochophore/veliger larva.

Examples : Snails [*Pila globosa* (Fig : 1), *Achatina fulica*], Mussels (*Lamellidens marginalis*) Squids (*Sepia rostrata, Loligo forbesii* (Fig: 2), *Octopus vulgaris* (Fig : 3)

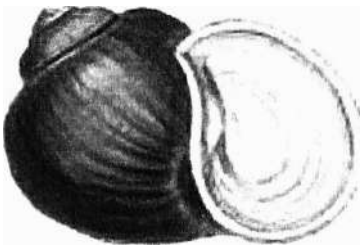

Fig. 1 *Pila*

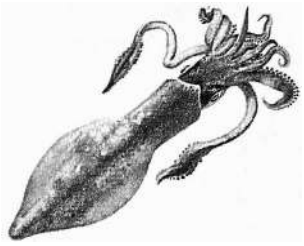

Fig. 2 *Loligo*

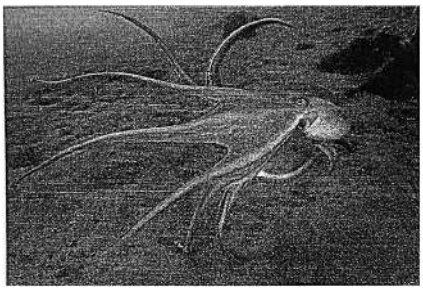

Fig. 3 *Octopus*

8.4 Pearl formation

Molluscs used as food, medicine, decorative and ornamental purposes, also the chank has a role to maintain religion in human society. As ornamental as well as for medicinal purpose, pearl is widely used in human society. It is undoubtedly, intriguing to gain knowledge on the mechanism of pearl formation in molluscs especially in oysters—the pearl oyster. Pearl producing oysters belong to the genus *Pinctada.* The species *Pinctada maxima* lives in the Indian ocean and the Pacific from Japan to Australia and produces pearls known as south sea pearls. However, pearls are formed by saltwater, freshwater oysters, mussels, clams, conchs and gastropods.

A pear is a resultant reaction to an irritant within a mollusc. Natural pearls form when an irritant, usually a parasite works its way into an oyster, mussel or calm. As a defense mechanism, a fluid is used to coat the irritant, the parasite. Layer upon layer of this coating called 'nacre' is deposited and as a consequencc a lustrous pearl is formed.

Pearl culture is nowadays an industry. In this process irritant is a surgically implanted bead or piece of shell called mother of pearl (the foreign body). These seeds or nuclei are most often formed from mussel shells. Quality cultured pearls require a sufficient amount to time—generally at least 3 years for a thick layer of nacre to be deposited, resulting in a beautiful, gem-quality pearl.

When a small parasite or foreign body invades in between the mantle and the shell it becomes enclosed in a sac of mantle (Fig : 4) epithelium which produces irritation. The irritation stimulates the mantle epithelium to secrete thin concentric layers of mother of pearl around the foreign body. The amount of deposition is in direct proportion to the degree of irritation.

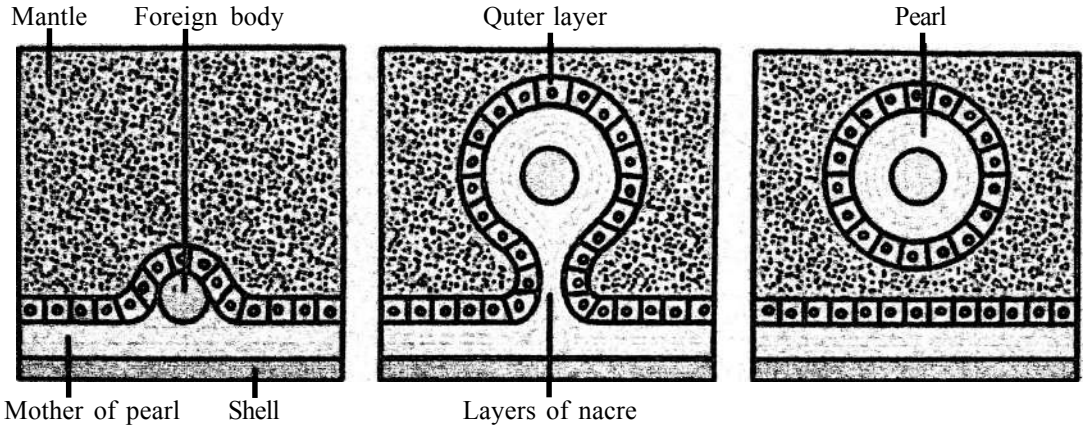

Fig. 4: Process of pearl formation in mollusca

8.5 Conclusion

Molluscs have undergone through remarkable morphological and anatomical modifications to adjust their mode of living in land, trees, freshwater and salt water under varying enviornmental conditions. Accordingly some species are with a hard shell covering while others are devoid of the same. Some are herbivorous while others are predacious or filter feeders. Thus, they have developed radula, tentacles, suckers, ink gland and in some cases by covering of the shell aperture for feeding. The organ system is highly developed to maintain feeding, respiration, excretion, reproduction etc. Also some of them have developed the art to protect them from the attack of any kind of foreign body by capturing the same by the layer of nacre which ultimately produces the pearl.

8.6 Summary

i) Soft, unsegmented, free-living, parasitic or predacious animals.

ii) In most cases body is covered by calcareous shell though some could be seen naked either in the land or trees or ponds or sea.

iii) Herbivores scrap food by the help of radula while carnivores capture the prey by different devices with the help of tentacles and suckers.

iv) In all cases a ventral muscular foot and a mantle covering could easily be revealed through a careful look.

v) In most cases eyes, tentacles, head, mouth and sense organs are prominent.

vi) Body cavity is truly a hemocoel. The coelom is confined to pericardial cavity, gonadal cavity and nephrida.

vii) Well developed digestive system.

viii) In most cases circulatory system is open type.

ix) Gills or ctenidia and pulmonary sac/lungs help in respiration.

x) Haemocyanin acts as respiratory pigment.

xi) Metanephrida serve as excretory organs.

xii) Well developed nervous system.

xiii) Statocyst, eyes and receptors act as sense organs.

xiv) Unisexual or besexual. Development may be direct, or indirect through the trochophore or veliger larva.

xv) Pearls are product by oysters and also by some gastropods. The commercial pearls are produced by the oysters in culture-farms.

8.7 Glossary

Rudula : Food scraping appartus in molluscs

Nacre : It is known as mother of pearl which is composed of organic-inorganic composite materials.

Osphradium : An olfactory organ found in certain molluscs. It helps to test incoming water for silt and possible food particle.

Mantle : It is the dorsal body wall which covers the visceral mass.

Metanephridum : An excretory gland which is also known as Bojanus organ in molluscs.

Apple snail : It is an amphibious gastropod. It's scientific name is *Pila globosa.*

Mother of pearl : Nacre is called the mother of pearl.

8.9 Questions

1. State any five salient features of Mollusca. Name two molluscs of which one respire by the help of lungs while the other depends on ctenidium.
2. What is radula? State its function. Name the mollusc-group where radula is absent. What is osphradium?
3. Name the molluscan animal group where the mouth and anus open at the anterior part. Explain the reason for such a phenomenon. What is haemocyanin?
4. Discuss the components of nervous system and sense organs in molluscs.
5. Name the larval forms of molluscs. What kind of fertilization is in practice in Mollusca?
6. What is pearl? Name a pearl producing oyster of Indian ocean. State the importance of pearl.
7. Discuss the mechanism of pearl formation in a pearl-producing mollusc.
8. Write notes on :

   (a) Mother of pearl; (b) South sea pearls;

   (c) Coelom in molluscs; (d) Foot of mulluscs.

8.10 Suggested readings

1. K.C. Ghose and B. Manna (2015). A textbook of Zoology. New Central Book Agency, Kolkata.
2. K.K. Chaki, G. Kundu and S. Sarkar (2014). Introduction to General Zoology, Vol. 1. New Central Book Agency, Kolkata.
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Unit 9 ❑ Coelomate Deuterostomes : General Characters of Echinodermata; Water Vascular System in Starfish

Structure

9.1 Objectives

By studying this unit, students will be able to have an idea regarding characteristic features of the colomate deuterostome animals belong to the phylum Echinodermata. Also, in this group of animals a special type of biological mechanism-the water vascular system is well marked and in this chapter the aim is to study the same in the starfish to ascertain the significance of such a system.

9.2 Introduction

Coelomate deuterostomes are advanced group of animals having highly organized biological systems.

Coclemate deuterostomes : During the embryonic development, tissues differentiate into germ layers at the gastrulation phase, which later form the organ and specialized tissues of the body. Two or three embryonic germ layers can be developed, based on which animals are also classified and called as diploblasts or triploblasts respectively.

Deuterostomes are animals in which the blastopore develops into anus (Fig: 1). The mouth forms later. Deuterostomes typically display radial cleavage of the blastula, indeterminate development and enterocoelic formation of the coelom. Paired mesodermal pouches develop from the primitive gut wall, they enlarge and fuse to form the coelom. In cases of radial cleavage the cells divide either parallel to or right angles to the long axis of the early embryo so that the cells produced lie directly above one another.

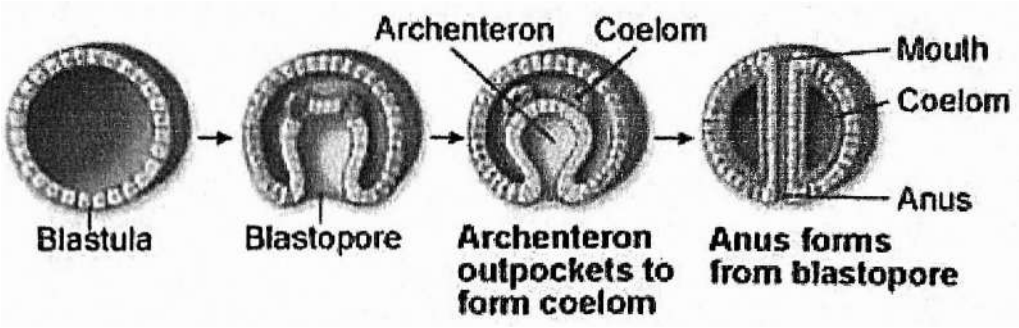

Fig. 1 Deuterostome

Enterocoelic is a method of coelom formation within pouches of mesoderm budded off from embryonic gut wall. This way of development is seen in echinoderms, hemichordates, brachiopods and also in some other groups of animal.

9.3 General characters of echinodermata

The name Echinodermata [Two greek words : Echinos-spine; dermatos-skin, that means "spiny skin"] was first coined by Kelin (1734) and referenced by Linnaeus (1758). The general characters of echinoderms are:

1. Bodyform varies considerably from star-shaped to spherical, cylindrical. Unsegmented body without head.
2. Most organisms bear spines and pincer-like pedicellariae. Spines help in protection. Pedicellariae keep the body surface clean from all kinds of debris and tiny organisms.
3. Adults show radial and pentamerous symmetry while the larval forms are bilaterally symmetrical.
4. Triploblastic animals having organ system level of organization.

5. In body wall epidermis is single layered and ciliated. In many species endoskeleton of calcareous plates could be seen in dermis. Spines are supported by the calcareous plates.
6. The body is differentiated into oral (mouth bearing) and aboral surface.
7. On the oral surface there are five grooves called ambulacra, radialing from the mouth to the tip of the arms, with intervening interambulacra.
8. Muscles are smooth and are found beneath the dermis.
9. A true enterocoelic coelom surrounded by ciliated peritoneum.
10. Except Brittle stars digestive system is complete.
11. Presence of water vascular system is the nontable characteristic feature in echinoderms. This is also known as ambulacral system. Madreporite, a perforated calcareous plate is present in this system. Madreporite pores allow water into the system. Tubefeet associated with this system help in locomotion, food-capturing and respiration. Water vascular system is of coelomic origin.
12. Coelomic origin haemal and perihaemal systems serve as an open circulatory system. No respiratory pigment and heart.
13. No specialized excretory organ but the nitrogenous waste, chiefly ammonia is diffused out via gills.
14. A nerve ring and radial nerve cords are the components of nervous system where brain is absent. Sense organs are also poorly developed.
15. All organisms are marine, either pelagic or sessile but prefer to live at the sea bottom.
16. Reproduces both sexually and asexually, but there exists no sexual dimorphism. Usual fertilization is external. Also some are viviparous.
17. Autotomy and regeneration are well marked in echinoderms.
18. Development indirect i.e. adult stage appears through the ciliated larval forms.
19. Echinoderms resemble chordates in early embryoric development. Thus it is assumed that the echinoderms are nearer to the Chordata.

