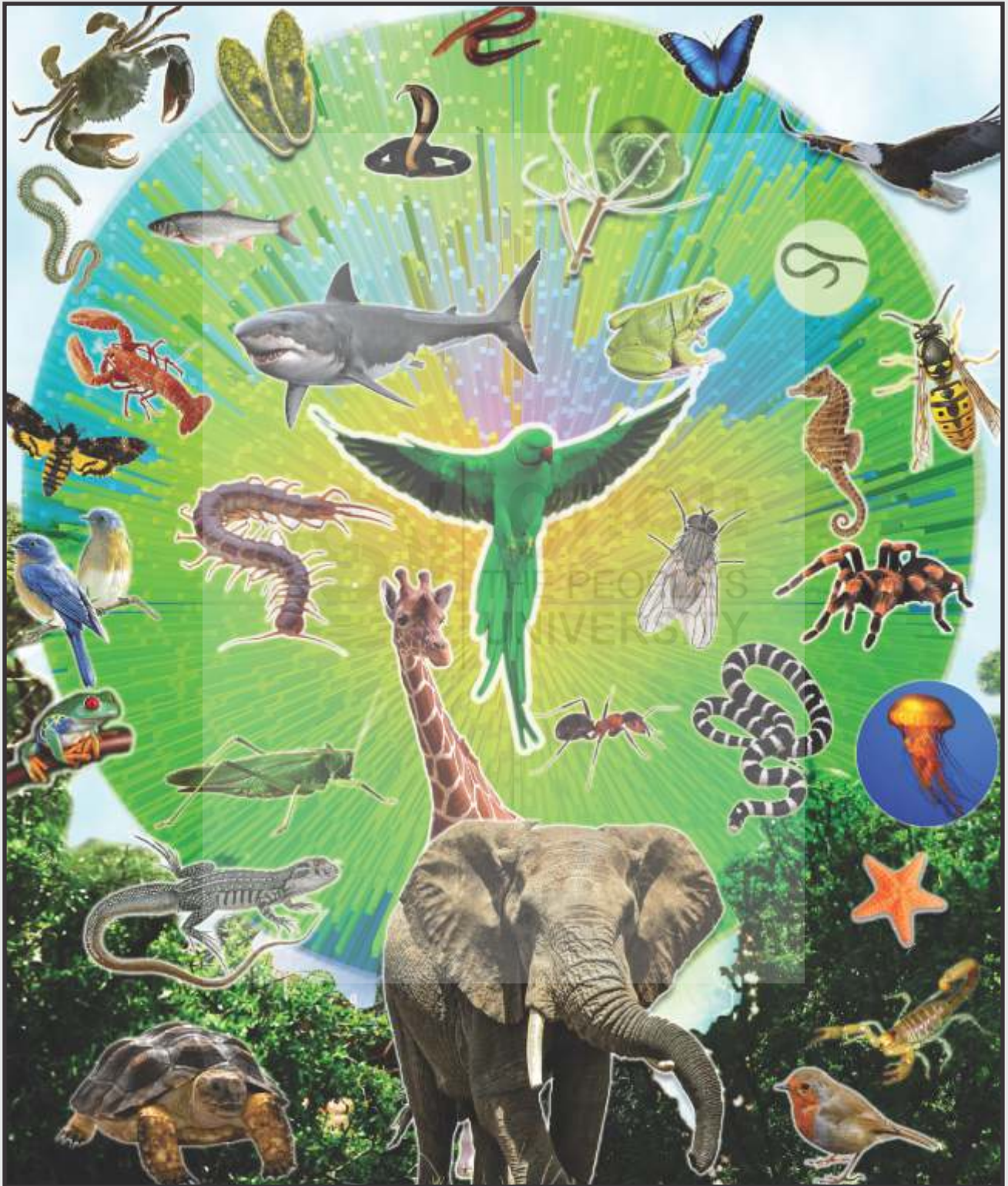




“शिक्षा मानव को बन्धनों से मुक्त करती है और आज के युग में तो यह लोकतंत्र की भावना का आधार भी है। जन्म तथा अन्य कारणों से उत्पन्न जाति एवं वर्गगत विषमताओं को दूर करते हुए मनुष्य को इन सबसे ऊपर उठाती है।”

— इन्दिरा गांधी



“Education is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances.”

— Indira Gandhi

Block

1

ACOELOMATES

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Acknowledgement : Mr. Vikas Kumar for word processing and Mr. Ajit Kumar for art works.

September, 2019

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ISBN: 978-93-89668-01-8

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Further information on the Indira Gandhi National Open University courses may be obtained from the University's office at Maidan Garhi, New Delhi-110 068 or the official website of IGNOU at www.ignou.ac.in.

Printed and published on behalf of Indira Gandhi National Open University, New Delhi by Prof. Poornima Mital, Director, SOS, IGNOU.

Laser Typeset by : Rajshree Computers, V-166A, Bhagwati Vihar, (Near Sec. 2, Dwarka), Uttam Nagar, New Delhi-110059

Printed by : M/s. Hi-Tech Graphics, D-4/3, Okhla Industrial Area, Phase-II, New Delhi-110020

ANIMAL DIVERSITY

Scientists estimate that about 7.7 million animal species inhabit our planet but only about 12% have been described so far. Thousands are being identified and described each year. Of the estimated animal species only about 3% are vertebrates that are animals with a backbone and 97% are invertebrates that are animals without a backbone.

This huge diversity of animal species forms the subject of this course-‘Animal Diversity’ which is the first course in Zoology that you will study. The variety of animal forms present on earth is mind boggling and through this course we will give you a glimpse into this fascinating world. Throughout the course the underlying thread is phylogenetic relationships among the different animal groups and we will discuss only the major phyla that have living representatives. You will notice that our descriptions are not too detailed, rather those points have been discussed that are essential characteristic of the group and with which the student should be familiar. To a large extent we have followed the most accepted classification system of the day. Conscious decision has been taken to limit the classification upto class level and in some instances upto the level of orders. It is expected that you would get a clear idea of the variety of animals from this mode of treatment, without getting bogged down in the quagmire of classification. The course has been divided into four blocks. The first two blocks deal with invertebrate animals and the next two blocks describe the vertebrate animals.

The first block: **Acoelomates** discusses the unicellular eucaryotes – the protozoans and the uncertainties in their relationships. Though modern classification does not include protozoans as part of Kingdom Animalia, they are still of interest to zoologists; and are discussed in most zoology courses as animals. Therefore, we have included them in this course as a separate unit. We study the general principles of structural organisation that are used in classifying the animal groups and emphasise that though all animals share some basic body features of structure and organisation, there is diversity in their body plans that is suited to the different habitats in which they have evolved. You will learn how these characters are used to categorise the animals into different groups or phyla. This course also focuses on the origin of multicellular animals from unicellular ancestors. Block 1 also includes metazoans like Porifera, Cnidaria, Platyhelminthes and Nematoda.

The second block: **Coelomates** deals with the classification and general features of invertebrates that have a body cavity or true coelom. All these animals can be grouped into two large assemblages: the protostomes represented by the annelids, arthropods, molluscs and the deuterostomes that include the echinoderms, and other vertebrates. In this block we include only the invertebrate groups.

Block three: **Anamniotes** and Block four **Amniotes** provide you the opportunity of studying the vast diversity of living chordates and their special adaptations, and evolutionary relationships. We proceed with a class by class approach of chordates. While discussing distinctive characteristics of each class, an attempt has been made that you don't lose sight of the basic unity of the structure among different groups or of the fact that structural modifications are a result of their long evolutionary history.

In all the eighteen units wherever required, interesting information in relation to the topic is given in as marginal remarks. Each unit in the course contains learning objectives, text summary and self assessment questions. You are advised to attempt all the self assessment and terminal questions as they help in understanding important concepts in the unit. A glossary of important words is given at the end of each block.

Objectives

After studying this course, you should be able to:

- state the huge diversity of animal species on planet earth;
- appreciate phylogenetic relationships among different animal groups;
- describe the acoelomates and coelomates and differentiate between them;
- explain the amniotes and anamniotes with their vast diversity in habit and habitat; and
- discuss their special adaptation with their varied environments and their evolutionary relationships as well.



BLOCK 1 : ACOELOMATES

This is the first block of Animal Diversity course and the block comprises 6 units dealing with the diversity of non-chordates. In this block we will study exclusively acoelomates which do not have body cavity and have solid type of body constitution and mesoderm completely fills the space.

In Unit 1 of this block, you will study about protists which did not photosynthesise, were heterotrophs with animal like characteristics and evolved further to give rise to different groups of single celled organisms that are collectively known as protozoa. Such types of organisms could perform all life's functions within the constraints of a single cell.

Unit 2 deals with all other multicellular animals that are placed in Kingdom Metazoa under different phyla. In this unit you will be introduced to fundamental rules and general principles used in classification of organisms in hierarchical system based on their evolutionary relationships.

Unit 3 speaks about pore bearing organisms called Porifera which are multicellular and incapable of making movement as they remain attached to the substratum like a plant presenting a great variety of forms.

In Unit 4 of this block you will observe the organisation of animals placed in Phylum Cnidaria which are sometimes referred to as coelenterates. They are successful group of animals, though of great structural and functional simplicity among metazoans which include *Hydra*, jelly fishes, sea anemones and corals.

In Unit 5 you will deal with animals of Phylum Platyhelminthes that are soft bodied, bilaterally symmetrical, popularly known as flat worms. The gelatinous mesoglea of cnidarians is replaced by a mesodermal cellular parenchyma, a type of packing tissue consisting of more cells and fibres than mesoglea. Platyhelminthes include free swimming and parasitic species.

In the last unit i.e., Unit 6 of the block you will learn about Nematodes, popularly known as roundworms. They are found in soil, in all types of aquatic environments, in animals and plants as parasites and otherwise. They are known to cause diseases in their hosts.

Objectives

After studying this block, you should be able to:

- list the characteristic features of acoelomate phyla;
- classify the various phyla into classes with examples;
- describe the skeletons of multicellular animals; and
- explain the phenomenon of polymorphism in cnidarians.

UNIT 1

ANIMAL LIKE PROTISTS: PROTOZOANS

Structure

1.1	Introduction Objectives	1.5	Locomotion in Protozoans Structure and Function of Cilia and Flagella
1.2	General Characters		Structure and Function of Pseudopodia
1.3	Classification Super Group Excavata Super Group 'SAR' Clade Super Group Unikonta	1.6	Summary
1.4	Structural Organisation and Function Body Form Nutrition Osmoregulation and Excretion Respiration Mechanism for Response Reproduction	1.7	Terminal Questions
		1.8	Answers

1.1 INTRODUCTION

The first evidence of life on earth appeared approximately 3.8–4.5 billion years ago and the first cells were prokaryotic bacteria like organisms that diversified through evolution over millions of years to give rise to single celled eukaryotic organisms. Even though, we do not know for sure, how and when the eukaryotic organisms originated, there is evidence to indicate that eukaryotic organisms arose through endosymbiosis (a relationship between two species in which one organism lives inside the cell of another organism). As the oxygen content increased in the earth's atmosphere certain aerobic bacteria may have been engulfed by larger anaerobes that were unable to cope with the increasing oxygen. These engulfed aerobic bacteria had enzymes that could generate energy and could have become the ancestors of mitochondria. Almost all present day eukaryotes have mitochondria and are mostly aerobic. Some ancestral eukaryotes would have engulfed photosynthetic bacteria which became chloroplasts and these could manufacture their own food using the energy from sunlight. Green algae and plants would have arisen from such primitive eukaryotes.

Some of the eukaryotes that did not photosynthesise were **heterotrophs** with animal like characteristics and evolved further to give rise to different groups of single celled eukaryotes that collectively became known as **Protozoa**. Such organisms could perform all life's functions within the constraints of a single cell.

Biologists in general now accept that all living organisms can be placed in three broad domains in the tree of life namely **Bacteria**, **Archaea** and **Eukarya**. In this course we look at the third domain Eukarya, which includes the unicellular eukaryotes of Kingdom **Protista** along with the multicellular eukaryotes included in Kingdoms **Plantae**, **Fungi** and **Animalia** that were earlier part of the Five-Kingdom system of classification. Of these, Protista (term coined by Ernst Haeckel in 1866) are a very diverse group of primitive unicellular eukaryotes. Though they represent only about 10% of the total eukaryotic species, their abundance is extremely high and biologists study them for several reasons:

- i) They are important medically- some of the protist species cause major infectious diseases,
- ii) They are critical to understanding the evolution of plants, fungi, and animals,
- iii) They play an important ecological role especially in aquatic systems. Because of the diversity of the ultra structure, life cycles, evolutionary relationships that have emerged in this group of eukaryotes, it is difficult to place them in a single kingdom 'Protista', in which they were placed earlier, but the general term protist is often used for these single celled eukaryotes.

This unit starts with a general description and the accepted classification of these single celled eukaryotes, however, over the past 30 years molecular phylogenetic studies have led to extensive modification in the classification, which is likely to change again as more evidences turn up to indicate evolutionary relationships among these unicellular organisms. We then go on to study only the protists formerly grouped under **Phylum Protozoa** or the "**unicellular animals**". We now know that protozoans are really a heterogeneous group of unicellular organisms and the term Protozoa has no formal biological status. Even so, because of their similarity to animals and because most zoologists are interested in this group of organisms too, this group is treated along with animals and thus continues to find a place in zoology courses.

We will go on to describe the structural organisation of protozoans and discuss in detail the locomotary organelles and the various methods of locomotion found in protozoans in a separate section.

Objectives

After studying this unit, you will be able to:

- ❖ enumerate the general features of unicellular eukaryotes (Protista) and outline their position in the general scheme of eukaryote classification;
- ❖ summarise the recent classification of protozoans;
- ❖ describe the structural organisation of protozoans with their special characteristics;
- ❖ distinguish between various protozoan groups using their characteristic features; and
- ❖ discuss the various modes of locomotion and the locomotory organelles involved in protozoans.

1.2 GENERAL CHARACTERS

Unicellular eukaryotes make up a group of all other eukaryotes that are not green plants, fungi, or animals. Unlike prokaryotes, eukaryotic cells have a membrane bound nucleus to enclose their genetic material and other membrane bound organelles such as mitochondria and Golgi apparatus or dictyosomes. These provide specific locations in the cell for its diverse functions, making the structural organisation more complicated than the prokaryotic cell. The differences between the prokaryotic cells and eukaryotic cells are summarised in Table 1.1.

Unicellular eukaryotes are a very diverse group. The single celled eukaryotes traditionally called protozoa are considered to be the simplest eukaryotes but at the cellular level they are very complex as they perform all the functions in a single cell that multicellular organisms perform in various organs. The organelles and cytoskeleton found in them vary in structure, and they also use different modes of nutrition. Some are parasitic and others are predatory or **mixotrophs** (combining photosynthesis and heterotrophic nutrition). Some may spend their lifetime in one position and others may be constantly motile. Reproduction and life cycles are also highly varied. Genetic and morphological studies have shown that some protists are more closely related to plants, or fungi or animals than they are to each other; as a result kingdom Protista in which all protozoans and plant like protists were placed has been abandoned and various lineages of protists are now recognised, but the term protists is still in use for convenience.

In this unit we provide you with a phylogenetic hypothesis for the relationship among the eukaryotes living presently on Earth in Fig.1.1. The groups that were formerly included in Kingdom Protista are given in single lined boxes and given the rank of phyla. The “supergroups” recognised today are given in yellow and grey shaded boxes show the unranked groups that include the phyla. Dashed lines indicate uncertain evolutionary relationships. You must remember that these relationships are still being investigated and may change in the future as new evidence is brought to light.

Table 1.1: Differences between the cells of Prokaryotes and Eukaryotes

	Feature	Prokaryotes	Eukaryotes	
			Higher Plants	Animals
1.	Size	0.2-500 μm ; mostly 1 μm	30-50 μm	10 μm – 20 μm ; mostly 10 μm
2.	Cell Wall	Usually non-cellulosic and made up of Peptidoglycan	Present; largely cellulosic	absent
3.	Endomembranes	Absent	Present	Present
4.	Nuclear membrane	Absent	Present	Present
5.	Chromosome	Single, circular. No histones	Multiple, linear; complexed with histones	Multiple, linear; complexed with histones
6.	Nucleus	Absent	Present	Present
7.	Division	Amitosis	Mitosis or Meiosis	Mitosis Meiosis
8.	Sexual Reproduction	Rare	Common	Common
9.	Ribosomes	Smaller, 70s	Larger, 80s	Larger, 80s
10.	Mitochondria	Absent; respiratory enzymes associated with plasma membrane	Present	Present
11.	Plastids	Absent; photosynthetic enzymes are associated with plasma membrane	Present	Absent
12.	Flagella or cilia (when present)	Present; simple; made up of single microfibril	Absent*	Present; complex made up of nine peripheral and two central microfibril (9+2) pattern.
13.	Endo and exocytosis	Absent	Absent*	Present

Note : *Although absent in higher plants, these features occur in more primitive plants. Apparently they have been lost during the course of evolution.

In the next section we will take a detailed look at the three major supergroups namely **Excavata**, **SAR clade** and **Unikonta** that include the animal like protists that were formerly known as Protozoa.