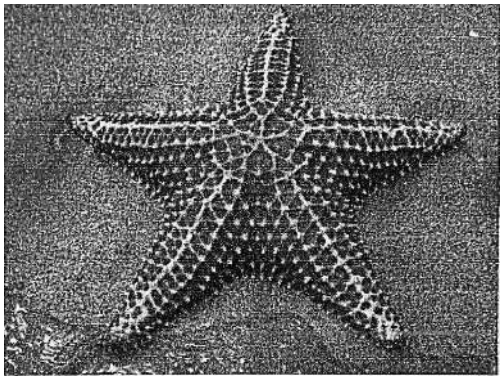

Fig. 2 Starfish

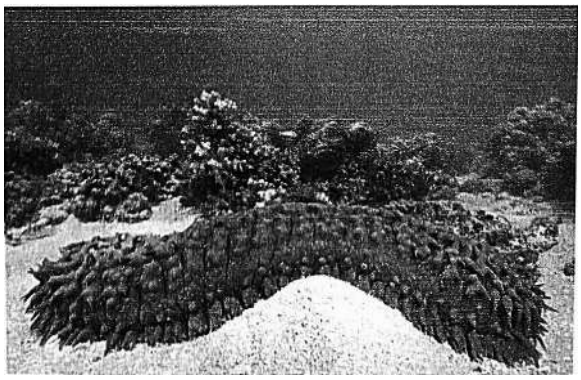

Fig. 3 Sea Cucumber

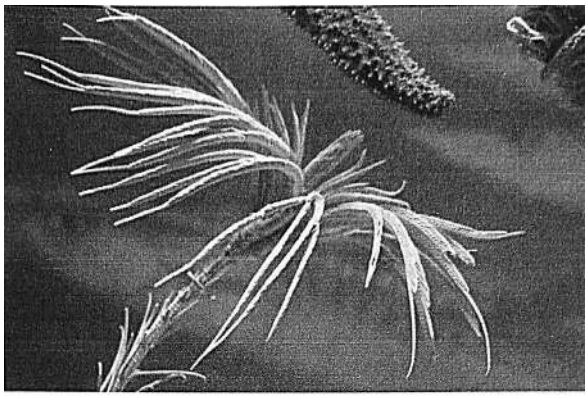

Fig. 4 Sea lily

Examples : Starfish (*Asterias rubens*) (Fig: 2), Brittlestar (*Ophiura ophiura*), Sea urchin (*Echinometra viridis, Echinus sp.*), Sea cucumber (*Cucumaria frondosa*) (Fig : 3), Sea lillies (*Cenometra bella, Antedon sp.*) (Fig: 4)

9.4 Water vascular system in starfish

Water vascular system (Fig : 5) is a hydraulic system used by echinoderms to accomplish various functions. This system is well developed in starfish and be treated as typical one. This system is also known as Ambulacral system. The system is nothing but a net-work of canals which remain filled with sea water. The entire tube is lined by ciliated epithulium. The system is composed of (1) Madreporite, (2) Stone canal, (3) Ring canal, (4) Radial canals, (5) Polian vesicles and Tiedmann's bodies, (6) Lateral canals and (7) Tube feet (Fig :5)

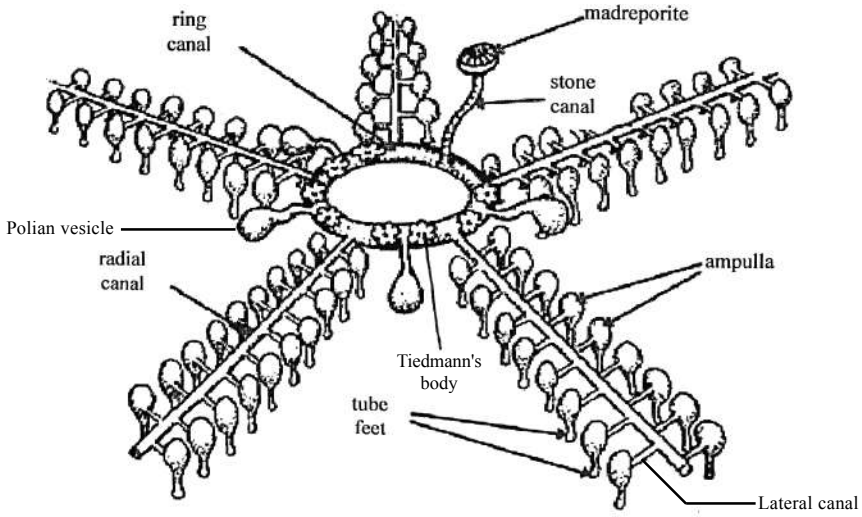

Fig. 5 Water vascular system in star fish

1. **Madreporite :** It is located on the aboral surface of the central disc of star fish. It is calcareous in nature and plate-like in structure. On the surface of madreporite grooves furrows are present. Each furrow is provided with a number of pores. These pores lead into small canal which opens into a stone canal.
2. **Stone canal :** This canal is 'S' shaped. The canal extends downwards (orally) and opens into a ring canal, around the mouth. The canal wall is supported by a number of calcareous rings, thereby it is named as stone canal. A ridge is projected from the wall of the stone canal. The ridge is bifurcated into two lamellae. The lamellae become spirally rolled and occupied considerable portion of the lumen of the stone canal. Sometimes the lumen of the stone canal looks very much complicated due to extensive development of the lamellae. The stone canal serves as pump to drive the circulation of sea water.
3. **Ring canal :** It is located around the mouth and directly above (aboral) to the hyponeural ring sinus. It is wide but pentagonal ring like canal.
4. **Radial canal :** The ring canal gives off five radial canals along the ambulacral grooves of the arms. This canal runs up to the tip of the arms and ends as the lumen of terminal tentacle.
5. **Polian vesicles and Tiedmann's bodies :** In certain star fishes there occur pear-shaped sacs called polian vesicles which are connected with ring canal

inter-radially. Tiedmann's bodies are small spherical yellowish, glandular bodies emerged from the neck of each polian vesicle, attached to the inner wall of the ring canal. The polian vesicles are absent in *Asterias sp*. Thus, the ring canal gives of inter-radially nine such Tiedmann's bodies. The function of the Tiedmann's bodies are not clearly known. It is assumed that, these help to filter fluid from the vascular system into the body cavity.

6. **Lateral (podial) canals :** These paired but alternately arranged small side branches projected from the radial canals. Each lateral canal is attached to the base of the tube-foot and contains a valve which prevents the back flow of water from the tube-foot to the radial canal. The flow of fluid from lateral canal to ampulla and podium of tube foot is controlled by the valve.
7. **Tube feet :** There are numerous tube feet arranged in two rows on either side of the ambulacral groove. A tube feet is a hollow, elastic, thin walled, closed cylinder or sac-like ampulla, a middle tubular podium and a lower disc like sucker. The ampulla lies within the arm, projecting into the coelom above the ambulacral pore—a gap between the adjacent ambulacral ossicles for the passage of the podium. Tube feet help in locomotion and respiration.

   Function of water vascular system: water vascular system helps starfishes in (i) locomotion, (ii) food-capturing and (iii) attachment to the rocks.

9.5 Conclusion

In deuterostome animals the first opening, during the development process of the embryo, becomes the anus. Deuterostome animals are enterocoelic. Echinoderms are marine animals with different shapes and sizes but without head. Many organ-systems are absent in echinoderms and to get the benefit of the organs which are absent in their body they have developed the unique device- the water-vascular system. Through this system water from the surroundings is taken in through the large pore and then passes through a canal system which is ramified throughout the body to suppy oxygen, food and to discharge the carbondioxide and nitrogenous waste from the body. Also, it helps them in locomotion.

9.6 Summary

i) Star-shaped, sphrical or cylindrical unsegmented body without head but most echinoderms are with spines.

ii) Adult forms are pentamerous and radially symmetrical while larval forms are bilaterally symmetrical.

iii) In many cases endoskeleton with calcareous plates may be seen.

iv) Enterocoelic coelom surrounded by ciliated peritoneum.

v) Presence of water vascular system.

vi) Tube feet help in locomotion, food-capturing and respiration also while associated with the water vascular system.

vii) Open circulatory system but no respiratory pigment and heart.

viii) Nitrogenous waste diffused out through the gills.

ix) Brain is absent, sense organs are poorly developed.

x) Marine, sessile or pelagic.

xi) Reproduces both sexually and asexually but fertilization is external.

xii) Autotomy and regeneration are well marked.

xiii) Indirect development is effected through ciliated larval forms.

xiv) Water vascular system is a hydraulic system used by echinoderms to accomplish different functions.

9.7 Glossary

Deuterostomes : Animals in which the blastopore develops into anus.

Pedicellariae : Pincer-like outer extension of the body of echinoderm which helps to keep the body surface clean.

Ambulacral system : The other name of water vascular system.

Madreporite : A perforated calcareous plate associated with the water vascular system which allows water into the body.

Tube feet : Associated with the water vascular system and help in locomotion, food capturing and respiration.

Autotomy : The casting off a part of the body.

Stone canal : One type of canal which is associated with the water vascular system. It is "S" shaped and opens into a ring canal.

Radial canals : Canal arising from the ring canal extends up to the tip of the arm. These are five in number.

Tiedmann's body : The sacs associated with the ring cannal of water vascular system is known as Tiedmann's body.

9.8 Questions

1. Explain the term 'deuterostome'. Explain why echinoderms are coelomate deuterostome.
2. Who first coined the term 'echinodermata'? Mention any five salient features of echinoderms. Cite two examples.
3. What are spines and pedicellariae. State their functions. Add a note on the nature of exoskeleton of echinoderms.
4. How does echinoderm get rid or nitrogenous wastes? Where we can get the echinoderms in sea water. What is Tiedmann's body?
5. What are autotomy and regeneration? What do you mean by oviparous? Name the scientific name of a starfish and a brittle star.
6. In brief describe the water vescular system in starfish and state its functions.
7. Write notes on :

   (a) Stone canal (b) Ring canal

   (c) Podial canal (d) Tube feet

9.9 Suggested readings

1. K.C. Ghose and B. Manna (2015). A textbook of Zoology. New Central Book Agency, Kolkata.
2. K.K. Chaki, G. Kundu and S. Sarkar (2014). Introduction to General Zoology, Vol. 1. New Central Book Agency, Kolkata.
3. A.J. Marshall and W.D. Williams (1985). Textbook of Zoology. Vol. 1. Invertebrates. The Macmillan press Ltd. London.
4. J.A. Pechenik (2000). Biology of the invertabrates. 4th edn. Tata McGraw-Hill edition. The Tata MacGraw-Hill Publishing Company Ltd. New Delhi.
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Unit 10 ❑ Protochordata : Salient Features

Structure

10.1 Objectives

By studying this unit, students will be able to gain knowledge regarding emergence of some chordate features in the protochordate animal groups.

10.2 Introduction

Protochordates are also known as lower chordates. They have many similarities with higher invertebrates and vertebrates. As these animals lack a cranium they are also known as Acraniata. Traditionally Protochordates consist of three sub-phyla in respect to the property of notochord. They are Hemichordata, Urochordata and Cephalochordata. But in modern concept Hemichordates are included among the non-chordates as a seperate phylum. Neverthless hemichordates are close relatives of the chordates.

10.3 Protochordata : salient features

1. Bilaterally symmetrical, coelomate triploblastic animals.
2. Presence of a single dorsal hollow tubular nerve cord, paired pharyngeal gill slits and an elastic, solid, rod-like structure the notochord either throughout the life or only during larval stage at certain part of the body.
3. Well developed organ system level of organization.

10.3.1 Characteristic features of Hemichordata

(i) Marine, solitary or colonial, filter feeder.

(ii) Unsegmented, cylindrical stout body.

(iii) Three distinct regions in the body *viz*.; proboscis, collor and trunk are well marked.

(iv) Collor bears arms and tentacles.

(v) Preoral extension of buccal cavity known as buccal diverticulum or stomochord be mistaken as notochord.

(vi) Complete digestive system.

(vii) Body surface and gills help in respiration.

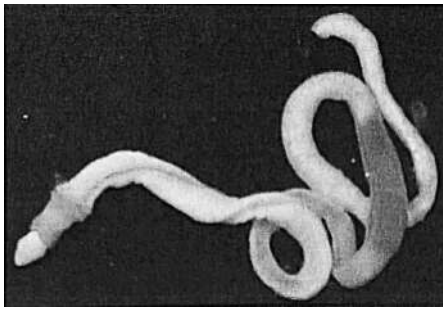

Fig. 1 *Acorn worm*

(viii) A heart with two longitudinal vessels are the main components of circulatory system.

(ix) Blood has no corpuscles and is colorless.

(x) Excretory system is confined to the proboscis gland or glomerulus.

(xi) Sexes separate

(xii) Fertilization is either external or internal.

Examples : Acorn worm (*Saccoglossus kowalevskii, Balanoglossus aurantiacus*) (Fig: 1), *Planctosphaera pelagica*

10.3.2 Characteristic features of Urochordata (Tunicata)

(i) Marine, sessile and filter feeders.

(ii) Body is surrounded by a leathery sheath called tunic and composed of tunic in protein and cellulose like polysaecharide. Thus, the name Tunicata is applied to this group.

(iii) Notochord found in the tail region in larval stage and disappears in the adult. This phenomenon is related with the retrogressive metamorphosis.

(iv) Neural tube of the larva is replaced by a dorsal ganglion in the adult stage.

(v) Pharyngeal gill slits present.

(vi) Circulatory system is open-type.

(vii) No excretory organ.

(viii) Reproduces both asexually (through budding) and sexually.