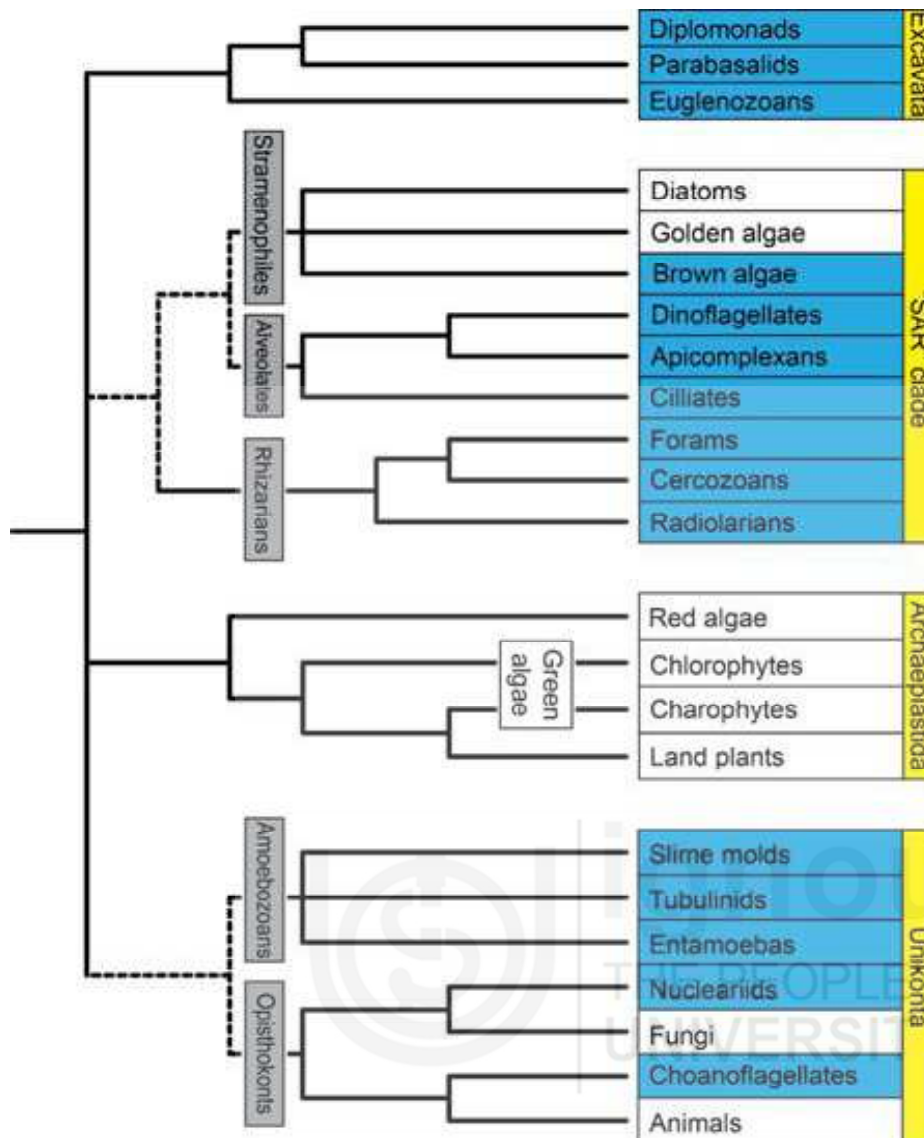


Fig. 1.1 : Phylogenetic hypothesis for evolutionary relationship among the present day eukaryotes. SAR stands for the first letter of Stramenopiles, Alveolata and Rizaria.

SAQ 1

List the three most important features of eukaryotes that distinguish them from prokaryotes.

1.3 CLASSIFICATION

Traditionally, the protozoans have been classified as flagellates, amoebae, sporozoans and ciliates. However, over the past thirty years molecular phylogenetic studies have led to extensive modifications of the traditional classification schemes and the most dramatic changes have occurred in the protist groups. The names of so many protist groups and genera have changed so many times since then, that the classification scheme is unclear and it is difficult to determine which name to use. However, scientists working with protists agree that these organisms as a group are **polyphyletic**, that is,

protists groups have arisen from several distinct ancestors and therefore, they cannot be placed in one single kingdom Protista. The classification scheme given by the International Society of Protistologists (Adl *et al.*, 2005) could not apply both, the International Code of Botanical Nomenclature and the International Code of Zoological Nomenclature because they differ in their norms. Hence they have come up with a classification system having **nameless ranks** rather than have a classification system with divisions of phylum, class, order etc. This will allow them to modify the classification in the future as the need arises.

However, for the ease of students, in this unit, we still use the traditional terms phylum, subphylum, class while placing the protists in groups. Look at Fig. 1.1 again, you can see that the key lineages in the eukaryotes have been placed under four broad super groups **Excavata, SAR clade, Archaeplastida** and **Unikonta**. We have listed and highlighted only the major lineages of protists that were put under the former Kingdom Protozoa. Each of these lineages can be distinguished by at least one morphological characteristic, often a change in structure or function of one or more organelles.

1.3.1 Super Group Excavata

All members of Excavata have similar cytoskeletal features. Some of the unicellular species that form this group have a distinguishing morphological feature that is an 'excavated' feeding groove found on one side of the cell. They include photosynthetic, parasitic, heterotrophic and symbiotic taxa. Mitochondria may be reduced or modified in some groups; have flagella in some that differ from other organisms. The main protozoans of this super-group are placed in:

1. **Phylum Diplomonada:** Characteristically they have reduced mitochondria known as **mitosomes** that cannot use oxygen hence these cells are found in anaerobic environments. They are commensals or parasitic and include the infamous *Giardia intestinalis* that infects mammals including humans and causes diarrhoea and abdominal cramps. Structurally diplomonads have two similar nuclei and four flagella associated with each nucleus (Fig. 1.2 a).
2. **Phylum Parabasala:** They are anaerobes that either lack functional mitochondria, or have reduced mitochondria known as **hydrogenosomes** that produce some ATP anaerobically, releasing hydrogen as a by-product. Members of this phylum have a stiffening rod composed of microtubules, the **axostyle** that extends along the longitudinal axis of their body. They have a modified region of the Golgi complex known as the parabasal body; and have single nucleus and several flagella associated with it. All are parasitic, the best known example is *Trichomonas vaginalis* (Fig. 1.2 b) which is a sexually transmitted parasite that affects both women and men. Several species for example, *Trichonympha* (Fig. 1.2 c) and *Mixotricha* live only in the gut of termites and woodroaches in mutualistic relationship and produce enzymes that digest cellulose. The insect host cannot survive without these symbionts.

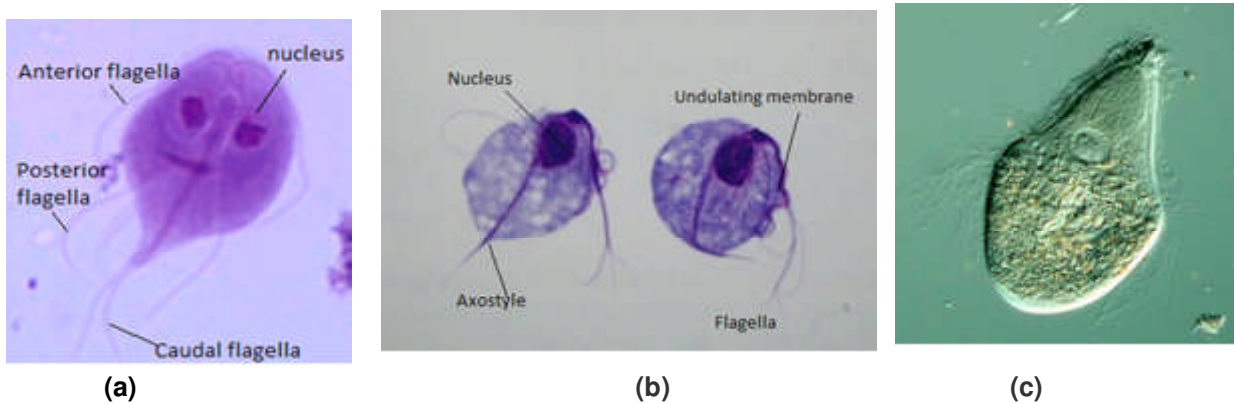


Fig.1.2: a) *Giardia intestinalis*; b) *Trichomonas vaginalis*; c) *Trichonympha*, a symbiont of wood eating termites.

3. **Phylum Euglenozoa:** This includes predatory heterotrophs, photosynthetic autotrophs, mixotrophs and parasites. Members of this phylum have a series of longitudinal microtubules that lie below the cell membrane and help it to stiffen into a pellicle. The main distinguishing feature is the presence of a rod with either a spiral or crystalline structure inside each of their flagella. The two best studied groups of euglenozoans are:

- i) **Subphylum Kinetoplasta:** This has a single large mitochondrion with a mass of DNA associated with the kinetosome or basal body of the flagellum forming a unique organelle **kinetoplast**. All kinetoplastids live in symbiosis with other organisms and some are pathogenic. They include species that feed on prokaryotes in fresh water, marine and moist environments, some are parasites in plants and animals.
 - **Class Trypanosomatidea:** One or two flagella arise out of a pocket typically with paraxial rod. All are parasitic; examples are *Trypanosoma gambiense* (Fig. 1.3 a) that infects humans causing sleeping sickness, a neurological disease that is invariably fatal if not treated and *Trypanosoma cruzi* that causes an important disease i.e. Chagas's disease. *Leishmania* (Fig. 1.3b) another pathogen is wide spread in Asia, Middle East, South America. It causes kala-azar or visceral leishmaniasis which is widely distributed in eastern India.

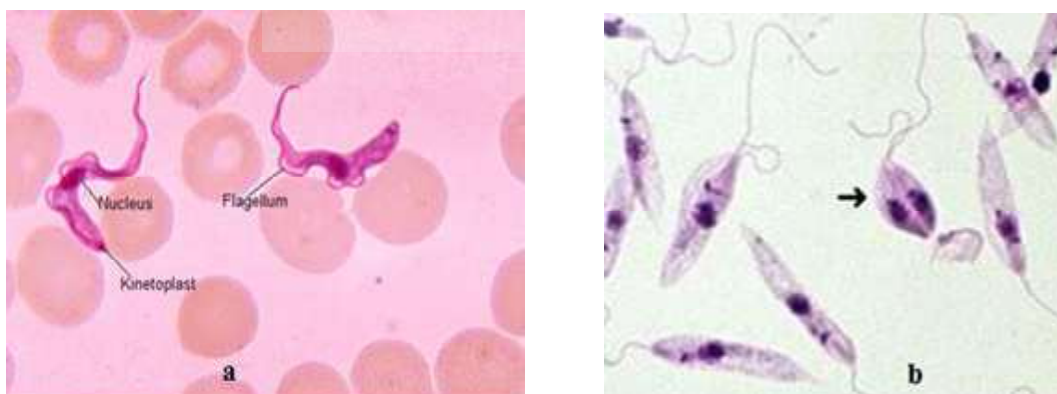


Fig. 1.3: Disease causing kinetoplastids. a) *Trypanosoma gambiense*; b) *Leishmania donovani* causes a serious and fatal disease kala-azar.

- ii) **Subphylum Euglenida:** Have pellicular microtubules that stiffen pellicle.
 - **Class Euglenoidea:** Have a pocket at one end from which arise two flagella, one is small and the other is large. Mostly photosynthetic, but some euglenids are mixotrophs. They have chloroplast b and these chloroplasts are surrounded by a double membrane and perform photosynthesis when sunlight is available and become heterotrophic in the absence of sunlight, absorbing organic nutrients from the environment. Many other species ingest prey by phagocytosis. The most frequently studied euglenid in the laboratory is *Euglena*. (see Fig.1.4). A red eyespot or **stigma** is present that functions to orient the organism towards light.

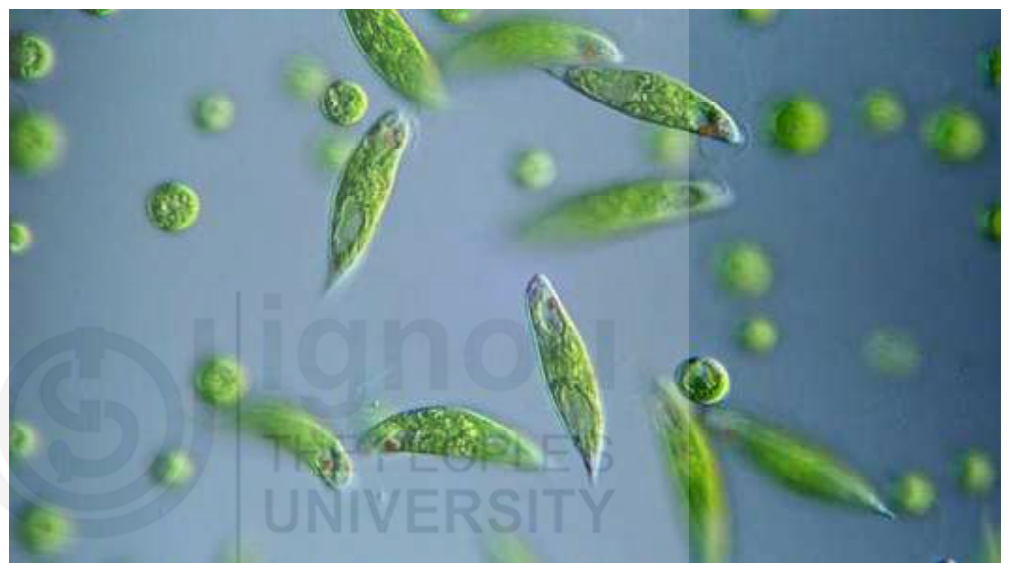


Fig. 1.4: *Euglena* is common in ponds and lakes. It is an example of the sophistication of protistan structure. Flagella are not clearly visible but the red eyespot is seen in some.

1.3.2 Super Group 'SAR' Clade

The SAR clade has been proposed recently (Adl *et al.* 2012) based on the whole genome DNA sequence analysis which has revealed that the three major groups of protists viz. Stramenopiles, Alveolata and Rhizaria can be placed together in a super group. This is a highly diverse collection of protists. Of the three major groups, Stramenopila includes the photosynthetic diatoms and golden and brown algae (these will be dealt in the course on Plant Diversity). The protozoan members are placed in Alveolata and Rhizaria which we will look into more detail.

- i) **Stramenopila (unranked):** Members of this group have tubular mitochondrial cristae. They may be flagellated having two different flagella; one long and hairy and the other short and smooth and both inserted at the anterior end. This clade includes brown algae, yellow algae, diatoms that collect energy from plastids. We will not be elaborating on these groups in this unit. However, opalinids that were once thought of as modified ciliates and that are commensals in frog, are

also placed in this group now. Molecular phylogenies have supported the placement of heliophytes (including genus *Actinophrys* and *Actinosphaerium* that were earlier included with amoebas), with Stramenopiles.

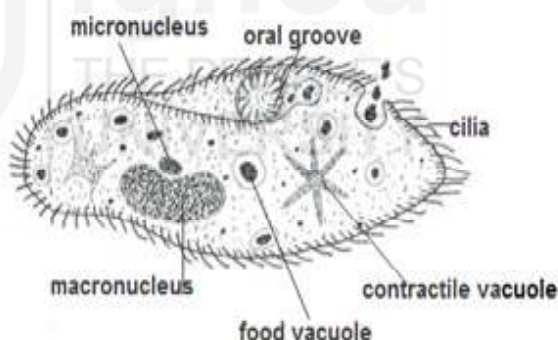
- ii) **Alveolata (unranked):** Have membrane enclosed sacs or alveoli under the plasma membrane. They include both photosynthetic and heterotrophic protists. The three important groups of alveolates are:

- a) **Phylum Ciliophora:** Ciliates are named because of the cilia that cover them. A structural system of fibers along with the kinetosomes (basal bodies of the cilia) forms the infraciliature just beneath the pellicle. They are present in fresh water and marine habitats as well in moist soils. They are free living, parasitic and symbiotic. The most common ciliate used as study material in labs is *Paramecium* and is shown in Fig. 1.5. Its distinguishing feature is the presence of two types of nuclei, one large macronucleus and tiny micronuclei. Macronucleus is responsible for the functioning of the organism and the micronucleus is diploid and involved only in reproduction. It has a special type of reproduction – conjugation (see Fig. 1.20 in Section 1.4) during which two cells line up and micronuclei are exchanged via a cytoplasmic bridge between the two cells.

Noctiluca has the same compound as fireflies-luciferin, that makes it glow and when millions of these protists float they form spectacular glowing tides.



(a)



(b)

Fig. 1.5: a) *Paramecium* sp under high power; b) diagrammatic representation showing the organelles.

- b) **Phylum Dinoflagellata:** Most of these are ocean dwelling plankton, though some are freshwater dwellers. The cells are naked or typically reinforced by cellulose plates. Dinoflagellates are distinguished by the arrangement of two flagella. One flagellum projects out of the cell and the other is located in a groove on the side of the body. The two flagella are perpendicular to each other and the cell rotates as it moves by the action of the flagella. Roughly half of the dinoflagellate species are purely heterotrophic and many of the photosynthetic species are mixotrophic. Some species are ecologically important primary producers. Periods of explosive reproduction cause a phenomenon called **red bloom** that is toxic to the invertebrates and fish. Fig. 1.6 shows some dinoflagellates.

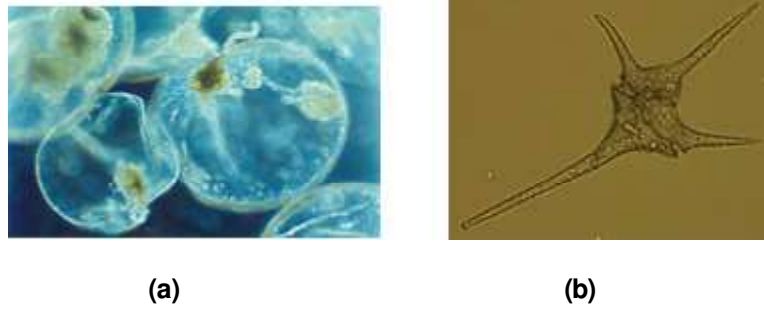


Fig. 1.6: a) *Noctiluca*, a bioluminescent dinoflagellate; b) *Ceratium* has a thick covering with long spines in which the cytoplasm extends. It can catch food by extending pseudopodia between the plates.

- c) **Phylum Apicomplexa:** All the species are parasitic and specialised for living and reproducing in animal tissue; the infectious stage is called **sporozoite**. The sporozoites have a system of organelles at one end known as **apical complex** that is usually present in some stages of development and allows the apicomplexan parasite to penetrate the host cell membrane. Although apicomplexans are not photosynthetic, they retain a modified plastid which suggests their algal origin. Most apicomplexans have elaborate life cycles involving one or two hosts.
- i) **Class Gregarineae:** Mature gamonts (individuals that produce gametes) are large, extracellular parasites of digestive tract or body cavity of invertebrates; Life cycle with one host. Example: *Monosystis* and *Gregarina*.
 - ii) **Class Coccidia:** Mature gamonts small, typically intracellular life cycle with two hosts. The best known example, *Plasmodium* (Fig. 1.7) that causes malaria, lives both in the mosquitoes and humans. Another important disease causing apicomplexan *Toxoplasma gondii* is a parasite of cats and can infect humans.

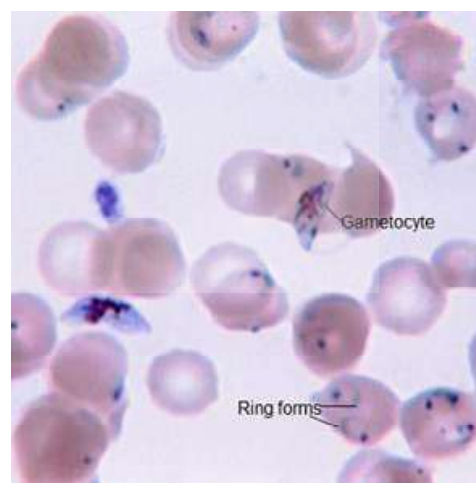


Fig. 1.7: Blood slide with malarial parasite *Plasmodium falciparum* showing a gametocyte and several ring stages in the RBCs.

- iii) **Rhizaria (unranked):** Many amoebas belong to this group. These are protozoans that move by means of pseudopodia and differ from other amoebas by having thread like pseudopodia.

- a) **Phylum Cercozoa:** Large group of amoeboid and flagellated protozoans that have no common body plan that feed using thread like pseudopodia. Found in marine, freshwater and soil ecosystems. Many are parasitic on plants and animals or other protists; they may be mixotrophic and at least one, *Paulinella chromatophora* is an autotroph and an example of a eukaryotic lineage that obtained its photosynthetic apparatus from a cyanobacterium (Fig.1.8).

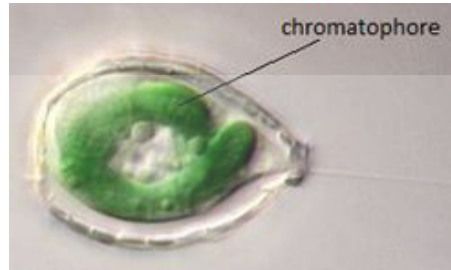


Fig. 1.8: *Paulinella chromatophora*

- b) **Phylum Foraminifera:** Phylum foraminifera or forams are named for their porous shells called tests that are hardened with calcium carbonate. These shells may be many chambered (multilocular) or single chambered (unilocular). The chambers are separated by partitions with small apertures or foramina hence the name Foraminifera. The living organism fills all the chambers in the shell.

Many obtain their nutrients from a symbiotic relationship with photosynthetic algae that live in their tests. Found in fresh and marine waters. Ninety percent of all known foram species are also found as fossils and form the sedimentary rocks on land and in marine sediment. Their presence serves as markers for finding the age of sedimentary rocks (Fig. 1.9).

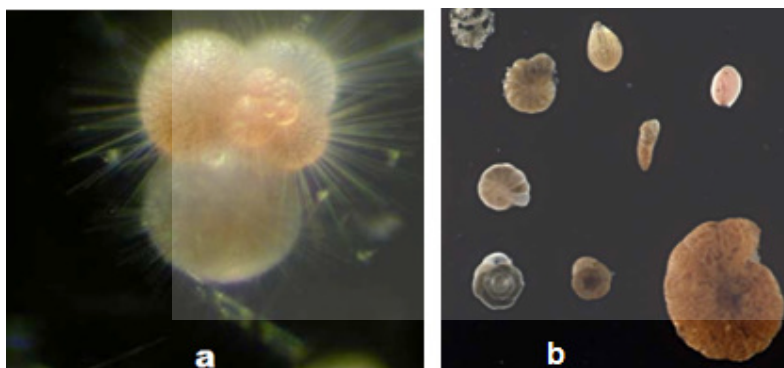


Fig. 1.9: a) *Globigerina* sp. have thread like pseudopodia. They start in one shell and as they grow they develop more chambers; b) some foram shell with multiple chambers. These protists have existed since the Cambrian period.

- c) **Phylum Radiolaria:** These have delicate, intricate, symmetrical internal skeletons that are generally made up of silica. Mostly planktonic, marine; radiolarians have a body divided by a central capsule that separates the inner and outer zones of cytoplasm. The central capsule has perforations which allow the cytoplasmic continuity with the outer frothy cytoplasmic zone. The pseudopodia

radiate from the central body supported by axial rods hence named axopodia. After radiolarians die their skeletons settle on the sea floor, where they accumulate as sea ooze (Fig. 1.10).

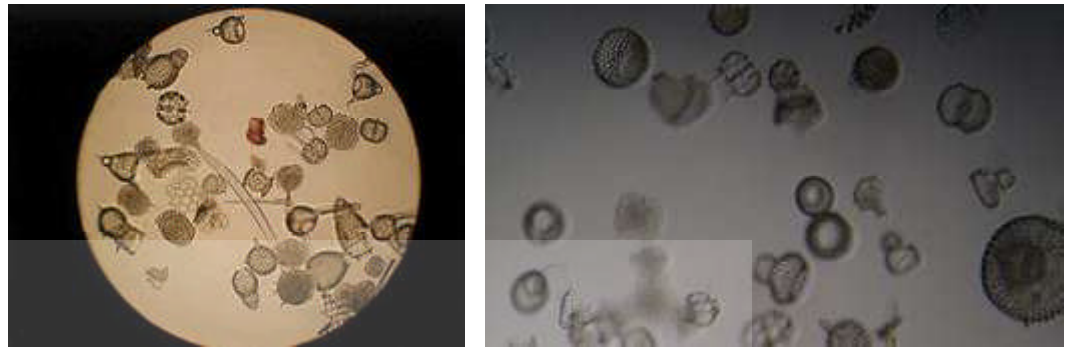


Fig. 1.10: Radiolarian skeletons under low power. These form the ocean ooze.

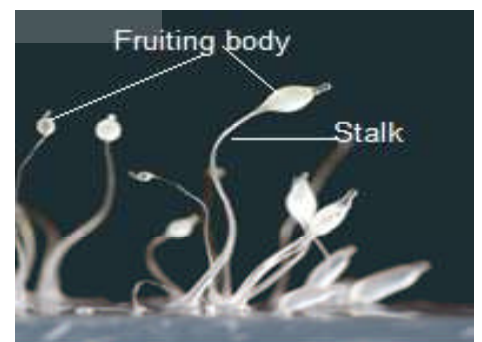
1.3.3 Super Group Unikonta

Unikonta includes protists that are closely related to fungi and animals. These protists form two large groups:

1. **Amoebozoa (Unranked):** This group includes many amoebas species that have lobe shaped or tube shaped pseudopodia. Amoebozoans include the slime moulds, tubulinids and entamoebas.
 - a) **Class Myxogastriida:** This group includes the plasmodial slime moulds that grow to form a mass called the plasmodium which may be several centimeters in diameter, which is not multicellular but multinucleated. It feeds by pseudopodia and when it lacks nutrients it stops growing but gives out fruiting bodies which function in sexual reproduction (Fig. 1.11 a).
 - b) **Class Dictyostelida:** This group includes the cellular slime moulds. The feeding stages are individually functioning cells but when nutrients are depleted the cells come together and form the slug like aggregate which functions as a unit, but the cells are still separated by their individual cell membranes. Ultimately the sluglike aggregate forms asexual fruiting bodies. The best known example is *Dictyostelium discoideum* a common slime mould that has become a model organism for study (Fig. 1.11b).



(a)



(b)

Fig. 1.11: a) Plasmodial slime mould *Leocarpus fragilis*, b) Cellular slime mould *Dictyostelium*.

- c) **Class Tubulinea:** This group makes a large and varied group of amoebas that have lobe or tube shaped pseudopodia. These protists are widely present in freshwater, marine environments and also in soil. Most are heterotrophs that prey on bacteria and other protists. The most well known example is *Amoeba proteus* (see Fig. 1.12).

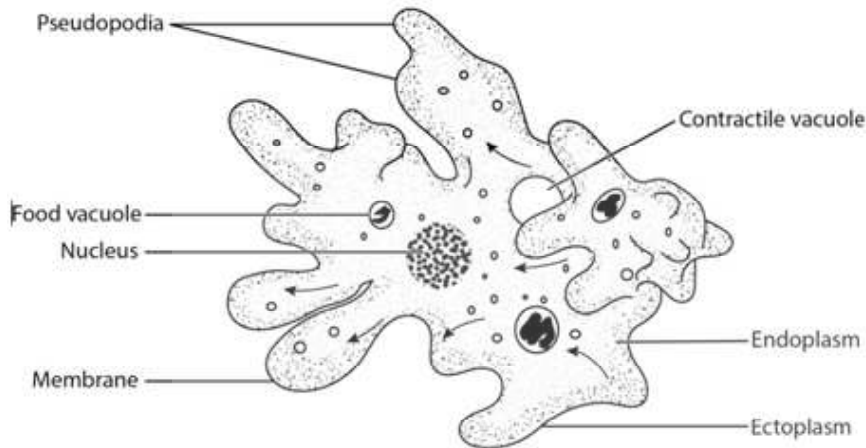


Fig. 1.12: *Amoeba proteus*.

- d) **Class Archamoebae:** Most amoebozoans are free living. However, individuals of genus *Entamoeba* are parasitic on vertebrates and some invertebrates. They are unusual in having flagellated stages in their life cycle and cysts with several nuclei. In humans *E. histolytica* is pathogenic and causes amoebic dysentery which is responsible for thousands of deaths worldwide (see Fig. 1.13).

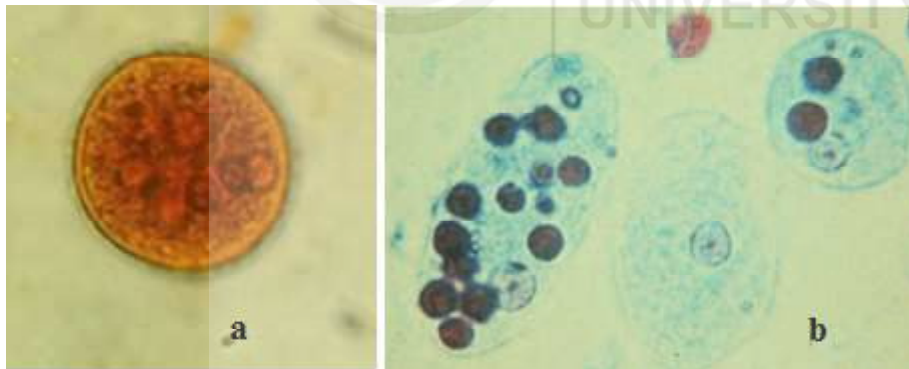


Fig. 1.13: a) *Entamoeba coli* cyst with several nuclei; a common dweller in human gut; b) *Entamoeba histolytica* cysts. They are the cause of amoebic dysentery.

2. **Opisthokonta:** It is a diverse group of eukaryotes that includes the animals and fungi as well as protists that are more closely related to fungi and animals than to other protists. In our scheme we will discuss the nucleariids that are related to fungi and the Choanoflagellates that are more closely related to animals than other protists.

- a) **Nucleariids:** They are a group of amoebas with filose pseudopodia (Fig. 1.14 a) that feed on algae and bacteria and DNA analysis suggests that these protists are closely related to fungi suggesting that fungi may have arisen from similar ancestors.

- b) Choanoflagellata:** Small group of protists found in both marine and freshwater environments and are considered sister taxon of animals. They are the closest living relatives of sponges. They are mostly tiny, bearing single flagellum surrounded by a collar of microvilli, that is so closely arranged that it appears like a transparent collar as it appears in Fig. 1.14. Choanoflagellates may be single celled or colonial free swimming or attached to the substratum by a slender stalk.

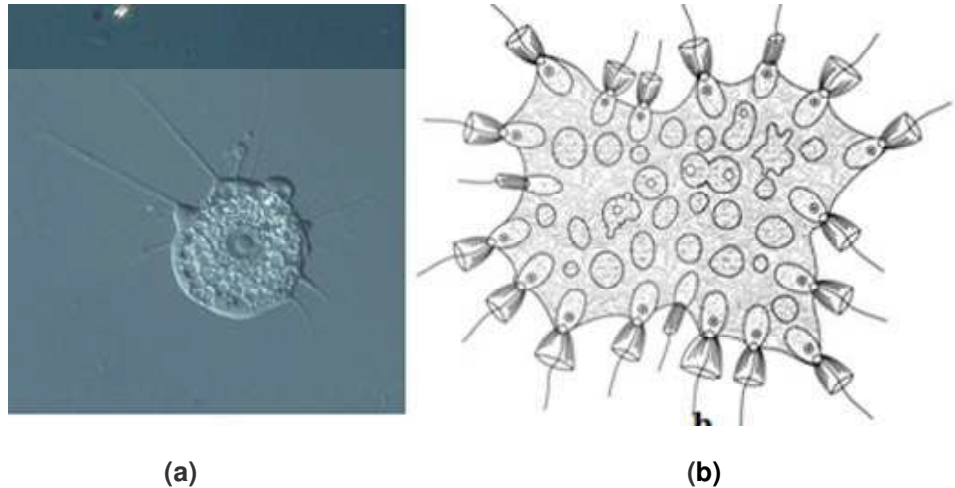


Fig. 1.14 : a) *Nuclearia* sp, an amoeba placed in Opisthokonta and considered closely related to fungi; b) *Proterospongia*, a colonial choanoflagellate. Each cell has a single flagellum surrounded by closely arranged microvilli that gives the appearance of a transparent collar.

SAQ 2

- a) Fill in the blanks:
- Protists with modified mitochondria and unique flagella belong to Super-group
 - Protista that have membrane enclosed sacs under the plasma membrane belong to group
 - Reduced mitochondria in parabasalids are known as while in diplomonads they are known as
 - Protists with delicate thread like pseudopodia belong to group
 - The amoebas with tube shaped pseudopodia are included in along with animals and fungi.
- b) Answer the following:
- What is the difference between dinoflagellates and apicomplexans?
 - What is the main feature that distinguishes euglenozoans from other protists?
 - Fossils of which protist group are used to find the age of sedimentary rocks?

- iv) What is the distinguishing feature of class Cercozoa?
 - v) List three unique features of Phylum Ciliophora.
 - vi) Which group of protists is closely related to animals?
-

1.4 STRUCTURAL ORGANISATION AND FUNCTION

In this Unit till now we have learnt about the broad classification of animal like protists or the protozoans (as we will continue to call them). In this Section we will discuss their structural organisation and functions. These eukaryotes form a group of more than 90,000 named species of single-celled organisms. Half of these species are known only as fossils. They occur in all habitats, marine, freshwater and terrestrial, including soil. About 25% participate in symbiotic associations and many are the causative agents of important human diseases including malaria, the most deadly human parasitic disease.

The unicellular level of organisation is the only character which is common to all members of Protozoa. In all other respects they display extreme diversity. The great majority of protozoans are microscopic. They range in size from one micron as in the case of the planktonic *Micromonas* to a few millimeters like some *Amoeba* species and ciliates and exhibit all types of symmetry and great range of complexity in their microanatomical structure.

Let us now consider in this unit the ways in which the single celled protistan body plan is used by its protozoan members to become capable of adapting to varied habitats.

1.4.1 Body Form

The protozoan body is usually bound only by the cell membrane called **plasmalemma**. In some protozoans (in ciliates) the rigidity and the flexibility of the body is maintained by a **cytoskeleton** located immediately below the cell membrane which together with it forms the **pellicle**. The cytoskeleton is composed of filamentous proteins (like actin), microtubules or vesicles or a combinations of all three.

A large number of protozoans also secrete certain organic materials like gelatin, cellulose or tectin on the outer surface of their plasmalemma forming a kind of exoskeleton. Some secrete an organic matrix containing silica or calcium carbonate particles and often foreign bodies like sand particles get entangled with the matrix to strengthen the external layer and provide protection. These chemicals organise to form theca (Fig. 1.15 a), lorica or loose covering (Fig. 1.15 b) or shells as seen in foraminiferans (Fig. 1.15 c). Shells or tests are in loose contact with the cell body and have one or more openings through which the protozoan is able to protrude itself.