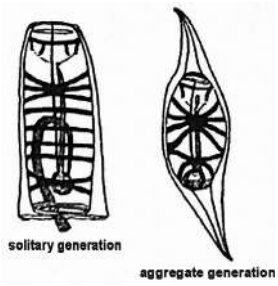

Fig. 2 *Salpa sp.*

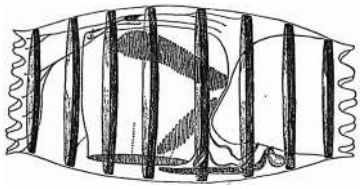

Fig. 3 *Doliolum sp.*

Examples : *Herdmania armata, Salpa fusiformis* (Fig :2), *Doliolum denticulatum* (Fig: 3)

10.3.3 Characteristic features of Cephalochordata

(i) Marine, mostly sedentary and burried with only anterior body end projecting above bottom sand.

(ii) Body 5-8 cm long, slender lancet-shaped and transparent.

(iii) No head but trunk and tail distinct.

(iv) Paired appendages lacking, median fins present.

(v) No exoskeleton, epidermis single-layered, muscles dorsolateral, segmented into myotomes.

(vi) Enterocoelous coelom is confined to the pharyngeal region through the development of atrial cavity.

(vii) Notochord rod-like, persistent, extending from rostrum to tail, hence it named as cephalochordata.

(viii) Filter feeders, digestive tract complete, pharynx with gill-slits.

(ix) '<' shaped myotomes present.

(x) Well developed, closed circulatory system without heart and respiratory pigment. Hepatic portal system developed.

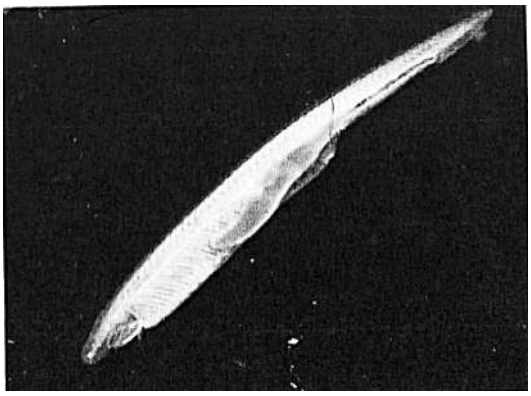

Fig. 4 *Branchiostoma sp.*

(xi) Protonephrida with solenocytes help in excretion.

(xii) Dorsal tubular nerve cord without ganglia and brain.

(xiii) Sexes separate, numerous gonads but no gonoducts. No asexual reproduction.

(xiv) External fertilization, indirect development through free-swimming larva.

Examples : *Branchiostoma belcheri* [common name=Amphioxus] (Fig: 4), *Branchiostoma lanceolatum, Asymmeton lucayanum.*

10.4 Conclusion

Chordates are characterized by having a notochord. But such a structure was developed through certain steps in the lower chordates where the notochord is confined to larval stages or at certain regions of the body in adult forms.

10.5 Summary

i) Protochordates are differentiated into three groups *viz*., Hemichordates, Urochordates and Cephalochordates depending upon the property of notochord but all animals bear pharyngeal gill slits and dorsal hollow tubular nerve cord.

ii) Marine, hemichordate animals having three distinct regions *viz*.; proboscis, collar and trunk in the body.

iii) Circulatory system consists of a heart with two longitudinal vessels.

iv) Blood is colourless and without corpuscles.

v) Excretory system is confined to glomerulus.

vi) Sexes may be united and separated.

vii) In Urochordata notochord is confined to the tail region, in Cephalochordata notochord is extended from rostrum to tail is a primitive character.

10.6 Glossary

Notochord : A cartilaginus skeleton rod found in all the embryonic and some adult chrodate animals.

Protochordates : A group of invertebrate chordate animals closely related to vertebrates.

Hemichordata : Absence to true notochord in these animals and usually considered as sister group of Echinodermata but very much related with the Chordata. Thereby they are known as half-chordata.

Urochordata : Protochordates where notochord is found in the tail region in the larval stage but disappears in the adult form.

Cephalochordata : Protochordates where notochord is extended from the rostrum to tail.

10.7 Questions

1. What are protochordates? State the characteristic features of Protochordata.
2. Mention the salient features of Hemichordate with examples.
3. Give a comparative account of Urochordata and Cephalochordata.
4. Write notes on :
   (a) Notechord; (b) Solenocytes; (c) Acraniata; (d) Metamorphosis in Tunicata

10.8 Suggested readings

1. K.C. Ghose and B. Manna (2015). A textbook of Zoology. New Central Book Agency, Kolkata.
2. K.K. Chaki, G. Kundu and S. Sarkar (2014). Introduction to General Zoology, Vol. 1. New Central Book Agency, Kolkata.
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5. E.J.W. Barrington (1975) Protochordates. Academic Press-Inc. (Sell on Amazon)
6. V.R. Misra and R. Gupta (1960). An Introduction to Protochordata. Indian Book Depot, Delhi.

Unit 11 ❑ Pisces : Osmoregulation, Migration of Fishes

Structure

11.1 Objectives

Fishes are adapted to live in freshwater, saltwaters as well as in esturaies. As the quality of water varies with the type of water it is intriguing to have an idea regarding the homeostasis in these aquatic organisms. Also they need different qualities water with a view to ensure reproduction and for the growth of young individuals the strategy of migration is well established in some fishes. The aim of the study is to gain knowledge on these aspects.

11.2 Introduction

Pisces, the first true jawed vertebrate group includes all the fishes, having paired and unpaired fins with finrays for swimming and gills for respiration in aquatic medium. Ichthyology is the branch of zoological science which deals fishes. Placodermi, the first jawed vertebrate appeared in mid-Silurian period though fishes flourished in Devonian period. Therefore, Devonian period is called the golden age of fishes. Fishes are adapted to survive in marine, fresh and estuarine waters.

11.3 Pisces : Osmoregulation

Osmoregulation is a process of regulation of water and electrolytic balance in the body of an organism with a view to maintain the homeostasis.

Fresh water fishes are hypertonic to their surrounding enviornment. This means that the concentration of salt is higher in their blood than their surrounding water. They absorb a controlled amount of water through the mouth and the gill membranes. Beacuse of hyperosmotic body fluid they are subjected to swelling by movement of water into their body owing to osmotic gradient. As the surrounding medium is with low concentration of salt, fishes are to face the loss of body salts almost continuously. Thus they have developed the art regarding net gain of water and net loss of salts. Net intake of water is regulated by kidney by developing the mechanism to produce a dilute, more copious urine. In course of urine formation useful salts are reabsorbed in tubules of kidney and thereafter refined in the blood. Gills of the fishes play important role in extracting Na^+ and Cl^- from surrounding water. Thus NaCl actively transported in the gills against a concentration gradient. Also depending upon the permeability and impermeability nature of the integument salt loss and water uptake are regulated by the fishes by not drinking the water. (Fig: 1)

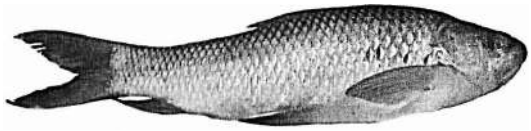

Fig. 1 Rohu fish

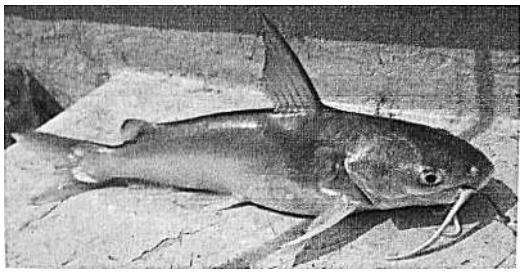

Fig. 2 Marine Cat Fish

In marine condition concentration of body fluid and marine water is almost same (isotonic). Thus, these fishes (Fig: 2) hardly face the osmoregulation process.

Elasmobranch fishes (such as sharks, rays, skates) coelacanth, Latimaria have iso-osomotic to sea water having capacity to maintain very lower electrolyte concentration. Kidneys of coelacanth and elasmobranchs excrete excess of inorganic salts such as NaCl. Also rectal gland located at the end of alimentary canal takes part in excretion of NaCl.

Marine bony fishes having hypotonic body fluid in respect to sea water have developed the tendency to loss water through the gills and to compensate the same by drinking sea water. (Fig: 3)

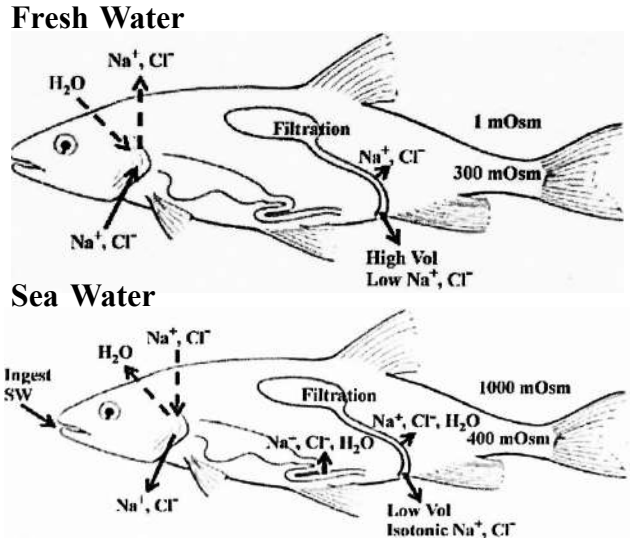

Fig. 3 Mechanism of osmoregulation in freshwater and marine teleost fishes (Evans, 2008)

The ingested NaCl and KCl enter the blood stream by absorption across the intestinal epithelium. However, Ca^{++}, Mg^{++} and SO_4^{++} when left in the gut are excreted out. Excess salts mainly sodium and chloride when absorbed are eliminated into the sea water by the gills via blood stream and salts if excreted in excess may be reabsorbed by the gills. Mg^{++} and SO_4^{++} are excreted by the kidney.

11.4 Migration of fishes

Simply, migration means movement (may be seasonal) of animals from one region to another. Migration of fishes is a regular phenomenon. This kind of behaviour may be exhibited in conncetion with the assurance of getting the food resources or/and to ensure reproduction by the fishes.

Fish migration are of following types :

1. **Diadromous migration :** This sort of migration of fish takes place between sea and freshwater. Such fish species are adapted to maintain the osmotic balance in both the habitats. This migration is of two types;

(a) **Anadromous migration :** This type of migration is exhibited by the marine fishes from sea to river for spawning. Therefore this migration is confined to breeding season.

Examples : *Hilsa, Salmon, Sea trout* etc.

(b) **Catadromous migration :** This sort of migration is exhibited by the freshwater fishes. They migrate from river to sea during breeding season for spawning.

Examples : *Eel.*

2. **Potamodromous migration :** This kind of migration takes place from one fresh water habitat to another for feeding or spawning.

Examples : *Carps, Catfish*

3. **Oceanodromous migration :** In this case fish migration is confined to the same sea but from one area to another in search of suitable feeding and spawning ground.

Examples : *Mackerel, Thummus, Tuna.*

4. **Latitudinal migration :** This type of migration is also known as climatic migration. Becasue, the fishes migrate from south to north to south in respect to climate change.

Examples : Sword fish migrate to north in spring and to south in autumn.

5. **Vertical migration :** This type of migration is exhibited by certain fish species daily from deep to the surface and vice-versa for food, protection and spawning.

Examples : Sword fish usally move vertically downward to greater depth for food.

6. **Shoreward migration :** In this case the fish migrate from water to land for short period. Thus it is a temporary migration.

Examples : Eel migrate from one pond to another pond via moist meadow grass.

Significance of fish migration :

(i) To get suitable feeding and spawning ground.

(ii) To protect the members from predators and hazardous climatic conditions.

(iii) To increase genetic diversity with a view to ensure survival and existence through the development of adaptive characters.

11.5 Conclusion

In freshwater fishes concentration of salt is higher in their blood than their surrounding water but in marine fishes the concentration of salt in the body fluid as well as in the surrounding water is almost same. Therefore, osmoregulation in freshwater fishes is a complicated process in respect to those adapted to lead a marine life. Various types of migration are recorded in fishes and the main purpose of migration of fishes is spawning.

11.6 Summary

i) Fishes are jawed vertebrate with paired and unpaired fins with fin-rays.

ii) Fishes are found in different habitats having variation in ionic concentrations in respect to external and internal environments.

iii) Electrolytic balance in the body of the fishes is essential to maintain the homeostasis.

iv) Freshwater fishes are hypertonic i.e. the concerntration of salt in their body is higher than the surrounding water.

v) In marine fishes ionic concentration in the body fluid is almost equal to the surrounding water body i.e. these fishes are isotonic.

vi) Fishes migrate from saltwater to freshwater or vice-versa to ensure spawning, protection from adverse condition as well as to maintain the genetic diversity.

vii) Migration may be diadromous (between sea and fresh water) anadromous (from river to sea), potamodromous (from any freshwater body to another), oceanodromous (from one area to other area in the same sea), latitudinal (from north to south or from south to north in respect to climate change), vertical (from deep to surface and vice-versa daily) and shoreward (from water to land temporarily).