As in other eukaryotes, the nucleus of a protozoan is membrane bound and may be diverse in structure and method of division. Two basic types are found, vesicular with considerable amount of nucleoplasm and the other compact. When more than one nucleus is present they are usually alike except in

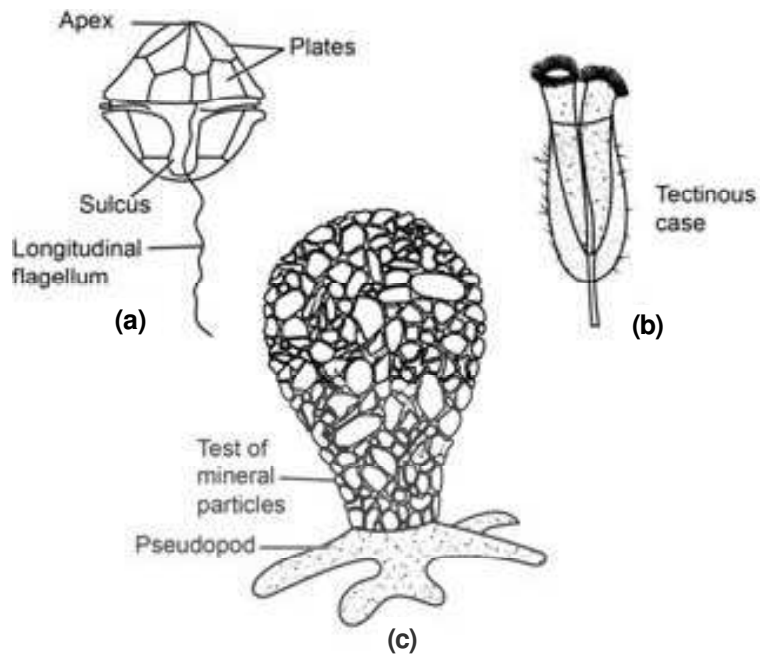


Fig. 1.15: Exoskeleton in protozoans. a) Theca in *Glenodinium radiolarian* skeleton; b) loose covering lorica as seen in *Cothurnia*, a ciliate c) sand particles and other hard substances stick to the chitinous secretions and form the external skeleton in the foram *Diffugia*.

Vesicular nucleus = chromosomal material is in irregular clumps leaving some areas within the nucleus clear containing the nucleoplasm.

ciliates, where a massive compact macronucleus and one or more compact micronuclei are present. Cytoplasm can be distinguished as **ectoplasm** and **endoplasm**.

Ectoplasm appears transparent under light microscope and bears the base of the flagella or cilia. The endoplasm appears granular and contains the nucleus and cytoplasmic organelles. The ectoplasm is more rigid and is in the gel state of a colloid while the endoplasm is in the sol or more fluid state.

1.4.2 Nutrition

All types of nutrition occur in Protozoa. Some protozoans synthesise their own food from inorganic precursors (carbon dioxide, nitrates or ammonium salts) and hence are **autotrophic**; e.g. chlorophyll bearing flagellates. Others are heterotrophic as they depend on organic and inorganic raw materials from the environment for their food.

Heterotrophs have varied food habits. Some feed on soluble organic nutrients from their environment and are termed **saprozoic** or **osmotrophs**, e.g. parasitic protozoa; still others are **holozoic** ingesting rigid or solid organic food or **phagotrophs** that is, they may ingest solid food of plant or animal origin. They may also feed on bacteria or other small protists which are ingested whole, and digest them within food vacuoles. Phagotrophic nutrition involves phagocytosis in which the cell membrane enfolds the food particle which is then engulfed. In amoebas phagocytosis occurs at any point by surrounding the food particle with pseudopodia (Fig. 1.16). The food particle is then enclosed in an intracellular membrane bound vesicle the **food vacuole** or **phagosome**. The food is digested by the action of enzymes contained in lysosomes and the undigested material is thrown out from the body by exocytosis. The digested material is absorbed by the cell. In most ciliates,

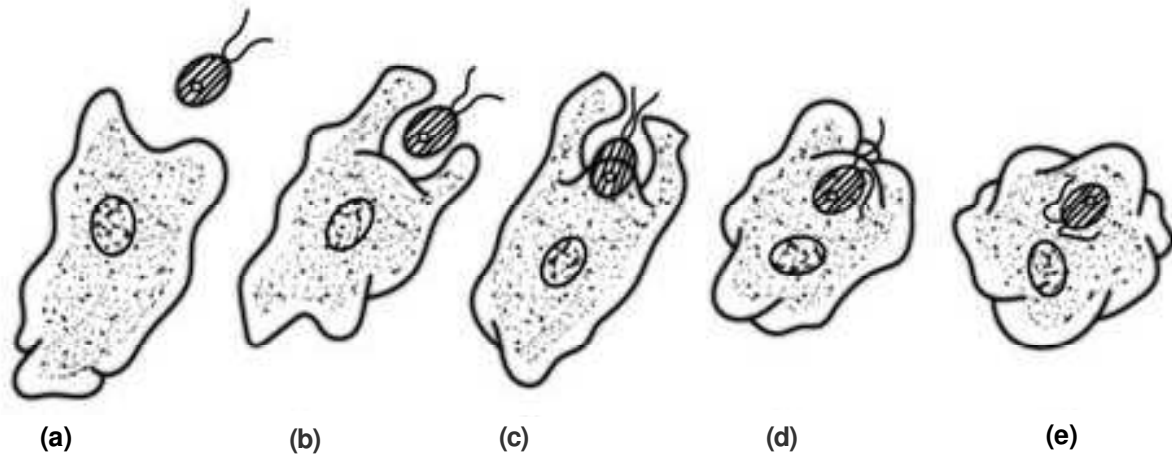


Fig. 1.16: Different stages of phagocytosis in *Amoeba*.

many flagellates (protozoans that bear flagellum) and apicomplexans the site of phagocytosis is a definite mouth structure called the **cytostome**. Flagellates may have a temporary cytosome usually in a characteristic position or the cytosome may be a permanent specialised structure.

Saprophytic feeding may take place by pinocytosis (extracellular fluids taken in the cell by infolding of the cell membrane) or through direct diffusion or facilitated or active transport of solutes through the membrane.

Autotrophic protozoa use light energy to synthesise their organic molecules but they often become phagotrophic or osmotrophic. Even among the heterotrophic protozoa few follow only one mode of nutrition exclusively. For example, in *Euglena* species there is considerable variety in modes of nutrition. Some species require some preformed organic molecules even though they are autotrophs, some species lose their chloroplasts if kept in the dark and become permanent osmotrophs.

1.4.3 Osmoregulation and Excretion

Osmoregulation or water balance in protozoa is accomplished by contractile vacuoles. One to several contractile vacuoles may be present within the cell which may or may not have fixed sites in the cytoplasm and may have contributory canals or other vesicles opening into it. These are water and ion regulating structures, acting as pumps to remove excess water from the cytoplasm. All freshwater protozoans have functioning systems of contractile vacuoles whereas; marine and parasitic forms have these less frequently.

Excretion of metabolic wastes is done almost exclusively by diffusion. All protozoans are ammonotelic i.e., the end product of their nitrogen metabolism is ammonia, which is readily diffused in the surrounding medium.

The contractile vacuoles may differ in complexity in various groups of protozoans. In amoebae the vacuoles are carried around in the cytoplasm. Small vesicles join them emptying their contents into the vacuoles till the vacuole joins the membrane emptying its content to the outside (Fig. 1.17).

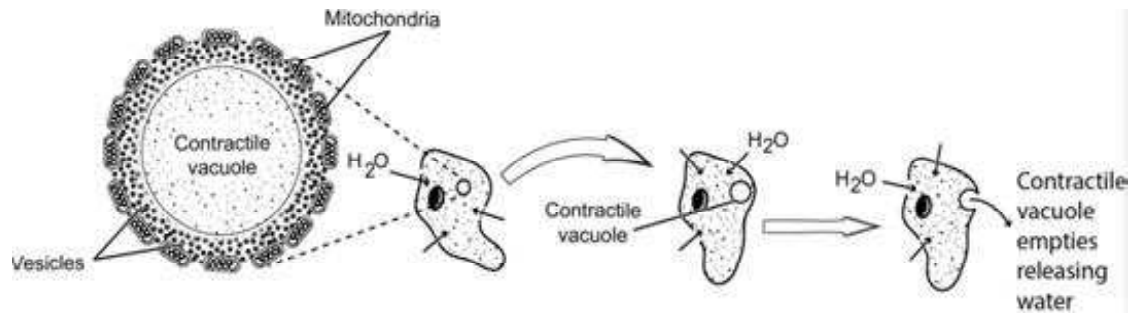


Fig. 1.17 : The contractile vacuole in *Amoeba proteus* is surrounded by tiny vesicles that empty their content in the vacuole. Numerous mitochondria surround the contractile vacuole to provide energy to adjust the salt content of the tiny vesicles.

In ciliates (e.g. *Paramecium*) the contractile vacuoles have a more complex structure. The contractile vacuole is located in a **fixed position** with an excretory pore leading to the outside surrounded by ampullae of feeder canals (Fig. 1.18 and also Fig. 1.5 for position of contractile vacuole). The feeder canals are surrounded by a network of fine canals 20 nm in diameter, which are also connected to the tubular system of endoplasmic reticulum. The ampullae are surrounded by a bundle of fibrils that contract the ampullae, thereby filling the vacuole and when it discharges the water outside the ampullae get disconnected thus preventing backflow.

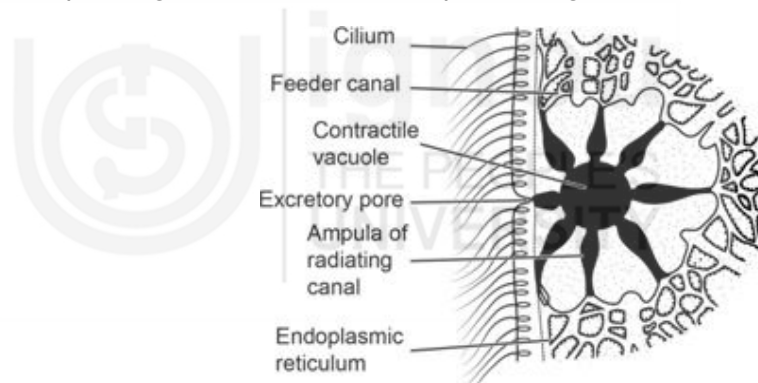


Fig. 1.18 : Enlarged section of a contractile vacuole in *Paramecium* which collects water and expels it outside, performing osmoregulatory functions.

SAQ 3

Match the following:

	A		B
a)	Ammonia	i)	Helps fresh water ciliates to get rid of excess water
b)	Cytosome	ii)	Excretion of metabolites in protozoans
c)	Contractile vacuole	iii)	In most ciliates and apicomplexans the site for phagocytosis
d)	Diffusion	iv)	Protozoans that obtain their food through formation of food vacuoles
e)	Phagotrophs	v)	The excretory product of protozoans

1.4.4 Respiration

Because protozoa are small, they have a large surface area in proportion to their volume. This facilitates gas exchange which involves acquiring oxygen for cellular respiration and elimination of carbon dioxide produced as a by-product. Some parasitic protozoans are capable of anaerobic respiration, for example *Monocystis*. Metabolic wastes like ammonia and carbon dioxide diffuse out of the organism.

1.4.5 Mechanism for Response

Protozoans are sensitive to many stimuli like touch, temperature changes, light, chemicals etc. Though the exact mechanism is not understood but *Amoeba* can constantly change their protoplasmic mass and respond to stimuli as well as conduct them. Cilia and flagella are highly sensitive to touch. One special sensory organelle found in photosynthetic flagellates is the light sensitive eye-spot or stigma which is located at the base of the flagellum. The stigma is often cupped shading the light sensitive portion from one side.

1.4.6 Reproduction

Both asexual and sexual reproduction occurs among protozoa. The most common form of asexual reproduction is **binary fission**. In binary fission the nucleus divides mitotically to produce two nuclei that are distributed to two similar sized individuals when the cytoplasm divides. During cytokinesis the cell organelles also duplicate so that both individuals have all the organelles required to continue life. Depending on the group of protozoans, cell division could be transverse or longitudinal (Fig. 1.19). Other forms of asexual reproduction are **budding** during which mitosis is followed by formation of a much smaller individual than the parent cell. **Multiple fission** or **schizogony** occurs when a large number of daughter cells form from the division of a single protozoan. In this process multiple mitotic nuclear divisions take place in a mature individual. When a certain number of nuclei are produced, then cytoplasmic division results in the separation of each nucleus into a new cell. This is seen typically in apicomplexans (malarial parasite).

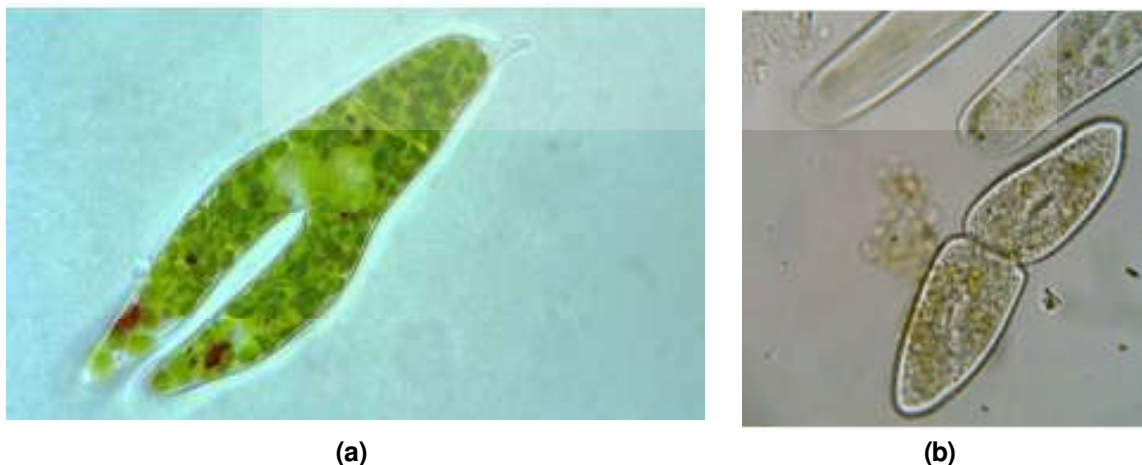


Fig. 1.19 : Binary fission in protozoans a) *Euglena* showing longitudinal fission; and b) *Paramecium*, here the cell division is transverse.

Sexual reproduction entails the formation of haploid gametes by meiotic nuclear division in some protozoans that fuse with another haploid gamete to form the zygote that restores the diploid chromosome number. In some groups the first division after zygote formation is meiotic resulting in haploid individuals that continue to divide mitotically up till next zygote formation. Ciliates have a special arrangement for sexual reproduction known as **conjugation** (See Fig. 1.20). The general features can be seen in *Paramecium* sp. which has one macronucleus and one micronucleus. Two individuals ready for conjugation unite at a point where a cytoplasmic bridge forms (A). The macronucleus disintegrates and the micronucleus divides twice to form four haploid nuclei (B). Three of these disintegrate and the fourth one divides again (C) to form a stable pronucleus (female) and one migratory pronucleus (male). The migratory pronuclei of each are exchanged (D). The conjugates separate and the pronuclei fuse to form the zygote in each individual (E). After several post-conjugation divisions, four daughter cells form from each exconjugant (F and G). The daughter cells have one macronucleus and micronucleus thereby, restoring the normal nuclear complement in each cell.

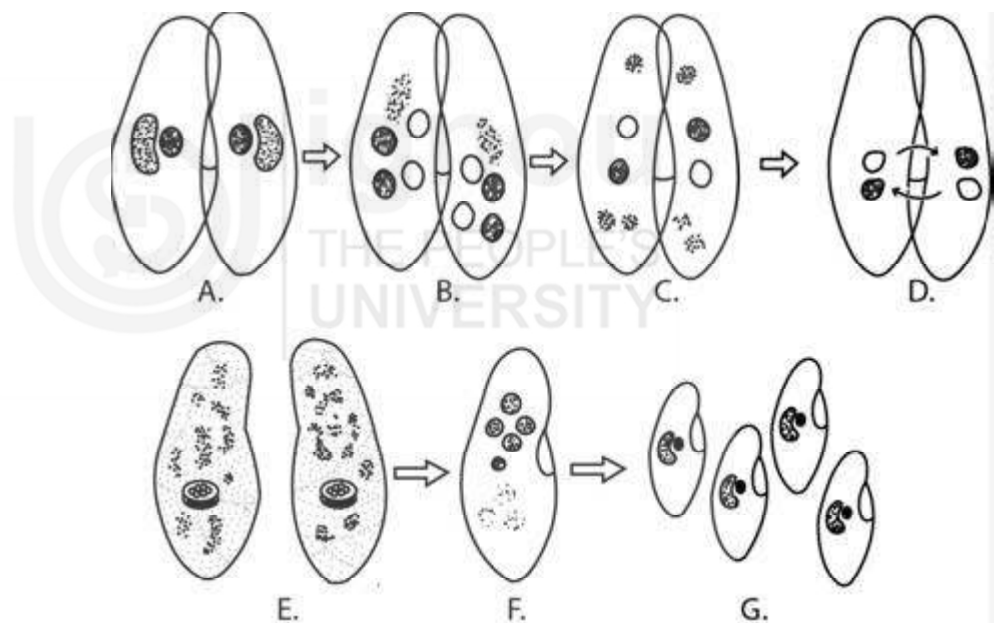


Fig. 1.20: Different conjugation stages in *Paramecium caudatum*.

SAQ 4

Correct the following statements:

1. Binary fission results in two daughter cells that are unequal in size and smaller than the parent cell.
2. Conjugation gives rise to haploid individuals.
3. Sexual reproduction takes place in all protozoans except ciliates.
4. All protozoans have a light sensitive stigma.
5. Schizogony is the formation of two daughter cells in ciliates after meiotic division.

In the next section you will learn about the organelles for locomotion and the various modes of locomotion used by Protozoa. These locomotor organelles are of considerable value in the classification of protozoans.

1.5 LOCOMOTION IN PROTOZOANS

Most protozoans actively move to find food, for finding protection and as response to stimuli. For example, most unicellular forms swim; the slime mould *Dictyostelium discoideum* is a predator that can crawl over a substrate in search of food. These movements are caused by using either cilia or flagella or by flowing cytoplasmic fingers called pseudopodia. Movement is another example of the diversification that occurred within the different eukaryote lineages. Let us look at the various structures used by protozoans for locomotion.