11.7 Glossary

Osmoregulation : The process of maintaining constant osmotic pressure in the fluid of an organism by controlling the water and salt regulations.

Migration : Movement of organisms from one place to another for a definite purpose.

Hypotonic : Having lower osmotic pressure in respect to a particular fluid.

Hypertonic : A greater concentration of solutes on the outside of a cell (organism) when compared with the inside of the same.

Anadromous : Migration of fish from sea to river (salmon fish exhibits this kind of migration for spawning).

Catadromous : Migration of fish from river to sea (eel exhibits this type of migration for spawning).

11.8 Questions

1. Define osmoregulation. Explain the mechanism of osmoregulation in freshwater fishes.
2. Describe the process of osmoregulation in marine fishes.
3. Define migration. State the different types of migration exhibited by fishes.
4. What kind of migration is exhibited by*Hilsa* and *eel*? State the significance of fish migration.
5. Write notes on :

   (a) Potamodromous migration; (b) Latitudinal migration;

   (c) Vertical migration; (d) Diadromous migration

11.9 Suggested readings

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2. Morais, P. and Daverat, F. (2016). An introduction of fish migration. CRC Press, Taylor and Francis group, Boca Ration, FL.

Unit 12 ❑ Amphibia : General Characters, Adaptations for Terrestrial Life, Parental Care in Amphibia

Structure

12.1 Objectives

By studying this unit, students will be able to gain knowledge on the characters of the first tetrapods appeared on the land, the adaptive features in these animals life, the parental care in order to lead a terrestrial mode of life by these animals.

12.2 Introduction

Of the vertebrates, animal belong to the class Amphibia first invaded the land. But they were unable to adapt themselves to lead a terrestrial life completely. Therefore, they had to go back, for certain purposes, to water to ensure their survival and propagation. Actually they depend on water for reproduction especially to deposit eggs and to ensure the development to the larval form the tadpoles. Tadpoles respire by the help of gills just like fishes and equally apt to swim by the help of the tail. Adult stage is with limbs and thus they are able to move freely on land and also they respire by the help of lungs while in land and are equally capable to use the skin

which is naked and moist for exhange of air. Such a dual mode of life is termed by amphibious (amphi=two, bios=life) to these animals.

12.3 General characters of amphibia

1. Tetrapod, aquatic or semiaquatic (freshwater) cold blooded animals.
2. Distinct head, elongated trunk; neck and tail may be present or absent.
3. Naked, moist, glandular skin with pigment.
4. Limbs 2 pairs but certain species are limbless. Fore limb with 4 fingers and hind limb with 5 fingers but clawless.
5. Median fins when present are without fin-rays.
6. Mostly endoskeleton is bony. Notochord is replaced by the vertebral column. Skull with two occipital condyles.
7. Small homodont teeth may be seen either in the upper or in both the jaws.
8. Protrusible tongue.
9. Well developed alimentary canal but terminates into colaca.
10. Lungs, gills, skin and inner lining of the buccal cavity take part in respiration depending upon the habitats.
11. Heart consists of three chambers (2 auricles and 1 ventricle). Sinus venosus present.
12. One to three pairs aortic arches.
13. Heptic portal and renal portal systems are well developed.
14. Red blood orpuscles are large in size, oval in shape and with a nucleus.
15. Poikilothermous i.e. variable body temperature.
16. Mesonephric kidney.
17. Large urinary bladder and urinary ducts open into cloaca.
18. Uricotelic organisms i.e. nitrogenous wastes mainly of uric acid.
19. Brain is located inside the cranium; ten pairs of cranial nerves.
20. Nostrils have direct connection with the buccal cavity.
21. Middle ear with a single rod-like ossicle.
22. Lateral line system is seen in larval as well as in aquatic adults.
23. Unisexual, no copulatory organ in male.
24. Gonoducts open into cloaca.
25. In most cases fertilization is external and females are oviparous.

Fig. 1 *Dyttaphrynus melanostictus*

Fig. 2 *Rana tigerina*

Fig. 3 *Tylototriton verrucosus*

26. Indirect development, cleavage unequal, extra embryonic membrane absent.
27. Larva i.e. tadpole metamorphoses into adult.

Examples : [Toad *Dyttaphrynus* (=Bufo) *melanostictus*] (Fig: 1), Frog (*Rana tigerina*) (Fig: 2), Indian Salamander (*Tylototriton verrucosus*) (Fig: 3), *Ichthyophis sp.*

12.4 Adaptation for terrestrial life of amphibia

Transition of vertebrates from aquatic environment to terrestrial environment compelled amphibians to solve the following problems on way of effective adaptations, such as:

(i) To avoid dehydration they have developed a thicker, impermeable skin which protects body from the loss of excessive water.

(ii) They have also developed the skin semipermeable in nature and thereby they have developed the art to respire through the skin under certain circumstance in land habitat.

(iii) To minimize the loss of body water, they have modified the mechanism of excretion by secreting nitrogenous wastes as urea and uric acid, as they need less water to dissolve instead of to release the excretory waste i.e. ammonia which is dissolved in water.

(iv) To protect them from the harmful solar radiation they have developed pigments in the skin to filter the harmful radiation.

(v) They failed to adapt fertilization in terrestrial environment and therefore, to ensure external fertilization both male and female are accustomed to go to the water to maintain their race.

12.5 Parental care in amphibia

Care to the brood i.e. eggs or young by the parents is known as parental care. Amphibians (anurans, urodelans and apodams) usually lay few eggs and thereby they are cautious to protect their eggs and developing young ones from any sort of adverse situations- be it natural enemies or the hazardous conditions of the habitats. The sole aim behind such care is only to ensure the survival and propagation of the race.

In Amphibians parental care is effected by two ways : (1) by providing nest, nursery or shelter and (2) by direct caring i.e. nursing. Toads, frogs are habituated to construct nest where they deposit eggs and the young ones find the space for development.

The tree frog, *Hyla faber* in Brazil, protects its progeny by building a basin-shaped nest in shallow water on the border of the pond (Fig: 4). The mud hole nest is protected from the water by constructing circular wall above the water surface. The nest-hole is made smooth by the help of limbs and belly. The eggs and early larval stages are thus protected from predators and following heavy rain the larva moves to the water body by protecting itself from the predators.

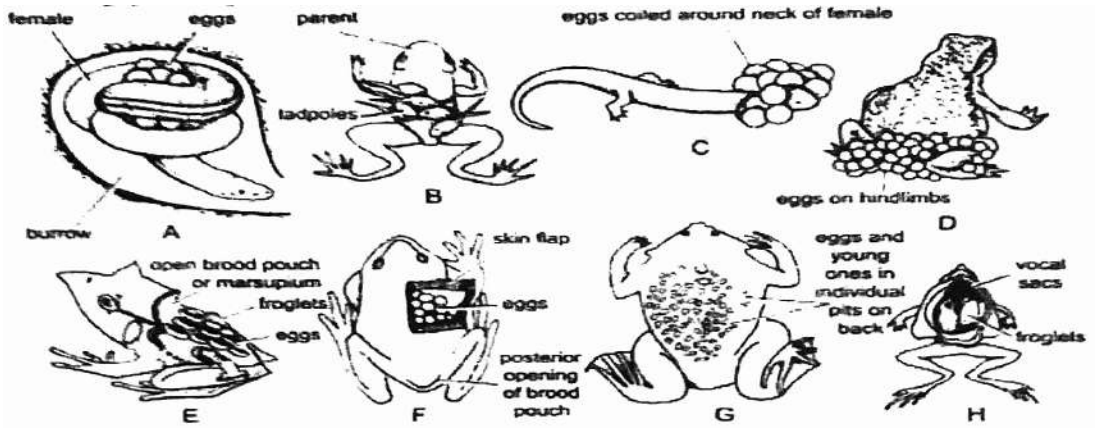

Fig. 4 Parental care in amphibians. *A.* ***Ichthyophis*** coiling round the eggs. *B.* ***Phyllobates*** transport tadpoles on back. *C.* ***Desmognathus fuscus*** with eggs.

The Japanese tree frog *Rhacophorus schlegelii* construct foam nest in sloping burrow near water (Fig: 5). The parents bury themselves in the damp earth on the edge of ditch or watery rice fields. The hole is made a few centimetres above the

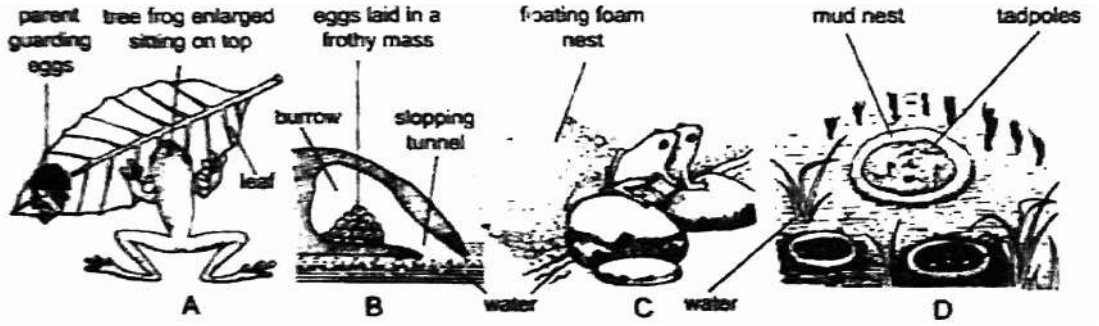

Fig. 5 Parental care in Amphibia. Protection by nests, nurseries of shelters. A-A tree frog guarding eggs glued to a leaf overthanging water. B-Form nest of *Rhacophorus schlegeli* in a sloping burrow near water. C-Form nest floating on water. D-Mud nest of *Hyla faber*.

water level. After entering into the hole-chamber the entry gallery gets obliterated. Then oviposition starts. The female produces a secretion from cloaca which is beaten by the limbs into a froth. The eggs are deposited into that froth. The male impregnates these eggs and then both the parents make an exit gallery towards the water body, obliquely downwards to the water. Later, the larvae use the said exit gallery to reach the water to complete development. The froth liquifies and these liquids act as an efficient vehicle to transport the larvae down the tunnel into the water.

- The south American tree frog *Leptodactylus mystacinus*, prior to egg deposition produces a frothy mass of mucus inside a hole near water. The eggs hatch there and in due course of time the tadpoles make their way to water.
- In some anurans (e.g. *Rhacophorus maculatus*) female discharges large amount of mucus and beat it into a foam and then deposits eggs there. The tadpoles in due course of time drop into water.
- Tree frogs like *Rhacophorus malabaricus* in India, *Phyllomedusa* in South America and *Chiromantis* in tropical Africa glue eggs to the leaf of the tree hanging close to the water body. Thereby, after hatching the tadpoles drop into the water. Parents in this case guard the nest throughout. The tree frogs *Hyla resinfictnix* use bees wax for the construction of shallow cavity in the tree. When the cavity is filled with rain water they deposit eggs there. The tadpoles develop and move away in due time.

- *Autodax* (an urodele) deposit10-20 eggs in a dry hole in the ground or tree. Both the parents remain inside the egg-nest hole, to provide required moisture, for longtime untill the tadpoles come out.
- *Phrynixalus biroi* produce large-sized eggs. These eggs are enclosed in sausage-shaped transparent membranous bag which is secreted by the female. The said bag is released in the mountain stream. The complete development takes place inside the bag and little frogs come out in due time.
- *Salamandrella keyserlingi* deposits small egg in a gelatinous bag which is attached to an aquatic plant just below the water level.
- Some tropical American Hylodes deposit their large eggs under stones, moss or plant leaves. Because of plenty of yolk in the egg young frogs come out following complete development.

Direct nursing by the parents :

- South American frogs *Phyllobates, Dendrobates* and the tropical African frogs *Arthroleptis* and *Pelobates* deposit their eggs on the ground. After hatching the tadpoles adhere by their sucker like lips and flattened abdomen to the back of one of their parents. They are, thus carried by the parents to the safe water body.
- The male *Mantophryne robusta* sits on the egg-mass strung together in an elastic gelatinous envelope for the entire development period until the larvae move to the water body.
- In Europe, the male Obstetric toad (*Alytes obstetricans*) carries the eggs round his body and hind legs adhering the eggs in a gelatinous material untill the tadpoles are released.
- The Sri Lankan female tree frog (*Thacophorus reticulatus*) carries the eggs glued to her belly.
- In urodelan species *Desmognathus fuscus* the eggs are laid in the form of rosary-like strings which is bounded round the body. The female nourishes them at any comparatively dry spot.
- Brazillan female tree-frog *Hyla goeldii* carries eggs on her back until the todpoles are released. The eggs remain exposed throughout.
- In *Nototrema* though eggs are placed on the back in a single large brood pouch, the same remain covered by skin. The tadpoles come out through an opening at the posterior end close to cloacal aperture.

- The Surinam toad, *Pipa americana, Pipa dorsigera* the male places the eggs on the back of the female in cell-like pouches. These eggs hatch and the larvae are capable of metabolic exchanges between the maternal and embryonic tissues in the manner of a primitive placenta (a phenomenon of pseudoplacentation). The tadpoles emerged out about after eight days after egg-deposition.
- The small South American male frog *Rhinoderma darwini* keeps the eggs in vocal sacs to ensure safe development of the tadpoles (Fig: 6). In contrast, male *Arthroleptis* frog keeps larva in his mouth.

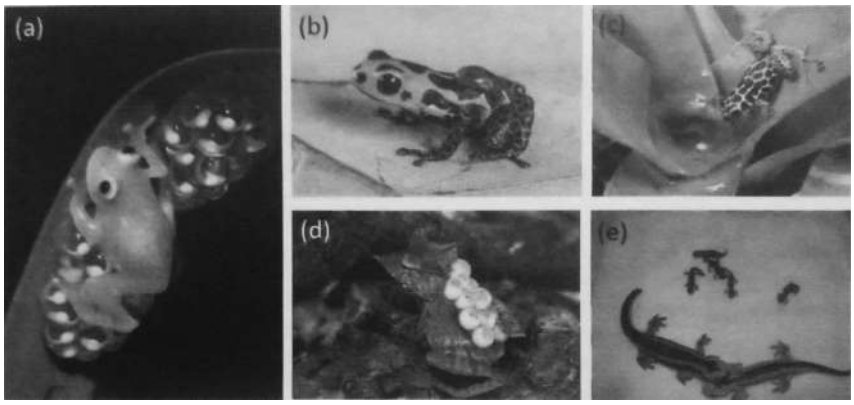

Fig. 6 Example of different forms of amphibian parental care. (a) attendance of eggs, (b) transport of tadpoles, (c) feeding to tadpoles, (d) brooding of eggs, (e) viviparity, or live-birth

- The female west African tree-frog, *Hylatobates breviceps* bears the eggs in her mouth.
- In Australian frog *Rheobatrachus silus* eggs are kept inside the stomach and the tadpoles, following completion of development, expelled through mouth.
- The female *Plethodon* (urodelan amphibia) deposits eggs in small packages (about 5) bencath the stones or in hollow of rotten log. The mother protects them coiling around. But in *Megalobatrachus maximus* the male coils the eggs.
- Caecilian *Ichthyophis* and *Hypogeophis* deposit eggs in burrows in moist soil and coil round the eggs until tadpoles are released.
- The small East African toads, *Pseudophryne vivipara* and *Nectophryne tornieri* are known to be vivparous but not yet confirmed and the Caecilian amphibians viz. *Typholnectes, Geotrypetes, Schistometopum* and *Gymnopis*

are ovoviviparous. Thereby, they have shown the strategy how to aviod the risk or uncertainty of loss of eggs or larval stage.

- In *Salamandra atra* and *S. maculosa* a clear case of viviparity is observed. Two eggs are laid in the uterine cavity at a time where entire development is completed. The larvae remain attached with the uterine wall by a membrane which physiologically acts like primitive placenta.

12.6 Conclusion

Amphibia being the first animal group to lead a terrestrial life, of couse, depends on water to perform various activities. Accordingly they have modified their body organization to a great extent to lead the life successfully in land as well as by developing remarkable strategies to ensure reproduction on way of adequate caring to the eggs and young ones by both the parents.

12.7 Summary

i) Aquatic, semiaquatic (freshwater) cold- blooded tetrapods, though some are limbless.

ii) Body is covered by naked, moist, glandular skin with pigments.

iii) 4-5 clawed toes.

iv) Median fins when present are without fin-rays.

v) Endoskelton mostly bony and skull with two occipital condyles.

vi) Heterodont teeth, protrusible tongue.

vii) Lungs, gills and skin and inner lining of the mouth cavity act as respiratory organs.

viii) Heart 3-chambered, 1-3 pairs of aortic arches. Hepatic portal and renal portal systems are well developed.

ix) Mesonephric kidney and large urinary bladder opens into cloaca, uricotelic.

x) Brain is located inside the cranium, ten pairs of cranial nerves.

xi) Middle ear with a single rod-like ossicle, the columella.

xii) Unisexual, no copulatory organ in male.

xiii) Mostly fertilization is external and females are oviparous.

xiv) Indirect development, larva or tadpole metamorphoses into adult.

xv) Highly adapted to prevent the loss of body water. Most skin as well as lungs help in respiration in land. Nitrogenous wastes are urea and uric acid as they need minimum water to be dissolved.

xvi) To ensure external fertilization both male and female depend on water body.

xvii) Various stategies have been developed to deposit eggs and/or to look after the young ones. Thus parental care is highly developed.

12.8 Glossary

Amphibia : Animals that spend part of their lives in water and part on land.

Cold-blooded : Animals whose body temperature varies with that of enviornment.

Tetrapod : Four-footed animals.

Cranial nerves : Nerves that emerge directly from the brain.

Oviparous : Animals produce eggs or egg-laying animals.

Adaptation : The evolutionary process whereby an organism becomes better able to live in its habitats by structural and physiological modification.

Parental care : A behavioural and evolutionary strategy adopted by some animals, involving a parental investment being made to the evolutionary fitness of offspring.

Anura : Living order of class Amphibia characterised by short and broad body with larger hind limbs than fore limbs e.g. Toad, Frog, ect.

Urodela : Living order of class Amphibia characterised by lizard like body with equally developed both the limbs. e.g. Salamander.

Apoda : Living order of class Amphibia characterised by eel-like body with no limbs. e.g. Ichthyophis.

12.9 Questions

1. What do you mean by tetrapods. Explain why animals belong to the class Amphibia are called tetrapods. What are the respiratory organs of Amphibians?
2. Mention any six salient features of the class Amphibia. Mention one similarity and one dissimilarity between a fish and a tadpole.

3. Discuss the adaptations in Amphibia to lead a terrestrial life.
4. How many cranial nerves and occipital condyles are there in an animal belongs to the class Amphibia? How many chambers are there in an amphibian heart? State the characteristics of middle ear in amphian animal.
5. Define parental care. Give an account of different types of parental care in Amphibia studied by you.
6. Write notes on :

   (a) Cloaca (b) poikilotherm (c) Parental care in *Autodax* (urodela), (d) Foam nest.

12.10 Suggested readings

1. T. J. Parker and W. A. Haswell (1985). Textbook of Zoology, Verteblate. Vol. 2. The Macmillan Press Ltd. London
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5. K. K. Chaki, G. Kundu and S. Sarkar (2008). NCBA, Kolkata.

Unit 13 ❑ Amniotes : Origin of Reptiles, Terrestrial Adaptation in Reptiles

Structure

13.1 Objectives

By studying this unit, students will be able to gain an idea about amniote animals and to study on the origin of Reptiles as well as to know the adaptive characters of reptiles in respect to lead a terrestrial life.

13.2 Introduction

Emergence of reptiles is a landmark in vertebrate evolution. Because, to lead absolutely a terrestrial life these animals had to develop the system to maintain their life on the land ecosystem as well as to ensure the protection of their embryos from any kind of adverse effect.

13.3 Amniotes

Amnitoes (from Greek *amnion*, "membrane surrounding the fetus") are a clade of tetrapod vertebrates—the reptiles, birds and mammals. As the embryo needs

water or fluid medium to grow as was the cases noted in fishes and amphibians, the amniotic animals have developed the device to retain water/fluid within a sac which is bounded by the membrane called amnion which encloses the embryo. Therefore, the term 'amniote' is applied to recognize these animals. But, amnion membrane is covered by allantois membrane which is covered by chorion membrane (Fig: 1). Thus, these three extra embryonic membranes protect the embryo. But, in cases of reptiles, birds and some egg-laying mammals the egg is further protected by a strong outer covering- the shell which may be soft, leathery or hard.

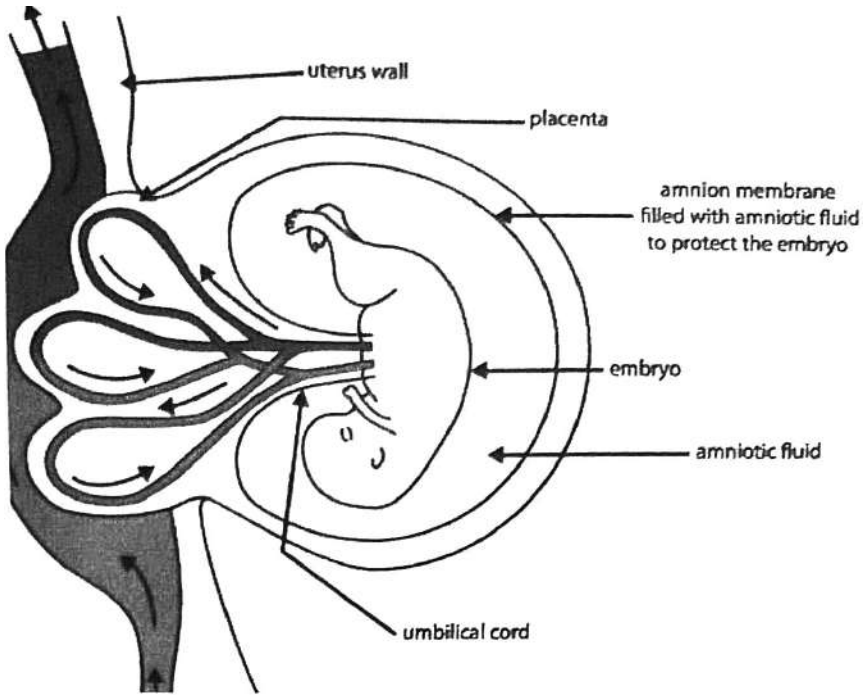

Fig. 1 Amnion membrane

13.4 Origin of reptiles

Reptiles originated from amphibians in the swamps of th Carboniferous period, about 320-310 million years ago. The labyrinthodont amphibians (Fig: 2) were the source of reptilian evolution.

The cotylosaurs (Fig: 3) were the earliest group of true reptiles. The first evolved reptile *Seymouria* (Fig: 4) was lizard-like animal with pentadactyle limbs and a short

tail, homodont labyrinthine teeth on the jaw bones as well as on vomer and palatine bones. Also presence of lateral line justifying its amphibian habit. Being monocondylic

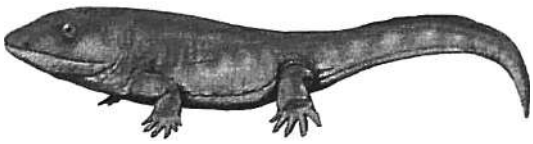

Fig. 2 *Labyrinthodontia*

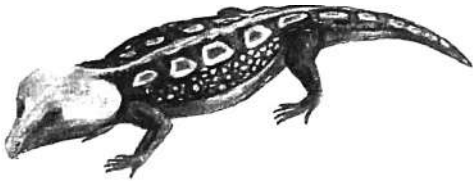

Fig. 3 *Cotylosaurs*

Fig. 4 *Seymouria*

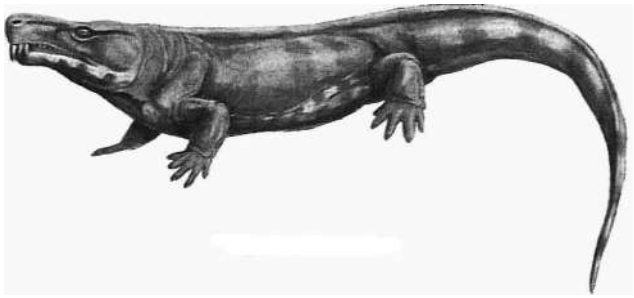

Fig. 5 *Limnoscelis*

it had no problem to move its head. Thus *Seymouria* indicates gradual transition from labyrinthodont amphibians to reptiles. Also the fossil *Limnoscelis* (Fig: 5), a captorhinomorph cotylosaur, found in Mexico supports the above view because of presence of large premaxillary teeth and long tail in its body.

However, there exists dispute regarding *Seymouria* origin of reptiles. Becasue, records suggest that, there were some other reptilian organism, probably for 50 millon years, while *Seymouria* started roaming on the earth in Pre-Permian period i.e. after carboniferous period. As *Seymouria* exhibited both amphibian and reptilian features the same was considered as a perfect intermediate form between amphibia and reptilia. Thus the true taoxonomic position of the said organism remained uncertain. But later on Romer considered it as a reptile under the order Cotylosauria while others clasified it as an Amphibia under the order Seymouriamorpha. Under such a situation *Seymouria* is considered as a connecting link between Labyrinthodontia and Cotylosauria.

Limnoscelis was a genuine reptile. Becasue Romer (1946) following critical studies suggested that *Limnoscelis* is the primitive reptile. Like *Seymouria* it was aquatic in habit, with anapsid skull compressed from side to side and dorsoventrally

flattened. The otic notch disappeared. Premaxillary teeth were elongated and overhung the front teeth in the lower jaw.

Diadectes (Fig: 6) was contemporary to *Limnoscelis* but had a different evolutionary line. It retains the otic notch at the back of skull. The front teeth were

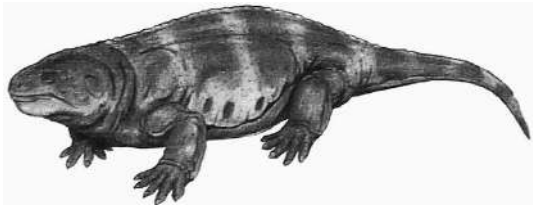

Fig. 6 *Diadeces*

Fig. 7 *Pareiasaurus*

chisel-shaped and back teeth had broad ridge crowns. The true large reptile the ***Pareiasaurus*** (Fig: 7) appeared in the late Permian had close relation to *Diadectes*. Spiny armour of bony plates along back, spiny excrescences on the head developed in this group perhaps to protect them from predators.