1.5.1 Structure and Function of Cilia and Flagella

Cilia and flagella are microscopic contractile filamentous organelles that are really extension of the cytoplasm which help to create food currents and help in locomotion. The ultrastructure of cilia and flagella is remarkably similar among all organisms in which they occur, from protozoans to vertebrates, suggesting evolution by common descent. Although modifications are found in some organisms, they are always cylindrical arising from a **basal body** known as the **kinetosome**. Within the cilium or flagellum are several rods called **microtubules** composed of a protein called **tubulin**. This protein is similar to myosin which is the metazoan protein of muscles. A cross section of the kinetosome in the **region below the outer body surface** shows that the microtubules are arranged in 9 groups in a ring with 3 microtubules in each group known as a **triplet** (Fig. 1.21). The **C** or innermost tubule of one group is connected to the outermost tubule **A** of the adjacent group via a thin filament. Additional filaments connect C of each group to an inner central tubule like the spokes of a wheel. This arrangement changes a little in the distal end of the cilium or flagellum.

A cross-section of the structure of cilium /flagellum **outside the body surface** shows 9 groups of microtubules, a ring with *only 2 microtubules to each group forming a doublet* (Fig. 1.21). Instead of a thin filament, a pair of **dynein arms** project from each **A** microtubule of one group towards **B** microtubule of the adjacent group. The principal protein **dynein** is similar to myosin in its ability to cleave ATP to release chemical energy which is used to move the cilia. One pair of microtubules is located in the center of the cilium/flagellum and forms the central shaft and is often surrounded by a membrane forming the **central sheath**. Filaments extend from A of each doublet towards the central sheath. The entire microtubular complex of 9 doublets and 2 central singlets is called the **axoneme**. The entire axoneme is covered by a membranous covering continuous with the plasma membrane of the cell surface (Fig. 1.21). As said earlier, all cilia or flagella arise from a basal body. A complex of filaments or **kinetodesmata** link the basal bodies of the cilia in ciliate protozoans.

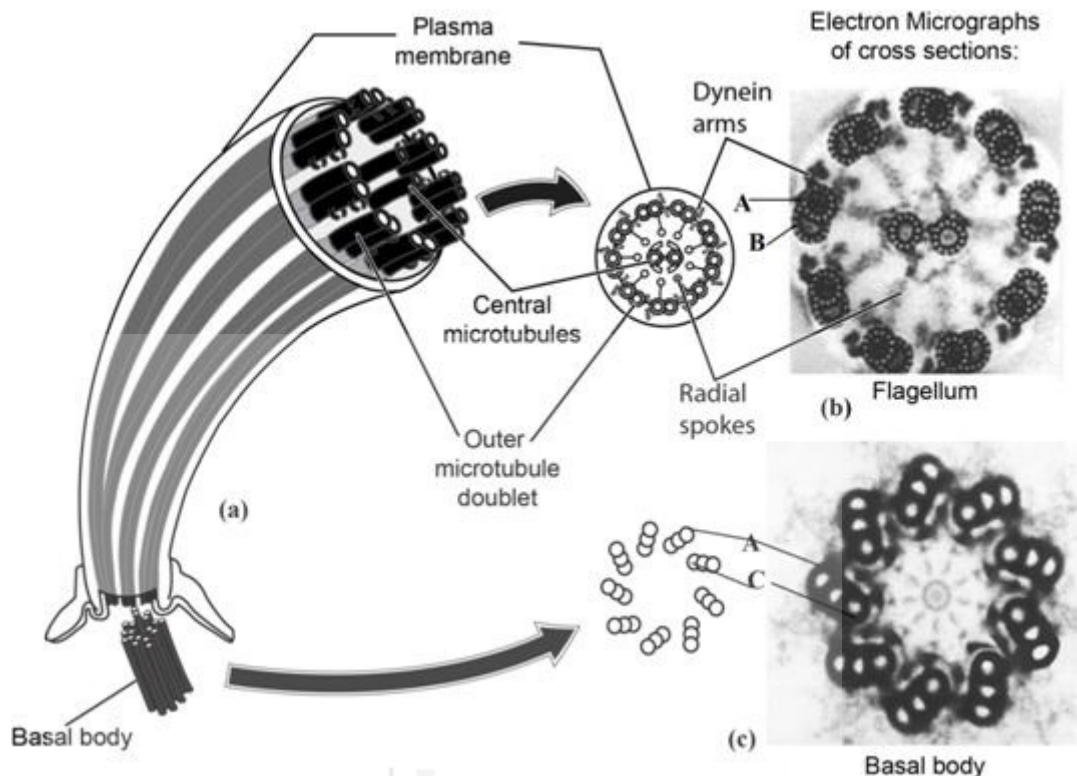


Fig. 1.21 : Diagrammatic representation of the structure of a eukaryote flagellum showing the cross section of the axoneme and kinetosome along with their transmission electron microscope images. The characteristic “9+2” structure of the eukaryotic flagellum is clear in the diagram; a) and in the TEM image; b) Dynein side arms project from the A tubule of each doublet. Also visible in TEM image are the radial spokes and the inner sheath. The Kinetosome TS; c) shows a structure similar to centrioles with “triplets” of microtubules and inward radiating microfilaments.

Though both cilia and flagella have identical morphological structure, they can still be distinguished from each other by their number, size and function. Flagella are long usually 5–10 nm and are found alone or in pairs; cilia are short (2–5 nm), stiff and rounded usually occurring in large numbers on any one cell. Cilia tend to move in a coordinated fashion beating in metachronic or synchronous fashion and propel water parallel to the surface where the cilia are attached. In metachronic rhythm, the cilia of a row beat one after the other while, in synchronic rhythm all the cilia beat simultaneously. Flagella beat independently in a whip-like or undulating motion (Fig.1.22) and propel water parallel to the main axis of the flagellum. There is evidence that ciliary or flagellar movement is achieved through differential sliding of some microtubules against adjacent microtubules relative to others in the same cilium. The energy for the movement is provided by the ATP. On average ciliates move faster than flagellate protozoans because of the number of cilia present on the cell surface of ciliates.

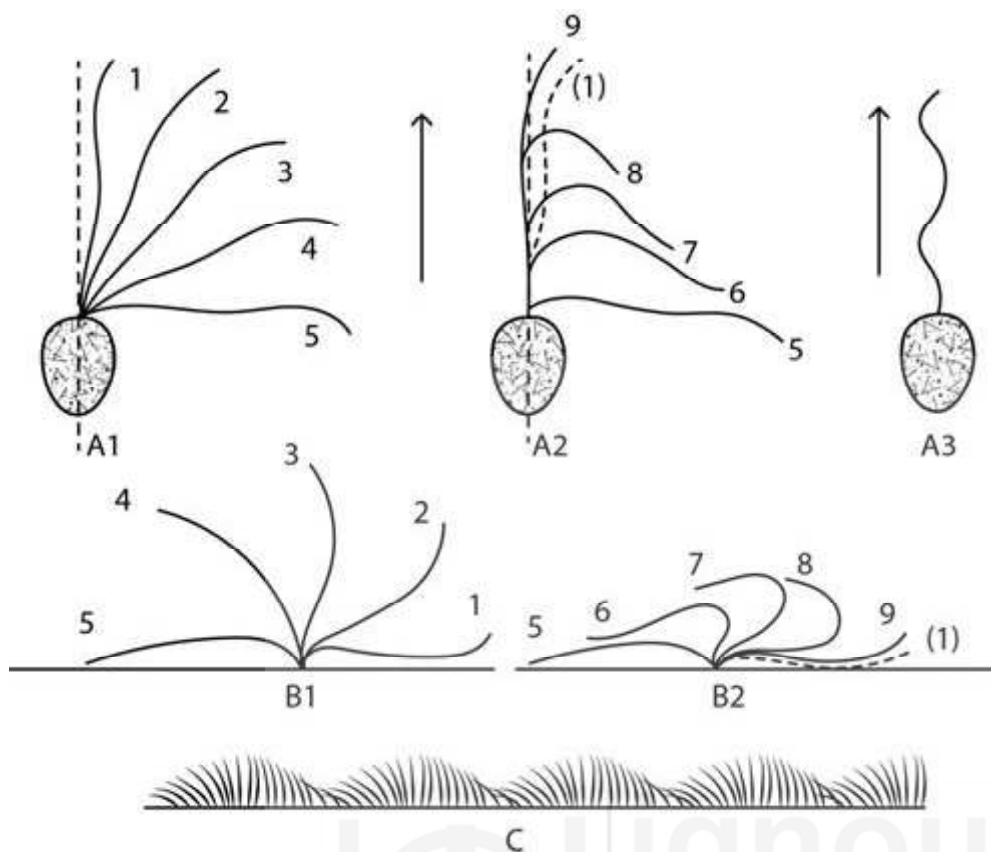


Fig. 1.22: Movement of a cilium and a flagellum. A1 shows propulsive stroke and A2 shows recovery stroke of a simple flagellum. Water moves at right angles to the surface of attachment of the flagellum. A3 shows several waves of bending creating continuous movement. Arrows show the direction of propulsion of water and locomotion. B1 and B2 show propulsive and recovery strokes respectively of a cilium. C shows the metachronal rhythm of ciliary beating. Each cilium is beating slightly later than the cilium in front of it, but in phase with its neighbour in adjacent row; thus waves appear to pass over the ciliated surface in the opposite direction to the effective stroke of the cilia.

1.5.2 Structure and Function of Pseudopodia

Pseudopodia (false feet) are flowing cytoplasmic protrusions of the cell causing amoeboid movement. They also function in feeding. In protozoans pseudopodia exist in several forms (Fig. 1.23). The most familiar are **lobopodia**. These are large blunt extensions of the body containing both **ectoplasm** and **endoplasm**. Thin extensions of the body are known as **filopodia**. These are often branched containing only ectoplasm. Repeated branching and rejoining of filopodia to form a net like mesh is known as **reticulopodia**. Long thin pseudopodia supported by axial rods of microtubules are known as **axopodia** which can be extended or retracted, apparently by addition or removal of microtubular material.

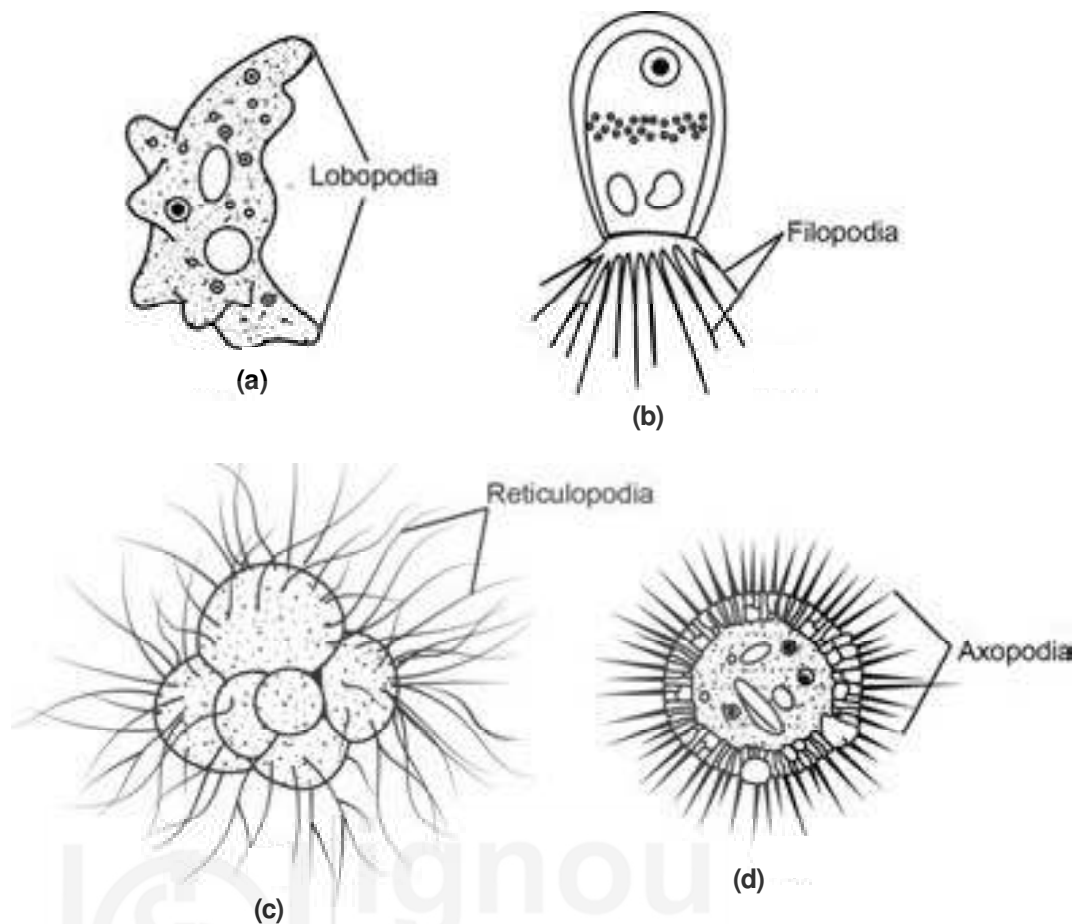


Fig. 1.23: Pseudopodia: a) Lobopodia in *Amoeba*; b) Filopodia in *Chlamydomorphys*, a freshwater amoeba; c) Reticulopodia of *Globigerina*; d) Axopodia of *Actinophrys*, often called sun animalcule.

As the amoeba's cell body throws out one or a few pseudopodial lobes, a temporary rear end or **uroid** is pulled along. The central, more fluid protoplasm, the **endoplasm** flows towards the extending pseudopodium, the advancing tip of which appears as a thicker gel, the **ectoplasm**. This is known as the **hyaline cap**. The flowing endoplasm contains actin subunits that are bound to regulatory **actin binding proteins (ABPs)**. During the amoeboid movement, the sol-like endoplasm is converted into gel like ectoplasm at the advancing tip of the pseudopodium; a reverse process simultaneously occurs at the uroid end where the gel changes into sol. At some point the pseudopodium gets attached to the substratum and the cell is moved forward.

It is also a widely accepted view that the amoeboid movements depend on the contraction of cellular proteins like actin and myosin found to be present in amoeboid cells, which are comparable to those occurring in the muscle and require ATP. Tropomyosin has also been demonstrated in some instances but at the level of the whole cell, the precise sequence of events during cell crawling are not fully understood. Fig. 1.24 shows the various types of amoeboid movements.

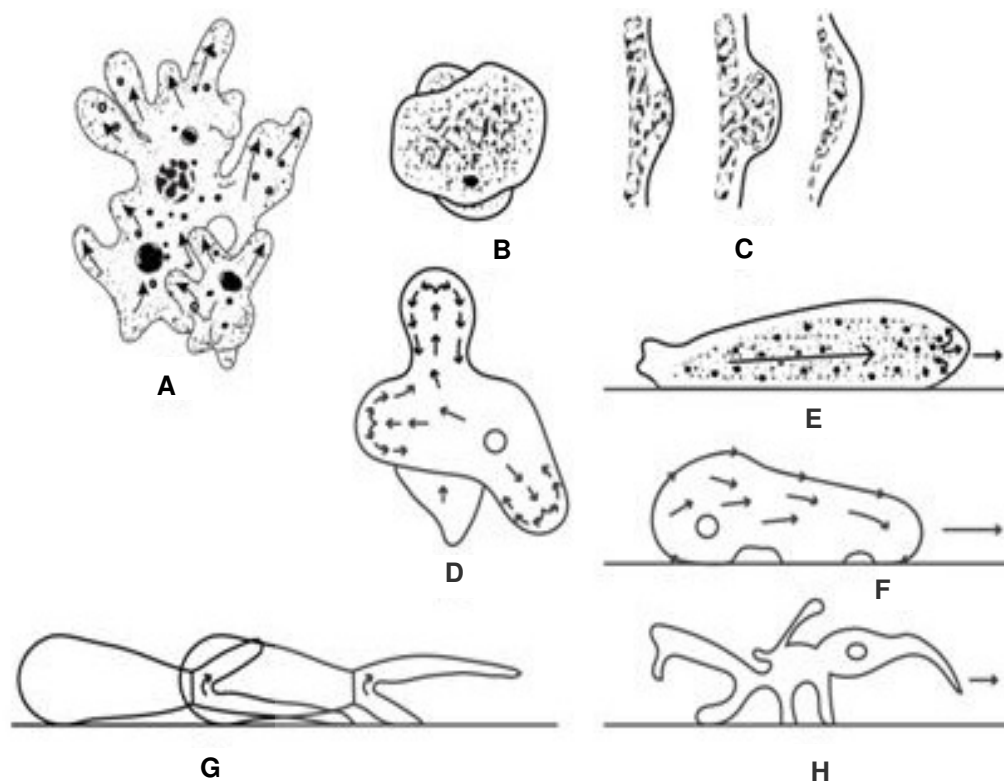


Fig. 1.24 : Amoeboid locomotion in different amoebae. A) *Amoeba proteus* (lobose pseudopodia); B) *Entamoeba histolytica* (broad lobose pseudopodia); C) Formation of lobose pseudopodia by sudden flow of endoplasm (dark zone) into ectoplasm (light zone); D) Streaming of protoplasm in an amoeba; E) Creeping movement of an amoeba; F) Rolling motion; G) Locomotion in an "inchworm" fashion in *Diffugia*; H) Walking motion (due to the formation of multiple pseudopodia).

SAQ 5

In what way are cilia and flagella different from each other?

1.6 SUMMARY

In this unit you have learnt that:

- All living organisms are placed in three domains namely Bacteria, Archaea and Eukaryota. Bacteria and Archaea are prokaryotes while the single celled eukaryotic protists belong to the domain Eukaryota along with the fungi, plants and animals.
- The classification of protists has undergone many changes. Protista are now placed in lineages recognised as separate kingdoms according to their differing characteristics.
- All eukaryotes are grouped in four super-groups: Excavata, SAR-Clade, Archaeplastida and Unikonta.

- The animal like protozoans are grouped under Excavata that includes protists with modified mitochondria (diplomonads and parabasalids) and those with unique flagella (Eugleazoans); SAR-Clade which is a highly diverse group including the alveolates and rhizarians; and Unikonta that includes the protozoans that are closer to animals and fungi like amoebazoans and Opisthokonts.
- Animal like protists that were earlier placed in a separate kingdom. Protozoa are an assemblage of unicellular, heterotrophic organisms found in the sea, fresh water and moist terrestrial environments. They have diverse shapes and though single celled, are capable of complex functions all carried out within their cell boundaries.
- Protozoans are diverse in their nutrition, but most of them are heterotrophic being free living, or parasitic, some are autotrophic, and some are mixotrophic combining photosynthesis and heterotrophic nutrients.
- Some have specialised organelles not found in other eukaryotes such as contractile vacuoles that pump excess water from their cells.
- Reproduction and life cycles are also highly varied. Some are known to reproduce only asexually while others can employ the process of sexual reproduction like meiosis and fertilization and have a special form of reproduction i.e. conjugation.
- Locomotion in protozoans takes place by action of cilia and flagella; and by formation of pseudopodia. Cilia and flagella are made up of microtubules and have similar ultrastructure though cilia are shorter and stiffer than flagella. Their movement patterns are different. Pseudopodia are varied in their form and cause amoeboid movement by cytoplasmic streaming and protrusion. Amoeboid movement depends on contractile proteins that are similar to muscle proteins.

1.7 TERMINAL QUESTIONS

- 1 Explain why a unicellular protozoan is considered a very complex cell in comparison to a single metazoan cell.
2. Make a table of the major Super groups that include the protozoan groups listed under them giving at least one important characteristic that distinguishes each group.
3. Outline the steps in the process of conjugation in ciliates.
4. Draw the cross section of a flagellum and describe its structure.
5. Explain the transition of ectoplasm and endoplasm in amoeboid movement.

1.8 ANSWERS

Self-Assessment Questions

1.
 - i) Nuclear membrane enclosing nucleus, nucleolus and chromosomes present.
 - ii) Chromosomes with histones
 - iii) 80S Ribosomes
2.
 - a) i); Excavata ii) Alveolata; iii) hydrogenomes; mitosomes;
iv) Rhizaria; v) Opisthokonta.
 - b)
 - i) **Dinoflagellates:** Cellular plates reinforce the cell in dinoflagellates; they are free living; two flagella present one free and other in a groove both perpendicular to each other.

Apicomplexans: All parasitic with one-two hosts; a collection of organelles at one end forms apical complex that allows them to penetrate their host.
 - ii) Flagella with paraxial rod; mitochondria with discoid cristae
 - iii) Phylum Foraminifera
 - iv) They feed using thread like pseudopodia; very diverse amoeboid flagellates; filose pseudopodia
 - v) Structure of interconnected basal bodies of cilia forming infraciliature; multinucleate with at least one macro and one micronucleus; cytosome or mouth for feeding.
 - vi) Choanoflagellates
3.
 - a) v; b) iii; c) i; d) ii; e) iv.
4.
 - i) Binary fission results in two daughter cells that are equal in size and smaller than the parent cell.
 - ii) Conjugation gives rise to diploid individuals.
 - iii) Sexual reproduction takes place in some protozoans, in ciliates it is called conjugation.
 - iv) Only euglenoid protozoans have a light sensitive stigma.
 - v) Schizogony is the formation of a large number of daughter cells from the mitotic division of a single protozoan. It is seen in apicomplexans (malarial parasite).
5. Hint: length, pattern of movement; location

Terminal Questions

1. Unicellular protozoan is a cell that is capable of performing all life functions within the confines of a single cell while a single metazoan cell is specialised for doing one particular function. You can elaborate this by giving examples from various tissues and organs in the metazoan body.
2. Refer to Fig. 1.1 and Section 1.3 for this question.
3. Refer to Fig. 1.20 and Section 1.4.
4. Refer to Fig. 1.21 and Subsection 1.5.1.
5. Explain referring to the change in endoplasm to ectoplasm and the proteins that bring about the change. Refer to Subsection 1.5.2.



UNIT 2

ANIMAL CLASSIFICATION AND ARCHITECTURE

Structure

2.1	Introduction Objectives	2.4	Origin and Diversification of Metazoa Origin of Multicellularity Diversification and Phylogeny of Animals
2.2	Classification of Living Organisms Binomial Naming of Organisms Concept of Species Classifying Organisms Modern Classification Systems	2.5	Summary
2.3	Organisation and Body Plan Symmetry and Cephalisation Germ Layers and Body Cavity Developmental Patterns Segmentation	2.6	Terminal Questions
		2.7	Answers

2.1 INTRODUCTION

In the first unit you studied about the unicellular eukaryotes (protists) that are considered animal like and formerly placed in Kingdom Protozoa. All other multicellular animals are placed under Kingdom Metazoa under different phyla. Recall the present day broad classification of three domains given in Unit 1, this classification system places all multicellular animals under the broad group Opisthokonta which also includes the fungi and some other closely related unicellular protozoans. When we study animal diversity we find that all animals including human beings share an intrinsic material design and fundamental functional plan despite the structural complexity. These fundamental structural designs that we see today have all been represented in the fossils of metazoan that were found from the Cambrian period. It is, therefore, reasonable to assume that they must have arisen from a common ancestral form and over time they became less and less like each other. Such assumptions are based on the morphological, developmental, physiological, biochemical and genetic similarities and differences among the animal groups.

To study this immense diversity of animal life and its interrelationships, it becomes important to place them into categories according to their similarities or differences. Therefore, various classification systems have been proposed for this purpose. However, it has not been easy to impose this artificial order that is being improved upon constantly as new evidences for relationships among animal groups arise.

In this unit we first introduce you to the fundamental rules and general principles used in classification of organisms in a hierarchical system based on their evolutionary relationships. We then briefly discuss the widely accepted classification systems used by biologists over the years. Next we consider the levels of body organisation and the limited body plans underlying diversity of animal forms. We will discuss the features that are of fundamental importance for describing and understanding the structural themes all multicellular animals share. Based on these themes we will outline the classification system that we will follow in this course on Animal Diversity. In the last section we will discuss the widely accepted theory of origin of animals from closely related single celled eukaryotic organisms along with their diversification into the extant groups that we see today.

Objectives

After studying this unit, you will be able to:

- ❖ explain the principles used in classifying living organisms;
- ❖ discuss the position of animals in the three domain system of classification and place them into hierarchical taxonomic categories;
- ❖ describe the fundamental structural plans of all metazoans based on levels of organisation, germ layers, symmetry, developmental patterns and nature of body cavity;
- ❖ classify animals on the basis of their structural organisation; and
- ❖ discuss the origin of metazoans.

Metagenome: All the genetic material present in an environmental sample, consisting of the genomes of many individual organisms.

2.2 CLASSIFICATION OF LIVING ORGANISMS

To organise the diversity of organisms on our planet we need more than just names for each of them and to be useful, the naming system must reflect the evolutionary relationship among them. The science of **Taxonomy** is the field of biology that is concerned with the theory, practice, and rules of naming and classifying living and extinct organisms and viruses. It is a part of the broader science of **Systematics**, in which a comparative study of the variations in animal populations is used to reveal their evolutionary relationships. Its goal is to identify all species of biological organisms, assess evolutionary relationships among them and to express these relationships as biological classification systems. Modern taxonomists not merely aim to group organisms as per their common features, but also aim to simplify and arrange the immense diversity of living organisms into coherent units called **taxa** (single taxon). These taxa are recognised and named according to the shared characteristics and

The given name of Linnaeus was Carl von Linnè which he latinised to Carolus Lineaus!

evolutionary relatedness of their members. These characteristics could be morphological; molecular; based on their genes and metagenome. The assignment of specific names to each taxon is known as **Nomenclature**.

2.2.1 Binomial Naming of Organisms

The system of **binomial nomenclature** of all living organisms accepted by biologists today was proposed in 1758 by the Swedish botanist Carolus Linnaeus (1707-1778) in his 'Systema Natura'. This system was based on morphology. Linnaeus proposed that each type of organism should be given a unique Latin binomial (consisting of two terms) to distinguish it from every other type of organism. The first word in this system designates the **genus** (plural: **genera**) to which the species belongs. A genus contains one or more closely related and similar species. The second word in the binomial denotes the species itself. For example, according to this system, the domestic cat is *Felis catus*. This indicates that the domestic cat has been placed in the genus *Felis* and within that genus, has been given the specific or species epithet *catus*. This complete name distinguishes the domestic cat from other species in the genus *Felis*, such as *Felis bengalensis* (leopard cat) and *Felis chaus* (jungle cat), all found in India. It also means that all species coming under the genus *Felis* are more closely related and similar to one another than to species coming under any other genus. When the genus is understood, the binomial can be abbreviated as *F. catus*, *F. chaus*. The generic name always begins with a capital. The specific name on the other hand begins always with a small letter. Both the generic and the specific names are italicised in print or are underlined in manuscript or typescript.

The binomial system of nomenclature is universal; no two animals have the same binomial name, and every animal has only one correct name as required by the International Code of Zoological Nomenclature (ICZN).

Sometimes it becomes necessary to add one rank below the rank of species i.e., sub-species to a scientific name for an animal. This is termed as **trinomial nomenclature** and is used when some species due to their different habits showed minor changes in external features. To differentiate this sub-species, the third name is given. The sub-species name is written in small letters, for example Indian and Pakistani crows are similar and their scientific names are *Corvus splendens* but Burmese and Sri Lankan crows are slightly different, they are named as *Corvus splendens isolens* and *Corvus splendens protegatus* respectively. Similarly purple faced langurs that are found in Sri Lanka have four distinct subspecies: *Trachypithecus vetulus vetulus*, *Trachypithecus vetulus nestor*, *Trachypithecus vetulus philbricki* and *Trachypithecus vetulus monticola*.

Before we discuss the classification systems used by biologists, it is important to understand the concept of species.

2.2.2 Concept of Species

Although the living world is vast and variable, scientists recognise well-defined forms or kinds of organisms that represent evolutionary independent groups known as **species** (singular is also species). The species is the basic category of grouping used in taxonomy.

Species are distinct from each other in appearances, behaviour, habitat with less obvious differences in physiology, biochemistry and DNA sequences that is, genetic makeup. Three concepts commonly used to identify species are:

- i) **Biological species concept** was formulated by leading evolutionary biologists of the last century Theodosius Dobzhansky and Ernst Mayr where the critical criterion for identifying a species is *reproductive isolation*. Ernst Mayr has given a good definition for biological species. According to him. "Species is a reproductive community of populations (reproductively isolated from others) that occupies a specific niche in nature". Accordingly a species can be defined as a population of individuals that have the potential to interbreed in nature producing viable and fertile offspring but *do not produce viable fertile offspring with individuals of other such groups*. This reproductive isolation is due to **absence of gene flow** between members of other species due to reproductive barriers. These could be pre-zygotic that is, preventing fertilization or post-zygotic that is, producing infertile nonviable hybrids. However, in a great many cases this strict definition or criteria cannot be applied, for example, it cannot be applied to asexually reproducing organisms or to fossils. Taxonomists often disagree on the degree of reproductive isolation necessary for considering two species as distinct from one another so alternate concepts have been proposed.
- ii) The **morphological species concept** uses the criteria of *differences in shape, size, and other morphological features, but emphasises the unity within species*. Biologists conclude that differences in morphological features are most likely to arise if the populations are independent. It is useful as it can be applied to sexually and asexually reproducing forms as well as to fossils. However, its disadvantage is that scientists often disagree on which structural features species can be distinguished.
- iii) **Phylogenetic species concept** is a recent addition for identifying species based on the *reconstruction of their evolutionary history or phylogeny*. It considers species as the smallest group of individuals that have descended from a common ancestor forming one branch on the tree of life and who all possess a combination of certain defining, or derived, traits. Hence, this concept defines a species as a group having a shared and unique evolutionary history. Again the difficulty with this concept of species is determining the degree of difference required for defining different species.

However, in present day practice the identification and description of animal species is largely based on all three concepts, using, reproductive isolation, morphological features, and common ancestry and by using sequence information from a standard gene present in all animals. For example, the mitochondrial gene encoding for cytochrome 'c' oxidase subunit 1 (*COI*), which contains 650 nucleotide base pairs is the standard "barcode" region for animals. Individuals belonging to the same species usually show very little variation in this barcode region of *COI*. DNA bar coding has not resolved all the differences regarding the use of different species concept but it is now possible to identify the origin of a species in a local population.

Although molecular techniques have proved of extreme value for modern animal taxonomists, they will not replace the traditional taxonomic methods. Moreover, traditional methods and molecular methods will complement each other in taxonomic studies.

SAQ 1

Distinguish between the biological species and the phylogenetic species concepts and give an acceptable definition of species.

2.2.3 Classifying Organisms

You have now seen that the binomial nomenclature gives each species a unique name. Linnaeus also grouped the species into a hierarchy of increasingly inclusive categories that is, **species** into genera and **genera** into higher categories, as this would reveal more information regarding their similarities and relationships to one another. Thus, a number of closely related genera are grouped together into a **family**; a number of closely related families into an **order**; a number of closely related orders into a **class**; a number of closely related classes into a **phylum**, (or division in case of plants) and the various phyla (or divisions) into a **kingdom**. The highest categories thus, in classification were the kingdoms. Now another higher category of **domain** has been added to include the kingdoms.

The names of higher categories are often synthesised from Latin words in the same manner as generic or specific names, and always start with a capital letter (e.g. Reptilia, Amphibia, Mammalia etc.). Their common versions however do not begin with capital letter (such as amphibians, mammals, annelids). Taxonomic terms above the level of genus and species are not italicised. Table 2.1 shows the seven main hierarchal taxonomic categories used in classification and gives you an idea of the classification of organisms using two examples that of humans and dog.

Taxonomists have the option of subdividing these seven ranks even further to recognise more than seven taxa: superphylum, superclass, superorder, suborder, superfamily, subfamily and others for any particular group of organisms.

Table 2.1 : Taxonomic categories of a human and a dog. The essence of Linnaeus's system is that lower level taxa are nested within higher level taxa

TAXON	HUMAN	DOMESTIC DOG
Domain	Eukarya	Eukarya
Kingdom	Animalia	Animalia
Phylum	Chordata	Chordata
Class	Mammalia	Mammalia
Order	Primates	Carnivora
Family	Hominidae	Canidae
Genus	<i>Homo</i>	<i>Canis</i>
Species	<i>sapiens</i>	<i>familiaris</i>

2.2.4 Modern Classification Systems

Humans had learnt to give living organisms specific names very early in history. Aristotle (384-322 BC) recognised two kingdoms in the living world i.e., **Plantae** and **Animalia** and since Aristotle's time, biologists have tried to assign every living organism into one of these two kingdoms. However this presented serious problems as many organisms were claimed by both botanists and zoologists. Several alternative systems were suggested to classify unicellular organisms.

Molecular studies have revealed that the ribosomal RNA is conserved in evolution which means that closely related organisms that have a common ancestor are likely to have similar ribosomal RNA and distantly related organisms have ribosomal RNA that is not so similar but still could have enough similarities to show a distant common ancestor. These studies have led systematists to conclude that all life shares a common ancestor.

Over time taxonomists recognised important differences between a nucleate bacteria, cyanobacteria (Prokaryotes) and all other nucleate unicellular organisms (Eukaryotes). In 1969, American ecologist Robert H. W. Hittaker proposed a five-kingdom classification. **Kingdom Monera** containing the prokaryotes; **Kingdom Protista** containing the single celled eukaryotes (protozoa and unicellular algae). Multicellular organisms were placed in three kingdoms based on their mode of nutrition and other differences in their organisation as **Kingdom Plantae** (including multicellular, photosynthesising organisms, plants and multicellular algae); **Kingdom Fungi** (including moulds, yeast, mushrooms etc., which do not synthesise their food but obtain it by absorption) and **Kingdom Animalia** including the non-chordates and chordates. His five kingdom classification was accepted by most zoologists.

In recent years systematists have taken phylogenetic relationships into account and depict evolutionary relationships among organisms as branching phylogenetic trees. New information providing a clearer understanding of evolutionary relationships among the organisms has challenged the five-kingdom classification system. Based on the information in the sequence of genes and ribosomal RNA American Biologist Carl Woese and his co-workers proposed in 1990 that the fundamental difference between organisms is not based on presence or absence of a nucleus, but living organisms descended from one of three original lines derived from a common ancestor (i) the **Bacteria**, comprising all true bacteria; (ii) the **Archaea** differing from bacteria in membrane structure and ribosomal RNA sequence and related more closely to eukaryotes than bacteria (iii) the **Eukarya** including all single celled and multicellular forms with a formed nucleus (the eukaryotes). These three major groups are now called **Domains**.

Biologists believe that all three domains evolved from a common prokaryotic ancestor. Recall the origin of organism you had studied in Fig. 1.1 of Unit 1. The earlier kingdom Protista is no longer valid and all the groups of unicellular eukaryotes are now regarded as separate kingdoms under domain Eukarya. Animals are placed in group Opisthokonta which also includes the fungi and choanoflagellates that are more closely related to animals than to plants or other unicellular organisms. Fig. 2.1 shows the three domain classification as proposed by Woese.

Zoologists currently recognise 34 animal phyla that have survived from perhaps 100 phyla that may have lived 600 mya in the Cambrian period. Of the living phyla 10 major phyla will be discussed in the course as these give an overview of the structural diversity found in the animal kingdom.