13.5 Terrestrial adaptations of reptiles

To ensure a successful terrestrial life reptiles have exhibited the following adaptations:

1. **Modification of skin :** In reptiles the skin is dry and cornified. It contains keratin, a water resistant substance. This protects them from dehydration. Also they have developed scales which help to protect the skin from any kind of damage. However, in turtles the scales fused to form a shell. This kind of skin have enabled reptiles to go to the water body in search of resources or to spent a substantial part of life in water; on way of engulfing air, they come to the surface water off and on.
2. **Limbs and their modification :** Though reptiles belonged to tetrapoda (having four limbs) many lizards and snakes are limbless. Limbs help them not only to move on the land but also to protect them from the attack of enemies. Because, these limbs are provided with strong and pointed claws

that act as weapons. Moreover, such type of limbs are effective to capture the prey as many of them are carnivorous.

3. **Camouflaging :** Certain reptiles especially the lizards have developed camouflaging nature to protect them from the enemies as well as to ensure trapping the prey animals. Besides, certain snake species have also developed the art of death feining strategy to capture the prey.
4. **For aerial respiration :** Instead of many respiratory devices as were exhibited by amphibians reptiles have developed the mechanism to depend absolutely on lung by exhanging air in the terrestrial envionment.
5. **Basking :** Being cold-blooded reptiles body temperature depends on thier surrounding enviornment. But they need required body temperature to make them effective to capture the prey animals. Therefore, they bask on rocks or on any other suitable platform to warm the blood.
6. **Water conservation :** In land access to drinking water is limited. Therefore, kidneys in reptile have adapted to produce less urine in a concentrated form with a view to conserve water in the body. The final excretory product is a chalky white mass of urates and it is almost dry due to reabsorption of water by cloaca.
7. **To ensure reproductive success :** Reptiles lay eggs on the land which are subjected to dessication and thereby unusual mortality of eggs could not be ruled out. To protect the eggs rather embryo they have developed a protective covering—the shell. It may be soft, leathery or hard. Even having the shell covering they are careful in selecting the nesting site in moist areas to save the eggs from dessication. Also some of them did not rely on these sorts of protection of the eggs and thus, they (especially the snakes) adapted for ovoviviparity where eggs are retained inside the body to hatch internally and the babies are released from the body in due time.

13.6 Conclusion

Vertebrates like reptiles, birds and mammals bear a membrane to protect the embryo in a fluid-filled medium. The said membrane is known as amnion membrane. Reptiles have evoled from the labyrinthodont amphibians. After emergence reptiles

have undergone through a number of adaptive changes by modifying the armature of skin, limbs, body colouration, respiratory organs, basking, water conservation and egg-laying process to ensure reproductive success and survival.

13.7 Summary

i) In amniotes embryo remains protected by the three membranes viz. amnion, chorion and allantois.

ii) Reptiles originated during late Carboniferous period from the labyrinthodont amphibians.

iii) The cotylosaurs were the first group of true reptiles.

iv) The first evolved reptile *Seymouria* was a lizard-like animal with homodont labyrinth teeth.

v) According to some authority *Limnoscelis* was a genuine reptile while *Seymouria* is a connecting link between Labyrinthodontia and Cotylosauria.

vi) The skin is keratinized to resist body dehydration.

vii) Being tetrapod many reptiles are limbless while in others limbs are provided with strong and pointed claws.

viii) Exclusively respires through lungs.

ix) They have developed the art of basking to adjust themselves with the surroundings.

x) Release concentrated urine with a view to conserve body water.

xi) To save eggs from dessication under land environment they have developed the art of deposition of eggs with shell covering.

13.8 Glossary

Amniotes : A clade of tetrapod vertebrates comprising the reptiles, birds and mammals which developed amnion to protect the embryo.

Labyrinthodont : A group of amphibian animals from which reptiles have evolved.

Pareiasaurus : The true large reptile which emerged in the late Permian.

Skin of reptiles : Dry and cornified.

Camouflage: A strategy to hide oneself in its surroundings.

Basking : To lie in or be exposed to pleasant warmth (especially to the sushine).

13.9 Questions

1. What are amniotes? Name two other membranes which are found covering the amnion membrane. What is labyrinthodont?
2. Write in brief the origin of reptiles.
3. Mention any two kinds of adaptation in reptiles to lead a terrestrial life. Add a note on *Limnoscelis*.
4. Describe in brief the terrestrial adaptations in reptiles.
5. Write notes on :

   (a) Basking; (b) Camouflaging; (c) Diadectes; (d) Seymouria.

13.10 Suggested readings

1. T. J. Parker and W. A. Haswell (1985). Textbook of Zoology, Verteblate. Vol. 2. The Macmillan Press Ltd. London
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Unit 14 ❑ Aves : The Origin of Birds, Flight Adaptations

Structure

14.1 Objectives

By studying the unit students will be able to gain knowledge on birds in respect to their origin and adaptation for flight.

14.2 Introduction

The class Aves represents the birds. A bird is characterized with spindle shaped body having four distinct regions viz. head, neck, trunk and tail. Forelimbs modified for flying, feathers (the unique feature of birds) covering the body are of various types and the legs with scales.

14.3 Origin of birds

Birds orginated from reptiles. But from which group of reptiles is an open question. On the basis of available evidences and information it is nowadays consensus that birds are a group of maniraptoran theropod dinosaurs that originated during Mesozoic era.

Maniraptora is a clade of coelurosaurian dinosaurs which includes the birds and the non-avian dinosaurs. They were very close to each other Maniraptorans (*Deinonychus, Archaeopteryx, Patagonykus, and Erliansaurus*) first appeared in the fossil record during the Jurassic period and are regarded as ancestral to living birds.

The hunt for the ancestors of living birds began with a specimen of *Archaeopteryx* (Fig: 1), the first known bird, discovered in early 1860's. It had feathers along the arms and tail just like birds but unlike living birds it had teeth and a long bony tail. Furthermore, many of the bones in *Archaeopteryx's* fore-arms, shoulder girdles, pelvis and feet were distinct i.e. not fused and are also not reduced as they are seen in modern birds. Based on these features *Archaeopteryx* was recognized as an intermediate form between birds and reptiles, but which reptiles?

Fig. 1 *Archaeopteryx*

Today there are 8 preserved fossils of *Archaeopteryx* in various museums of the world. But the amazing aspect of *Archaeopteryx* lies with its superficial resemblances both a bird and a reptile. But as a fact, except for the feathers and the bird-like feet, the presence of a wishbone (furcula) its real appearance as bird is questionable. Moreover, teeth in jaws and the ankle bone fused to the shinbone confirmed the presence of dinosaur's and bird's features in *Archaeopteryx*. So, question still in the air—from where did birds evolve?

Thus, three hypotheses on the origin of bird were proposed.

1. Theropod dinosaur hypothesis : This hypothesis (first one) advocated that theropods were meat eating dinosaurs such as Allosaurus and the birds were evolved from them.
2. Crocodiles hypothesis : According to this hypothesis because of presence of an endolymphatic duct which is present in crocodiles, the birds were emerged from crocodiles. But further research suggested that, there exists tremendous amount of variation in the duct even among the lizards and other reptiles. Therefore, nowadays, no much attention is given to this hypothesis.
3. Neither crocodiles or dinosaurs hypothesis.

   As several dinosaurs were very much specialized, the possibility of origin of bird form the crocodile line or dinosaur line is confusing.

Today it is clear that birds are related to dinosaurs in many ways. But using key characters we can use cladistics to understand the better relationships. For instance, we can look at the feathers they share in common with animals such as reptiles and ancient dinosaurs in order to figure out where they may have evolved. They can thus, be linked generally to *Ornithodira* and more specifically to *Maniraptorans*. In a cladogram of diapsids which include snakes, lizards, crocodiles (archosaurs) and dinosaurs and birds it seems to be easier to get a better picture as to where birds fit in.

Dinosaur cladogram : Looking in particular at the Ornithodira, Dinosaurs, Saurischian dinosaurs, Theropods tetanurae, Coelurosaurs and others we can get the following facts.

Ornithodira : Advanced mtatarsal angie.

Dinosauria : 3+ sacral vertebrae, reduced fibula.

Ornithischia : 5+ sacral vertebrae, opisthopubic pelvis, pre-dentary bone in lower jaw.

Sauropodomorpha : 10+ sacral vertebrae, ankles have an ascending process.

Theropoda : Elongate narrow metatarsus, hollow bones, metatarsal 5 reduced.

Tetanurae : 'Allosaurus etc.' tooth row (upper) does not extend back beyond the orbit also, with an antorbital fanestra.

Maniraptora : With a semi-opisthopedic pelvis, this indicates that the pubis bone of the pelvis is rotating backwards and has a foot. It is regarded as feathered dinosaurs.

Avialae : Presence of feathers.

Summarization of the set of derived characters that link them to Dinosaurs.

- Pelvis
- Clavicles
- Wrist

Once the idea that birds came from dinosaurs, then there was scurry

➔ To find fossil evidence that could link birds back to their dino-roots.

➔ Several different dino-birds, fossils were discovered in the last century. One was Caudipteryx.

Caudipteryx : It was a dinosaur-like fossil but had feathers. However, the wings were to small to allow them to fly. But presence of wing was a significant character.

Microraptor : It had four wings and possessed long feathers on both it arms and legs but was closely related to dinosaurs and birds; it was very small and appeared to be arboreal. This tiny fossil was about to fly. But presence of wing was a significant character. This tiny fossil was about 10 cm long. If it lived in the trees could have glided from tree to tree.

Thus, it is most likely that birds originated from dinosaurs through Archaeopteryx which were not only with the feathers or wings but also have the gliding ability from tree to tree—an attempt to ensure flying in the air. From the following Fig : 2 the possible pathway of the origin of bird could be visualized at a glance. Thus birds are often called "glorified reptiles".

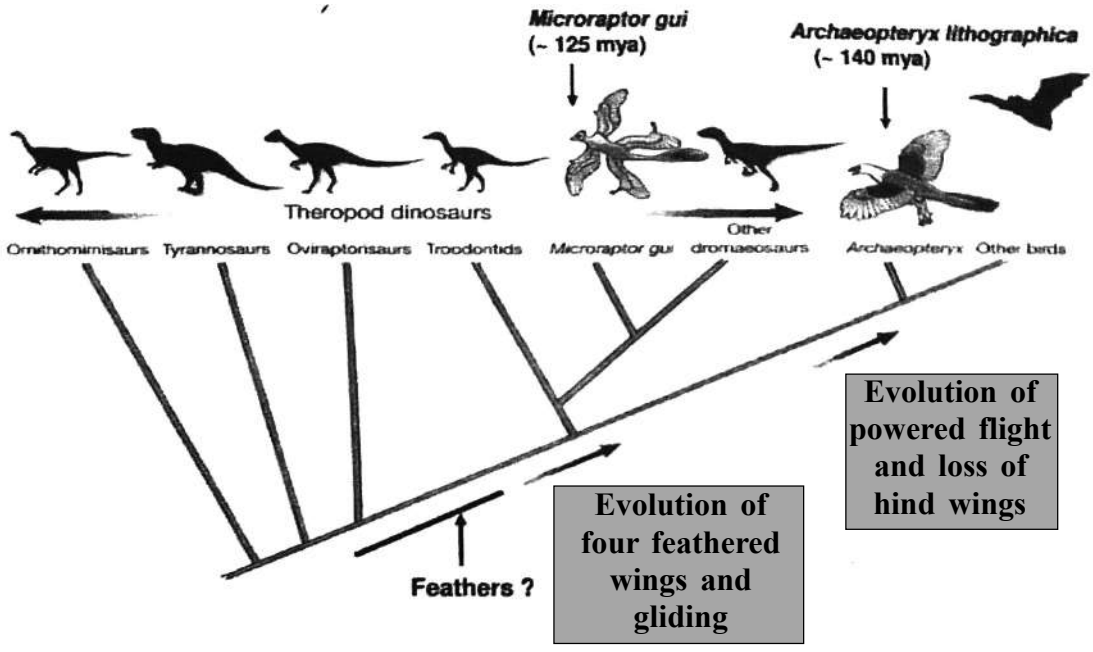

Fig. 2 Origin of birds within Theropod dinosaurs by Prum, 2003

14.4 Flight adaptation

Birds are efficient flyers. To gain the said ability they exhibit a number of adaptive features both externally and internally of their body configuration. Such adaptations are as follows.