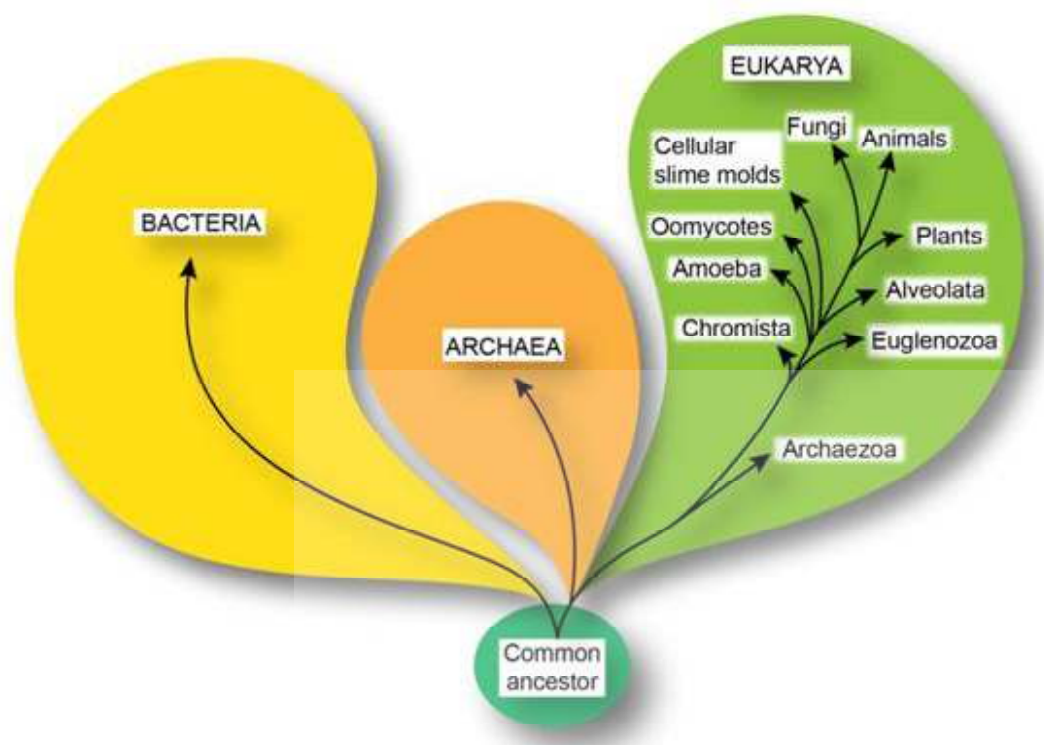


Fig. 2.1: The three domain classification scheme proposed by Carl Woese. The three domains encompass Whittaker's five kingdoms. Monera of the five-kingdom is split into two domains Bacteria and Archaea because of the striking differences between these prokaryotes. Domain Eukaryota includes the single celled Protists as well as the multicellular Plantae, Fungi and Animalia (modified from Pearson Education).

SAQ 2

Choose the correct option in the following:

- i) Which of the following classification levels is the least inclusive?
 - a) family
 - b) order
 - c) genus
 - d) class
- ii) A group of organisms at any level of classification is called
 - a) phylum
 - b) taxon
 - c) genus
 - d) class
- iii) When writing a scientific name only the _____ is capitalised.
 - a) Phylum
 - b) Class
 - c) Genus
 - d) Species
- iv) If two organisms are placed in the same phylum then they must be in the same
 - a) Genus
 - b) Species
 - c) Order
 - d) Class

In the next section we shall learn how animals can be characterised and placed in different groups according to their cell numbers and architecture

2.3 ORGANISATION AND BODY PLAN

Kingdom Animalia had traditionally been divided in two groups based on their cellularity – the **single celled** Sub-kingdom Protozoa and the **multicellular** Sub-kingdom Metazoa or the true animals. Further they can be organised in five grades according to their complexity. These grades are summarised in Table 2.2. You will recognise in the table that most animals display the fifth grade of organisation.

Table 2.2: Grades of organisation in the animal kingdom from single celled to organ level complexity

Protoplasmic grade 	Single celled, all life functions confined inside one cell; protoplasm is differentiated into organelles that perform different functions.
Cellular grade 	Aggregate of cells that is functionally different; colonial flagellates like <i>Volvox</i> are at the cellular level and some authorities place sponges in this category.
Cell-Tissue grade 	Aggregate of similar cells that perform same functions and form tissue. Some authorities place the sponges and cnidarians in this grade. Nerve net is an example of tissue in cnidarians.
Tissue-Organ grade 	More complex than the previous grade; tissues aggregate to form organs. Organs may have different types of tissues. Platyhelminthes are placed in this grade, they have eye spots, proboscis, reproductive organs that are organised to form a system.
Organ system grade 	Different organs work together to perform a function forming a system. This is the highest grade of organisation. Most animals belong to this grade.

When you look at a multicellular animal, its body plan generally is apparent though, sometimes looks are deceptive and you will actually have to dissect the animal to determine its body plan features. However diverse multicellular animals may appear to the eye, the basic body plan is highly conserved

throughout evolution; it is possible to place all metazoans in four basic body plans according to:

- i) type of body symmetry and degree of cephalisation (formation of a head region);
- ii) the number of tissue layers (germ layers) found in the embryo
- iii) presence or absence of a fluid filled body cavity and
- iv) the way the earliest events in development of their embryo take place, that is, the fate of blastopore.

We will now examine these different body plans in this section.

2.3.1 Symmetry and Cephalisation

Symmetry describes how the parts of an animal are arranged around a point or an axis. Its presence or absence is a basic feature of the body plan.

The animals, which cannot be cut into two equal parts passing through any plane or axis are called **asymmetrical**. Their body lacks a definite form and the body cannot be divided into mirror halves by any plane. Most of the sponges (Fig. 2.2) fall in this category of body symmetry. However, two basic types of symmetries **radial** and **bilateral** are recognised in the metazoan animal body plan.

Radial Symmetry

Arrangement of body parts such that any plane passing through the oral (top side) and aboral (bottom) sides around a central axis will give identical halves is known as radial symmetry. Animals with radial symmetry can interact with the environment from any direction, examples are cnidarians (Fig. 2.3 a). Most of the radially symmetrical animals living today either float in water or live attached to the substratum and the two phyla – Cnidaria and Ctenophora that are primarily radial as adults have been placed in the group **Radiata**.

Bilateral Symmetry

Arrangement of body parts such that a single plane passes between the upper and lower body surface through the longitudinal axis of an animal dividing the body in left and right mirror images is known as bilateral symmetry. Bilateral animals generally move in one direction and the end that encounters the environment shows **cephalisation** which is the development of a definite head that occurs at the anterior end of the animal. This end encounters the environment first and develops the sensory, nervous and feeding organs. The other end of the body becomes the posterior end. The back or the upper side is called the dorsal surface and the front or belly side is the ventral side. See Fig. 2.3 b to learn about some other terms associated with locating the regions of a bilaterally symmetrical animal, these are: lateral or the sides; medial or the midline of the body; distal end or parts are farther away from the midline and proximal parts are nearer to the midline. A frontal plane divides the body into dorsal and ventral regions; sagittal plane divides the body into left and right sides. Animals that show bilateral symmetry are placed in the group **Bilateria**. Except for sponges, ctenophores and cnidarians, almost all animals including humans, are bilateral.



Fig. 2.2: Asymmetrical form as seen in sponges.

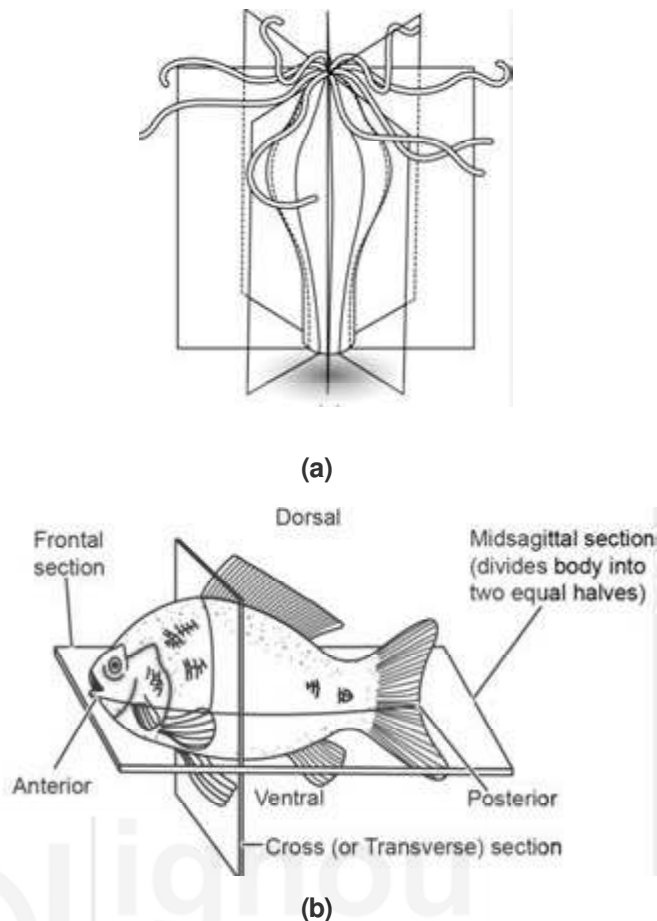


Fig. 2.3 : a) The planes of symmetry as seen in a radially symmetrical animal *Hydra*; b) bilateral symmetry and the various planes of the body.

Biradial Symmetry: This symmetry is a combination of radial and bilateral symmetry; here, the body components are arranged with similar parts on either side of a central axis, and each of the four sides of the body is identical to the opposite side but different from the adjacent. This is seen in ctenophores; comb jellies are globular with tentacles (see Fig. 2.4 a).

Pentaradial symmetry is another variation of radial symmetry seen in echinoderms that are bilateral in their larval stage but pentaradial as adults (Fig. 2.4 b).

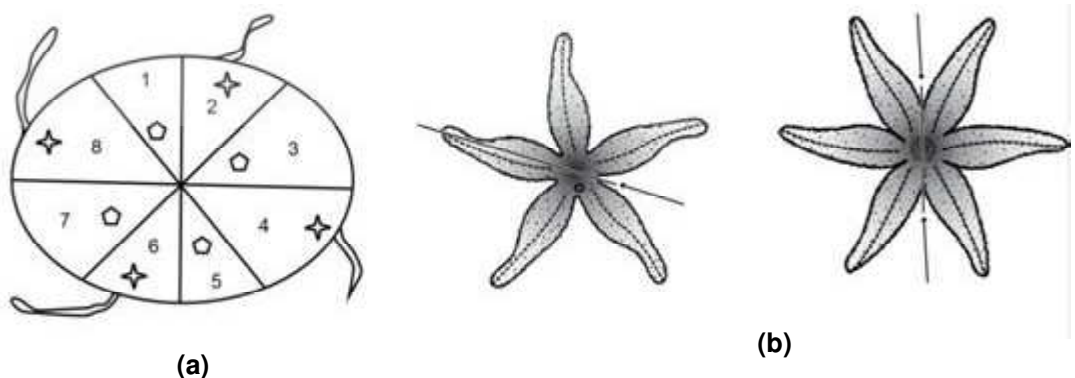


Fig. 2.4 : a) Biradial symmetry in comb jelly, notice that, opposite parts are similar but adjoining parts are different. Such an arrangement of some structures in radially symmetrical animals results in biradial symmetry; b) pentaradial symmetry as seen in starfish.

Spherical Symmetry

This type of symmetry is seen in some unicellular forms and is rare in animals. It means that any plane passing through the organism's center is able to cut it into many identical halves. Spherical symmetry is best suited for rolling and floating and is seen in the unicellular radiolarians and heliophytes (Fig. 2.5).

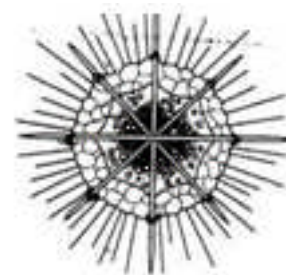


Fig. 2.5: Spherical symmetry as seen in a radiolarian.

SAQ 3

- i) Which of the following is not true for animals with radial symmetry?
 - a) No front and back ends b) Are always sessile
 - c) No left or right sides d) Face the environment from all sides
- ii) Match the following:

a) frontal plane	I) Divides body into left and right
b) sagittal plane	II) Only one imaginary line divides the body into mirror images
c) bilateral symmetry	III) Cannot be divided into mirror images
d) asymmetrical	IV) Divides body into dorsal and ventral parts

2.3.2 Germ Layers and Body Cavity

In the previous sub-section you learnt that metazoans can be placed basically in two groups on the basis of their body symmetry. Metazoans can be further divided in two groups based on the number of germ layers formed during embryogenesis. Germ layers are groups of cells that behave as a unit during early stages of development. These germ layers give rise to all the tissues and organs of the body of the adult. Animals that develop from only two germ layers that are formed by cell movement into the embryo's interior are called **diploblastic**. They have an outer layer of cells the **ectoderm** and inner layer of cells called **endoderm**. Between these two layers is a matrix of non-cellular jelly like substance known as *mesoglea* which binds the two cell layers. Only two groups of animals Cnidaria and Ctenophora are diploblastic. For example, if we cut a longitudinal section of *Hydra* which is a cnidarians, we can see two distinct layers bound together by a non-cellular mesoglea (Fig. 2.6). All the cell types in cnidarians and ctenophores develop from these two germ layers. Rest of the animals from platyhelminths to mammals are **triploblastic** as the embryonic endoderm gives rise to a third layer of cells the **mesoderm** which always lies between the outer ectodermal tissue and inner endodermal tissue.

All animals possess some kind of body cavity, the most primitive type is seen in poriferans (sponges) and cnidarians. Sponges have a cavity which is called spongocoel (see Fig. 2.7 in margin) in which the water along with the food particles enters through the ostia and leaves by the osculum or the mouth of the sponge while in cnidarians the body cavity is known as coelenteron or gastrovascular cavity (see Fig. 2.6 again) but this is different from the body cavities found in triploblastic animals.

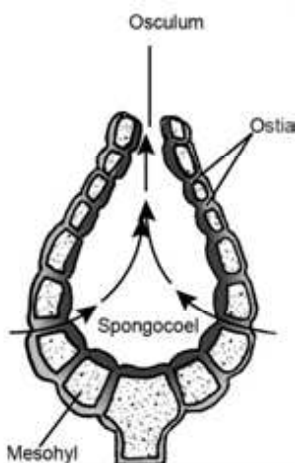


Fig. 2.7: Spongocoel in a poriferan.

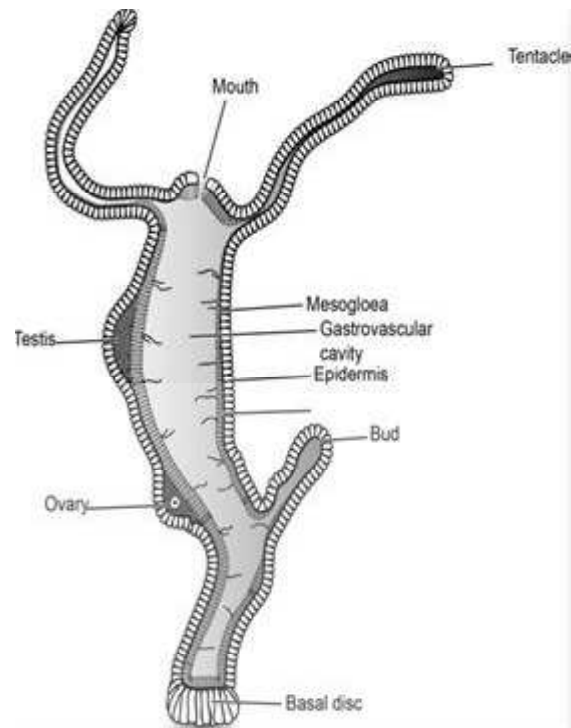


Fig. 2.6: Longitudinal section of *Hydra* showing the different types of cells that have their origin in the two germ layers.

Triploblastic animals have been further divided into three sub-groups of body plans based on the presence or absence of an internal body cavity between the outer body wall and the gastric cavity; and if present, how this cavity is formed during embryogenesis. Some triploblastic animals that do not have an internal body cavity are called **acoelomate**. The space between their ectoderm and endoderm is solid and filled with mesodermal cells (Fig. 2.8 a). The internal cavity does not form at all during embryogenesis.

Some triploblastic animals have a fluid filled internal cavity between the outer body musculature and the endoderm of the gut. This kind of space is termed *pseudocoel* and the animals possessing it are called **pseudocoelomate** (with false coelom). *The mesoderm in such animals does not surround the gut cavity but lines only one side of the blastocoel* (Fig. 2.8 b).

Triploblastic animals that have an internal fluid filled cavity lined completely by tissue derived from mesodermal cells are called **eucoelomates**. They have a true coelom that is formed by two different methods, a characteristic that has been used to assign the triploblastic animals to one of two major groups viz. the protostomes and deuterostomes. In **protostomes** the mesoderm cells fill the blastocoel forming a solid band around the gut; then by programmed cell death a space forms inside the mesodermal band. This space enlarges to form the coelom. This process is termed **schizocoely** (see Fig. 2.8 c).

Among **deuterostomes** on the other hand, the cells from the center of the gut wall begin to outpocket into the embryonic blastocoel. The expanding pouch wall forms a mesodermal ring enclosing a space. This space enlarges and merges to become the coelomic cavity. Because the coelom is formed from the gut wall, this type of formation is termed **enterocoely** (Fig.2.8 d).