1. Body shape stream-lined. This helps birds to reduce air resistance.
2. Feathers—the exoskelton are developed to protect the body from a number of environmental factors especially the water. This is why they can fly in rains also. Flight feathers are effective in generating both thrust and lift and thereby enabling the birds to fly. It also increases the surface area of the wings.
3. Modifications of fore-limbs into wings : The fore-limbs are transferred into potential propelling organs, the wings. The feathers of the wings form a broad surface for striking the air. The flight feathers of the wing also form a broad surface for supporting the bird in the air. The wings of the bird are not flat but are concave below and convex above. The air that passes over the top of the wing and below the wing regulates the speed for flying and pressure to drop. This acts effective sucks the wings up.
4. Tail feathers : Tail feathers form a steering apparatus. They are used jointly as a radder and help in balance and twisting and turning during flight. Also, they act as a brake for landing.
5. They have acute vision. This enables birds to flight to distant places safely.
6. Well developed flight muscles. Pectoralis major is the breast muscle that powers the upstroke for flight. Pectoralis minor muscle is found just beneath the pectoralis major. The action of the muscle is stabilization, depression, abduction or protraction, upward tilt and downward rotation of the spcapula.
7. Long bones are pneumatic having air cavities, skull bones are thin and papery. These make the bird's skeleton light.
8. No gall bladder, no urinary bladder and the rectum is reduced to a great because of minimum undigested waste. Therefore, birds adapted in an efficient way to reduce the body weight to be the good flyers.

9. The lungs are highly adapted to supply required energy to maintain flying for a long time. There is a great interconnection with the organs which generates the required energy. In birds development of thin-walled bladder-like air-sacs is unique and the major air-sacs directly originate from lungs. The air that is taken in passes to the air sacs on the posterior side then reaches the lungs. Birds lack alveoli, instead many small sacs called parabronchia are present that are connected to the capillaries.
10. In most of the female birds liver is pushed towards right side in order to balance the weight of the body.
11. Ovaries and tests are reduced in size to a great extent and in some birds only one ovary i.e. left one is functional. Right oviduct is vestigial in many birds.
12. Birds can rotate their heads to 180° for a wide range of vision all around.

14.5 Conclusion

Class Aves represents different kinds of birds. Birds originated from reptiles. Though controversy exists it is assumed that the birds are a group of maniraptoran therepod dinosaurs that originated during Mesozoic Era. The first fossil bird *Archaeopteryx* discovered in early 1860's provided the key to trace the origin of modern birds. Birds are efficient flyers. To enable them to be the efficient flyers, they have shaped their body stream-lined, developod wings and feathers with effective flight muscles, to develop pneumatic bones, air sacs, reduction or abolition of certain organs to make the body light.

14.6 Summary

i) Aves is class which represents all kinds of birds.
ii) It is assumed that the birds evolved from the maniraptoran therepod dinosaur during Mesozoic era.
iii) The fossil records of Archaeopteryx and some other maniraptorans enable the scientists to trace the origin of birds.

iv) Finally, the theories (a) the theropod dinosaur hypothesis (b) crocodiles hypothesis and (c) neither crocodile nor dinosaurs hypothesis are now considered unncessary for discussion on origin of birds.

v) Dinosaur cladogram revealed the progresive evolutionary path of birds.

vi) To be an efficient flier birds have not only change the shape of their body but also modified the fore-limits into wings. They have developed feather and strong muscles for flying in the air at length. The bones are filled with air, the air-sacs contain adequate oxygen and the organs in some cases converted or deleted to make the body lighter.

14.7 Glossary

Maniraptora : Maniraptora is a clade coelurosaurian dinosaurs which includes the birds and the non-avian dinosaurs.

Archaeopteryx : A fossil of the first bird specimen discovered in eary 1860's.

Ornithodira : Advance metatarsal angle.

Tail feathers : Streering apparatus of birds.

Air-sacs : Extension of a bird's lung cavity into a bone or other parts of the body.

Pneumatic bone : Bones contain air inside.

14.8 Questions

1. State any two characteristic features of Aves. *Archaeopteryx* was a bird—explain why?
2. Give a schematic representation of the origin of birds.
3. Explain the hypotheses proposed on the origin of birds. Add a note on Maniraptorans.
4. Discuss the dinosaur cladogram to trace the origin of birds.
5. Give an account of the flight adaptations in birds.
6. Mention the organs in birds which ensure flight adaptations. State the functions of tail feathers in birds.
7. Write notes on :

   (a) Microraptor (b) Air-sacs (c) Flight muscles (d) Ornithischia

14.9 Suggested readings

1. T. J. Parker and W. A. Haswell (1985). Textbook of Zoology, Verteblate. Vol. 2. The Macmillan Press Ltd. London
2. K. C. Ghose and B. Manna (2011). A Textbook of Zoology, New Central Book Agency, Kolkata.
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Unit 15 ❑ Mammalia : Early Evolution of Mammals; Primates; Dentition in Mammals

Structure

15.1 Objectives

By studying this unit students will be able to gain knowledge on the early evolution of mammals and the primate gruop of mammals. To have an idea regarding dentition in mammals.

15.2 Introduction

Mammals are recognised on the basis of four main characteristic features viz. presence of mammary glands, presence of hair, presence of external pinna and the three bones in the middle ear.

15.3 Early evolution of mammals

Mammals evolved from a group of reptiles called synapsids. These reptiles arose during the Pennsylvanian sub period (310-275 million years ago) of the late Carboniferous period. By the mid-Triassic many mammal-looking synastids were

came into the existence. The lineage leading to present day's mammals split up in the Jurassic period. Thus *Dryolestes,* the advanced form of synapsids emerged. *Dryolestes* exhibit a close relation with the extant placemental and marsupials than to monotremes. With the progress of time eutherian and metatherian lineages separated. Metatherians are closely related to the marsupials and the eutherians have close affinity to the placentals.

Paleogene extinction event occurred at the end of Cretaceous period when non-avian dinosaurs were completely disappeared and mammalian groups—placental and marsupials were diversified into various new forms occupying different ecological niches throughout the Paleogene and Neogene. The modern orders of mammals appeared by the end of these events.

Mammals are the only living synapsid. They have undergone various changes during Permian and Triassic periods. They were carnivores and herbivores. But a group of sauropsids, the archosours, became then dominant. At this time the mammaliaforms appeared. They had superior sense of smell, backed up by a large brain enabled them to get access into suitable nocturnal niches to aviod exposure to archosaur predation. This sort of adaptive behaviour may have contributed greatly to the development of mammalian traits such as endothermy and hair. Later, in the Mesozoic with the disappearance of Rauisuchians (a group of mostly large triassic Archosaurs), the dominant carnivores, mammals spread to other niches even to the water body.

Earliest crown mammals : The crown groups of mammals or the "true mammals" are the extant mammals and their relatives back to their last common ancestors. The family tree of early crown mammals could be revealed from the following cladogram (Luo, 2007) :

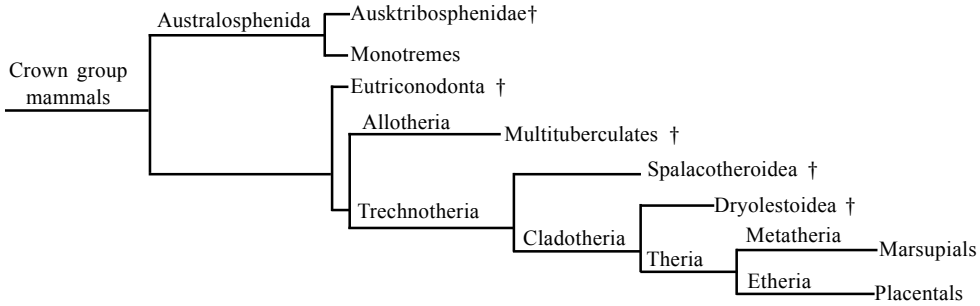


Fig : Cladogram after Z.–X Luo (2007); (+= Extinct)

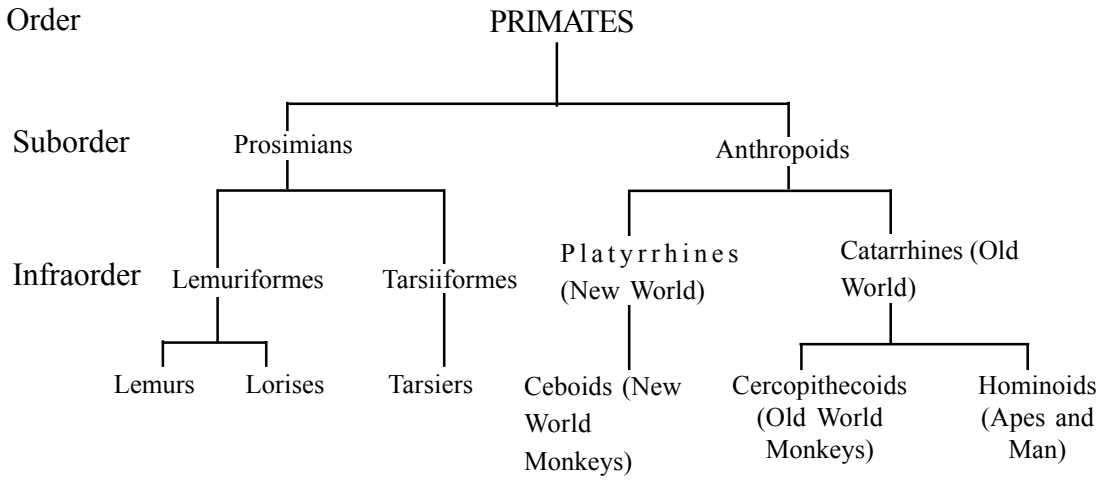
15.4 Primates

Primates are a group of eutherian mammals confined to the order Primates. They emerged 85-55 million years ago from small terrestrial mammals who were adapted to live in trees of tropical forest.

The characteristic features of primates are :

1. **Prehensile hands and feet :** Almost all living primates have prehensile hands and feet and most have five digits on their appendages, including opposable thumbs.
2. **Shoulders and hips :** Flexible and rotating shoulder and hip joints.
3. **Brain :** The olfactory region is reduced to a great extent in most species (in humans also), the cerebrum is expanded with a view to develop increasing reliance on sight and stereoscopic vision with colour vision along with binocular vision.
4. **Nail and claw :** Each digit has a flat nail instead of a claw.
5. Possess a clavicle or collar bone.
6. Exhibit the tendency to be erect. This trait is visible when even quadrupedal primates sit or stand. Also a good number of species sometimes exhibit bipedalism or standing on hind legs like humans.

All primates exhibit adaptations for climbing trees and have evolved into two main groups and subsequently into some sub-groups.



● **Prosimians :** Prosimians are primitive primates. All living and extinct strepsirrhines (lemurs, lorisoids and adapiforms) as well as the haplorhine tarsiers and their extinct relatives, the omomyiforms i.e. all primates excluding the simians are prosimians. They exhibit more privitive or ancentral characters in respect to simian group. Thus, lemurs, lorises and tarsiers are the example of prosimians *Lemur* (Fig: 1) are mostly found in Madagascar and neghbouring islands. They mostly live in trees and are active mostly in night. *Loris* (Fig: 2) are nocturnal and arboreal.

Fig. 1 *Lemur*

Fig. 2 *Loris*

They are found in propical and woodland forests of India, Sri Lanka and part of South-east Asia. *Tarsiers* (Fig: 3) are small leaping primates found only in the islands of South-east Asia, including the Philippines. They are intermediate form (about 9-16 cm in length excepting the tail) between lemurs and monkeys. They are nocturnal and are with well developed sense of smell. But like monkeys and apes and humans they have a nose that is dry and hair covered. The eyes and placenta are also simiiform in structures.

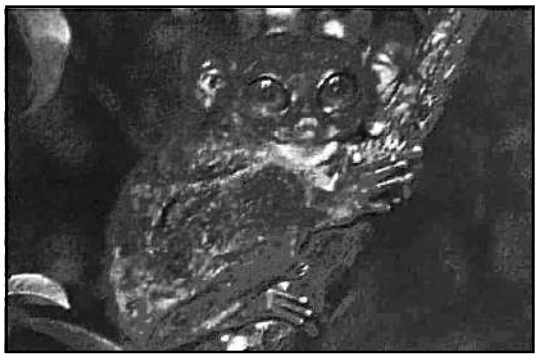


Fig. 3 *Tarsiers*

Fig. 4 *Spider Monkey*

● **Anthropoids (Smimians) :** Simians or Anthropoids or higher primates are familiar to us as the old world monkeys and apes, including humans—as Catarrhines

and the new world monkeys or Platyrrhines. Simians are usually larger than Prosomians. Ceboids the new world monkeys believed to have evolved from prosimians isolated in South America. Examples : Marmosest, Capuchins, Tamarins and Spider Monkeys (Fig: 4)

The Catarrhines or the old world anthropoids are the sister group to new world monkeys categorized into two groups vis. Cercopithecidae and Hominidae.

- **Cercopithecidae :** Is a family of primates which is represented by old world monkeys. It is the largest primate family and includes. The langurs, the baboons (Fig: 5) and macaques.

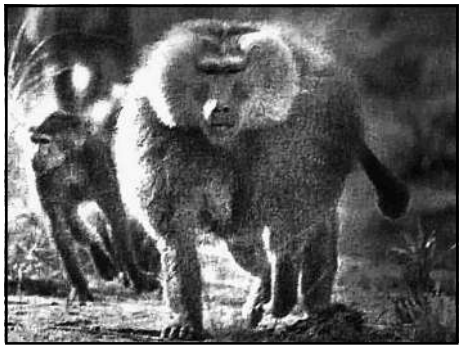


Fig. 5 *Baboon*

- **Hominoids :** Are the members of the primate family hominoidae which includes apes and man. Men and apes had common ancestor. Apes are capable of communi-cation by vocal means. Gibbon, Orang-utang Chimpanzee and Gorilla are examples of apes.

- **Gibbons** (*Hylobates*) (Fig: 6) **:** Are most gentle smallest (90-95 cm in height and 15-25 lbs in weight) and cleanest apes with remarkable vocal power. Gibbons belong to the family hylobatidae. They are distributed into 18 species under 4 extant genera. They live in tropical and sub tropical rain forests from eastern Bangladesh to Northeast India to southern China and Indonesia. They are the only apes which can walk errect.

Fig. 6 *Gibbon*

Fig. 7 *Orang-utang*

- **Orang-utangs** (Fig: 7) **:** Are great apes (135 cm in height and about 150 lbs in weight). They are distributed into 3 extant species. Being natives of Indonesia and

Malayesia they are now found in the rainforests of Borneo and Sumatra. They are very intelligent and are habituated to use different kinds of sophiisticated tools and construct eleborate sleeping nests in the tree. The learning ability of Orang-utang is very high.

● **Cimpanzee** (Fig: 8) **:** Also known as chimp is a type of great ape which is confined to the forest and savanah of tropical Africa. Chimps are highly intelligent and are closest relatives of men.

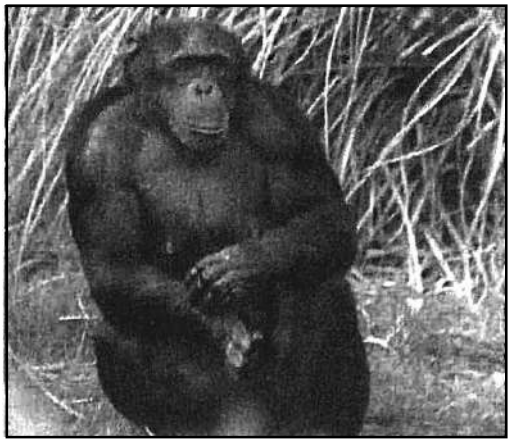


Fig. 8 *Chimpanzee*

Fig. 9 *Gorilla*

● **Gorilla** (Fig: 9) **:** Is ground—dwelling predominantly herbivorous ape inhabits the forest of central and sub Saharan Africa. There are two speices of the genus *Gorilla*. These species again subdivided into 4-5 sub species. It is the largest living primate. Apes, irrespective of the types exhibit a social bonding through the development of a social culture.

● **Man** (*Homo sapiens*) (Fig: 10) **:** *Homo sapiens* are the dominant primate group of the world. They are most intelligent, social and cultural entities of the world. The facial gestures are quit good-looking. They are well-adapted to a bipedal mode of walking. They have opposable thumbs. The most significant is that they have a language and speech.

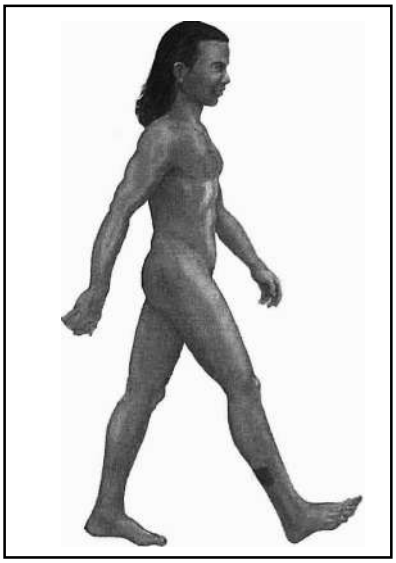


Fig. 10 *Homo sapiens*

15.5 Dentition in mammals

The arrangement of teeth in the upper and lower jaws, specifically on premaxilla, maxilla and dentary bones is called dentition (Fig: 11).

Teeth are present in mammals though a secondary toothless condition is found in some mammals. In some monotremes like echidna—the spiny ant-eaters teeth are completely absent. In Platypus embryonic teeth are replaced in the adult by horny epidermal plates but no true teeth are present. The great ant eater of South America (*Myrmecophaga*-an edenttate) also lacks teeth. The whale-bone whale and many edentates lack teeth in the adult condition. In mammals, morphologically teeth may be of two types.

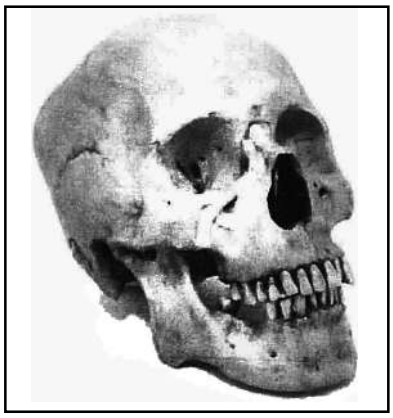


Fig. 11 Denitition of man

1. **Homodont :** All teeth are similar in shape. This type of teeth are found only in certain cetaceans. But in toothed whales, dolphins, porpoises and armadillos, teeth become secondary uniform as homodont.
2. **Heterodont :** Characteristically mammalian teeth are heterodont. That is, the teeth are dissimilar in shape, size and functions. Heterodont dentition commonly includes four kinds of teeth viz, incisors, canines, premolars and molars. Incisors help in nipping, canines perform the functions of grasping the prey and tearing the food, pre-molar and molars help in grinding and shearing the food with the help of tooth row in both upper and lower jaws.

Depending upon the number of cusps the teeth are four types. Cusp is a pointed projection or elevated feature. In mammals it is usually refer to as raised points on the crown of the teeth.

(a) **Monocuspid :** One cusp is present. e.g. canine tooth
(b) **Bicuspid :** Two curps are present. e.g. premolar teeth in human
(c) **Tricuspid :** Three cusps are present. e.g. molar teeth
(d) **Polycuspid :** More than three cusps are present. e.g. molar teeth

On the basis of the shape of the cusps the cheek teeth are of following types :

(a) **Bunodont :** The cusps in the check teeth remain separate and rounded. That is many cusps in the teeth. This type of teeth are found in man and also in some carnivorous mammals. The function of these teeth is to grind food.

(b) **Lophodont :** In this case the cusps are joined to form ridges or lophs. This type of teeth are found in elephants. These teeth are used to grind all sorts of plants and also grasses.

(c) **Secodont :** In this type the cheek teeth are with sharp cutting crowns. This kind of teeth are found in land carnivores. These teeth help in cutting and shearing the flesh.

(d) **Selenodont :** Cheek teeth with crescent-shaped cusps are known as selenodont. These are found in runminants cattle, camel and horses. They help in grinding the plant matter.

(e) **Brachydont :** Tooth with a low crown and comparatively long root is termed as brachydont. This kind of teeth are found in man.

(f) **Hypsodont :** Here the crown is high but the root of the tooth is short and open. These type of teeth are found in horse and incisors of elephant are of this type.

Teeth have evolved from denticles which are released from armour near the margins of mouth as ossification in the integument.

A typical mammalian tooth can be distinguished mainly into two regions—crown and root. The crown is the exposed part of the tooth and situated above the root. The root is the hidden part in the gum which anchored in the socket or alveolus of the jaw bone. The tooth enclosed a pulp cavity that contains blood vessels, nerves and connective tissues.

The junction of the root and crown is called neck. In typical tooth there are three kinds of tissues—enamel, dentine and cement. The bulk of the tooth is formed by a hard calcium rich dentine. The dentine is covered by a coat of hard shiny enamel in the region of crown. The root of the tooth is covered by a thin layer of cement and a vascular periodental membrane.

According to the mode of attachment of teeth, thecodont type dentition is the rule among mammals. In this condition the teeth are lodged in bony sockets or alveoli of

the jaw bone and capillaries and nerves enter the pulp cavity through the open tips of the hollow roots.

According to the succession or replacement, the teeth of mammals can be grouped into monophyodont (when one set of teeth only develops in life time. e.g. Marsupials, squirrels etc.) and diphyodont (when milk teeth are replaced by permanent teeth. e.g. Man)

Dental formula in some mammals : Dental formula in mammals varies with the groups. In primitive eutherian mammal the formula is

$$I\frac{3}{3},\ C\frac{1}{1},\ Pm\frac{4}{4},\ m\frac{3}{3} = 22\times2=44$$

[I = Inisors, C = Canines, Pm = Pre-moatrs, m = molars]

In kangaroo (macropus) $\frac{3,1,2,4}{1,0,2,4}$ ——— = 34

In horse and pig : $\frac{3,1,4,3}{3,1,4,3} = 44$

in bat : $\frac{2,1,0,4}{3,1,0,5} = 32$

in cat : $\frac{3,1,3,1}{3,1,2,1} = \frac{8}{7} = 30$

In dog and bear : $\frac{3,1,4,2}{3,1,4,3} = \frac{10}{11} = 42$

In seals : $\frac{3,1,4,1}{2,1,4,1} = \frac{9}{8} = 34$

In rat : $\frac{1,0,0,3}{1,0,0,3} = 16$

In rabbit : $\frac{2,0,3,3}{2,0,2,3} = \frac{8}{7} = 30$

In man : $\frac{2,1,2,3}{2,1,2,3} = 34$ (Fig : 11)

15.6 Conclusion

Mammals evolved from a group of reptiles called synapsids. During mid-Triassic many mammal-looking synapsids came into the existence. However, the lineage leading to present day's mammals split up in the Jurassic period. Mammals being the only living synapsids have undergone various changes during Permian and Triassic periods. Cladogram suggests that from the crown group mammals Monotremes as well as eutherian mammals were evolved in due course of time. Primates are a group of eutherian mammals emerged 85-55 million years ago in the tropical forests. They are characterized by prehensile hands and feet, movable shoulders and hips, brain, nail instead of claws. In due course of time through successive evolutionary stages hominids (apes and man) appeared. Mammals may be homodont or heterodont. Also depending on the number of cusps the teeth may be monocuspid, bicuspid, tricuspid and polycuspid. Also on the basis of the shape of the cusps teeth are again divided into a number of groups. Usually incisors, canines, pre-molar and molars are found in mammals but the number of such teeth varies in groups or species. Thus, a dental formula for different species of mammals is well established.

15.7 Glossary

Synapsids : A group of reptiles from where mammals emerged.

Marsupials : Any member of the mammalian infraclass Marsupialia. The female members posses marsupium where immature young are developed.

Monotremata : Most primitve order of mammals characterized by certain reptilian features. They are egg-laying mammals.

Theria : A subclass of mammals which includes examples that give birth to live young without using a shelled egg.

Eutheria : One of the two mammalian clades with extant members that diverged in the early Cretaceous perhaps the late Jurassic. Mature youngs are born in these members.

Thecodont : The arrangement of teeth in which the base of the tooth is completely enclosed in a deep socket of bone.

Heterodont : Animal which possesses more than a single tooth morphology. In vertebrates especially in mammals there are incisors, canines, pre-molars and molars.

Bunodont : The cusp in the cheek teeth remain separate and rounded. That is many cusp in the teeth. Found in man and also in some carnivorous animals.

Prosimians : Primitive primates.

Hominids : Members of the primate family Hominidae which includes apes and man.

Paleogene : It includes Paleocene epoch, Eocene epoch and the Oligocene epoch.

Neogene : It includes Miocene and late Pliocene epoch.

15.8 Summary

i) Mammals are identified on the basis of the presence of hair, mammary gland and the three bones in the middle ear.

ii) Mammals evolved from a group of reptiles called synapsids.

iii) *Dryolestes* exhibit a close relation with the extant placemental and marsupials than to monotremes.

iv) Mammals are the only living synapsids. They have undergone various changes during Permian and Triassic periods.

v) Eutherian mammals are placemental mammals.

vi) Primates have prehensile hands and feet.

vii) Lemurs, lorises and tarsiers are prosimian primates.

viii) Monkey, apes and man are simian primates.

ix) Gorilla is the largest living primate.

x) Of the primates man has a language and speech.

xi) Various types of teeth are found in mammals.

xii) Dental formula in mammals varies with the groups.

15.9 Questions

1. How could you identity an animal as a mammal? In which geological period and from which group of reptiles mammals were evolved? What is *Dryolestes*?

2. Present the cladogam as per Luo (2017) showing the family tree of early crown mammals.
3. State the characteristic features of Primates with examples.
4. Distinguish between prosimians and simians with examples.
5. What are hominids? Give an account of hominids with examples.
6. Mention the salient features of Homo sapiens. What do you mean by homodont and heterodont? Write down the dental formula of (a) pig and (b) man.
7. Give a comparative account of lemurs, lorises and tarsiers. Add a note on gibbon.
8. Write notes on :

   (a) Metatherian mammals; (b) Monotremes; (c) Brain of primates; (d) Chimpanzee.

15.10 Suggested readings

1. T. J. Parker and W. A. Haswell (1985). Textbook of Zoology, Verteblate. Vol. 2. The Macmillan Press Ltd. London
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NOTES