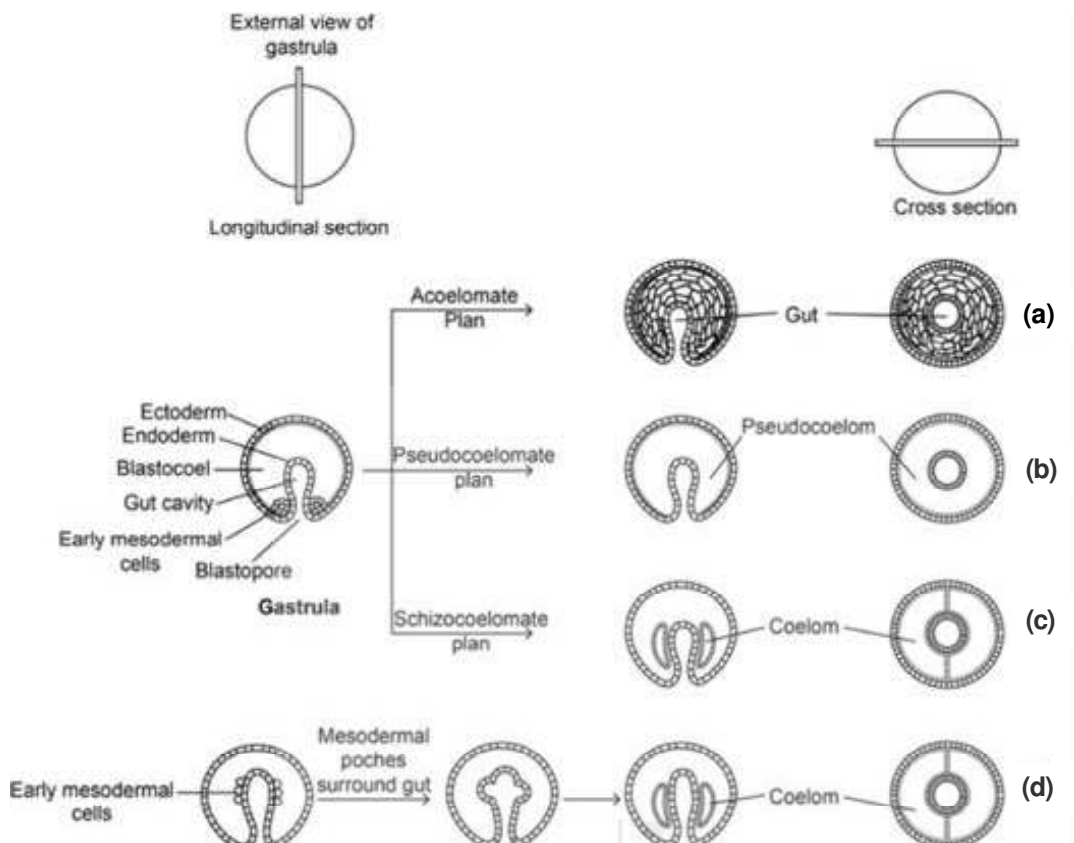


Fig. 2.8: Diagrammatic representation of the three body plans based on the presence or absence of an internal body cavity and how that body cavity is formed during embryogenesis; a) acoelomate plan; b) pseudocoelomate plan; c) schizocoelous eucoelomate plan found in protostomes; d) enterocoelous eucoelomate plan seen in Deuterostomes.

Whatever the method of formation, the end result is the same, that is, a fluid filled internal body cavity between the outer body wall musculature and the gut that is lined by an epithelium known as **peritonium** derived from the mesoderm. The organs of the body are suspended in the coelom by mesenteries formed by the peritoneum. A pseudocoelom lacks this peritoneum.

The coelom provides the *tube within a tube* type of body plan for triploblastic animals, which provides greater flexibility when compared to animals that do not have a coelom. The fluid filled coelom additionally serves as a hydrostatic skeleton in some forms such as worms, aiding in burrowing and in movement. The coelom is of great significance in animal evolution. It is the stepping stone for evolution of more complex and larger body forms.

SAQ 4

- An animal whose body cavity is lined with..... is called coelomate.
- The body cavity in triploblastic animals that is formed between the mesoderm and endoderm is a
- The coelom that is formed by the evagination of cells of the gut wall is termed
- The coelom that is formed by enlargement of the split in the mesoderm is termed

2.3.3 Developmental Patterns

Apart from the type of coelom formation, based on certain characters in early development, triploblastic animals can be placed into two large groups:

Protostomia and **Deuterostomia**. These terms were given to reflect the difference in origin of the embryonic mouth (*stoma*=mouth).

In Protostomia the **blastopore** of the embryo forms the mouth and the anus develops later. The pattern of cleavage (see Box 2.1) in the embryo is **spiral and determinate** (Fig. 2.9). This means that the planes of cell division are diagonal to the vertical axis of the embryo as seen in Fig. 2.9 e, where the smaller cells are centered over the grooves between the larger cells below them. The developmental fate of each cell in the embryo is fixed that is, each cell even in the 4 cell stage if isolated, cannot develop into a complete individual but gives rise to a defective embryo. Platyhelminths, nematodes, molluscs, annelids, arthropods are the animal groups that are placed in Protostomia.

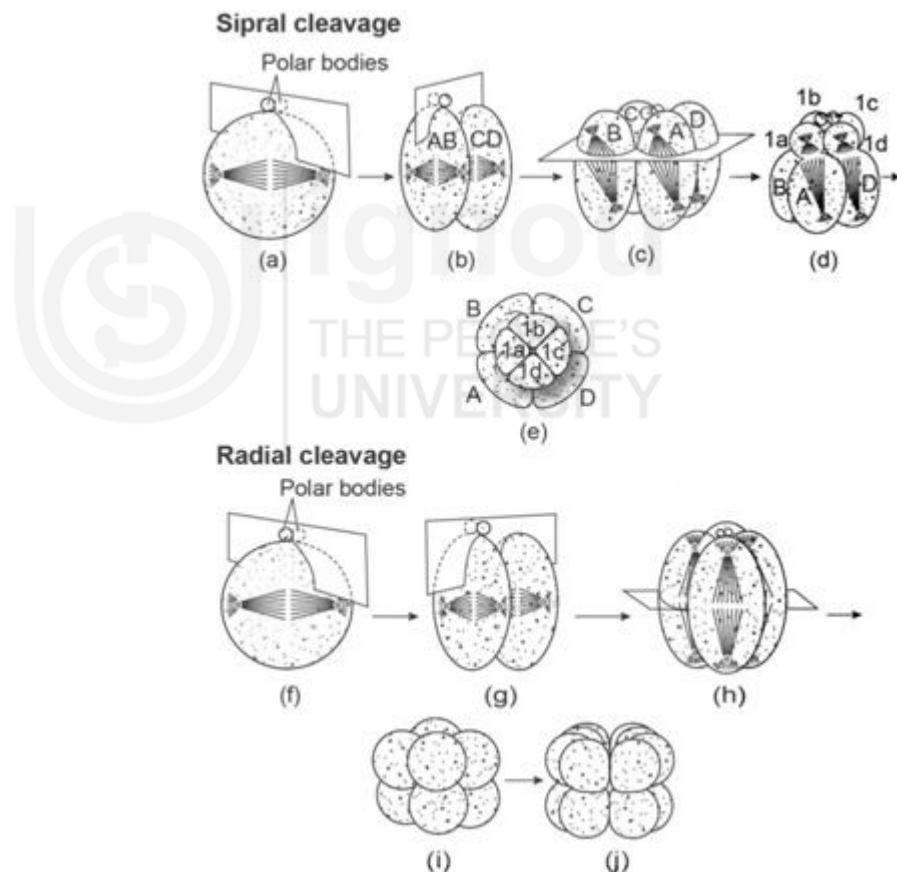


Fig. 2.9: Patterns of cleavage. The first two divisions in the zygote are vertical and similar in both spiral and radial cleavage (a, b, f, and g), however, the third and fourth divisions (c and d) in spiral cleavage are oblique to the polar axis resulting in blastomeres that do not lie exactly one above the other as found in radial cleavage (i and j) but above the furrows between the blastomeres lying below (e).

In contrast, among Deuterostomia the anus forms first from the blastopore and the mouth forms later and the pattern of cleavage in the embryo is **radial and indeterminate**. The cleavage planes are either parallel or perpendicular to the vertical axis of the embryo as seen in Fig. 2.9 f to h. You can note that the cells

are aligned one on top of the other. Indeterminate cleavage means that each cell produced by the early embryo, if separated, can give rise to a complete well formed embryo. It is the indeterminate cleavage in the human embryo that forms identical twins.

Hemichordates, echinoderms, chordates are placed in the group Deuterostomia.

Box 2.1

After fertilization the zygote divides forming two cells, these re-divide further to form four, then eight cells and so on till a ball of cells forms; this is known as **morula**. The cells of this ball are known as **blastomeres**. The planes of the first and second cleavage (cell division) are vertical passing through the axis but at right angles to each other. These two cleavages form the four blastomeres lying side by side around the axis. The plane of the third cleavage is horizontal, at right angles to the first two planes and to the axis. Therefore, it is parallel to the equator of the zygote. This gives rise to eight cells or blastomeres, four lie on top of the other four.

This arrangement of blastomeres in the zygote and pattern of cleavage can be of two types:

- i) **Spiral cleavage:** Where the first two divisions are vertical and similar to radial cleavage but the third and fourth cleavage planes are oblique to the polar axis and resulting blastomeres do not lie on top of each other, but above the furrows between the cells lying below. The spindles of cell during third cleavage are arranged in a spiral, therefore, the name spiral cleavage. Spiral eggs are said to be determinate and mosaic, that is, the organ forming area of the egg are strictly localised from the very beginning.
- ii) **Radial cleavage:** Where the cells are formed one on top of the other. It is indeterminate and regulative, because the fate of each blastomere of the early embryo is not yet determined and if separated, it can regulate its development.

You will learn more about the different types of cleavage in a later course.

SAQ 5

In addition to formation of coelom, what other characteristics differentiate protostomes from deuterostomes?

2.3.4 Segmentation

Segmentation is the division of the body into smaller transverse compartments along the longitudinal axis of the body. It is another common feature of the metazoan body plan. Each segment is called a metamere or a somite. True segmentation occurs in annelids, arthropods and most chordates though some other groups show superficial segmentation of the ectodermal body wall.

Segmentation permits greater body mobility and complexity of structure and function. It divides the body into a series of compartments in which

appendages, musculature, ganglia, nerves, blood vessels, coelom and all other body organs are replicated. This arrangement is best seen in annelids and you will learn more about true segmentation as seen in annelids in Unit 7. In chordates, segmentation is usually apparent in the axial skeleton, muscles and nerves (Fig. 2.10).

In the next section we will discuss the prevalent hypothesis regarding the origin of metazoans and the phylogeny of living animals.

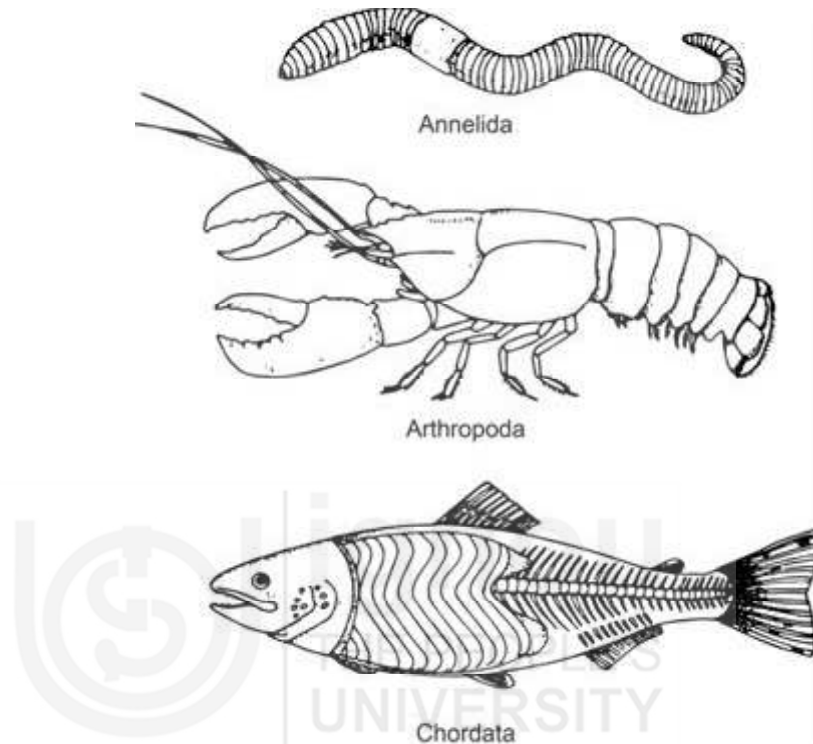


Fig. 2.10 : Segmentation as seen in three phyla: in earthworm (an annelid); lobster (an arthropod) and fish (a chordate).

2.4 ORIGIN AND DIVERSIFICATION OF METAZOA

Ediacaran hill in Australia became famous because some of the oldest fossils of animals were discovered there in 1946.

The fossil record of early metazoans is extremely fragmentary. The earliest known fossils of metazoans have been found from Ediacaran period (from 600 to 545 mya) in various parts of the world like in Canada, Australia, Russia and southern China in rocks dated 540 to 635 mya. Researchers have found fossilized biochemical evidence that suggests that the common ancestor of all living animal species may have existed about 770 mya. What would have this common ancestor looked like and how did unicellular organisms give rise to multicellular organisms is a subject of debate amongst zoologists.

2.4.1 Origins of Multicellularity

Recall that we had said earlier in the unit that animals along with fungi, choanoflagellates and some other groups of unicellular organisms are placed in a super group called Opisthokonta. Molecular studies and cDNA studies show that among the opisthokonts, choanoflagellata is a sister group of Metazoa. Morphological and phylogenetic evidences in support of their relationship have been cited.

1. Choanoflagellates have flagellated collar cells that are similar in structure to choanocytes found in sponges and some cnidarians and echinoderms (Fig. 2.11). Sponges are morphologically the simplest multicellular animals and considered the basal group of Metazoa and this position is supported by molecular studies.

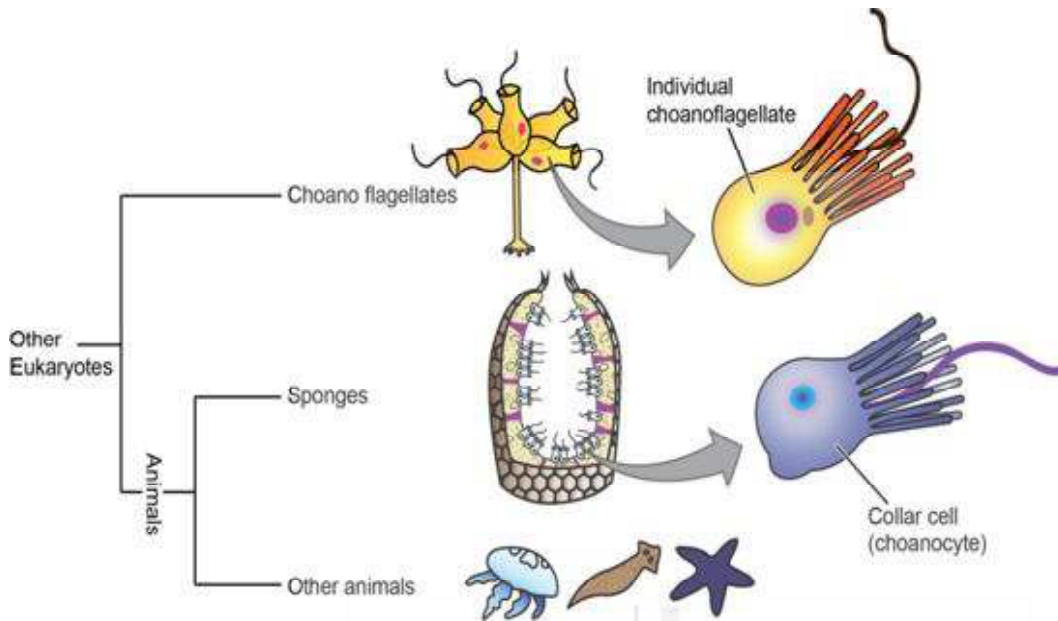


Fig. 2.11: Similarity between choanoflagellata and sponges.

2. Flagellated sperms are present in all metazoans.
3. Genes that code for certain proteins that have a role in cell-to-cell adhesion, cell to matrix adhesion and cell signaling, that were known only from Metazoa, have now been found to be homologous to genes that have similar function in choanoflagellates. Similar genes for cell adhesion and cell signaling have also been found in other unicellular organisms indicating that cell signaling predated the transition from unicellularity to multicellularity.
4. Molecular phylogeny shows that colony formation arose early in the choanoflagellate lineage. Among the living choanoflagellates *Proterospongia* is a colonial form that is able to propel itself by the action of its flagella in water.

This brings up the question: whether the common ancestor of Choanoflagellata and Metazoa was a colonial or a unicellular organism? Several hypotheses were suggested to explain the origin of Metazoa. The most prevalent hypothesis is that they arose from colonial flagellated forms in which the cells gradually became more differentiated and interdependent.

The colonial flagellate hypothesis that was first proposed by Haeckel in 1874 with several later revisions, has been in favour for more than a century. In this classical scheme metazoans descended from a hollow spherical colony of flagellated cells.

This hypothetical organism was named **blastaea** and was considered to be similar to the blastula stage of the present day metazoans.

Similar structure and organisation of cells is also seen in the colonial phytoflagellate, *Volvox* and the colonial choanoflagellate *Proterospongia*. Though molecular data shows that metazoans did not arise from *Volvox*, rather they evolved in parallel.

This premetazoan may have been a sphere of mono-flagellated collared cells that adhered to each other by a gelatinous extra cellular matrix in which the cells may have been embedded (Fig. 2.12 a, b).

There must have been a distinct anterior-posterior axis in the premetazoa and it may have swum with the anterior end forwards. This hypothetical structure resembles the blastula stage seen in metazoans (Fig. 2.12 c).

The individual cells in the colony became differentiated into specific cells like reproductive cells, feeding cells, sensory cells and somatic cells, thus allowing the colonial organisms to work as a whole. The blastaea became double walled by invagination of its cells. The colonial form must have been radially symmetrical.

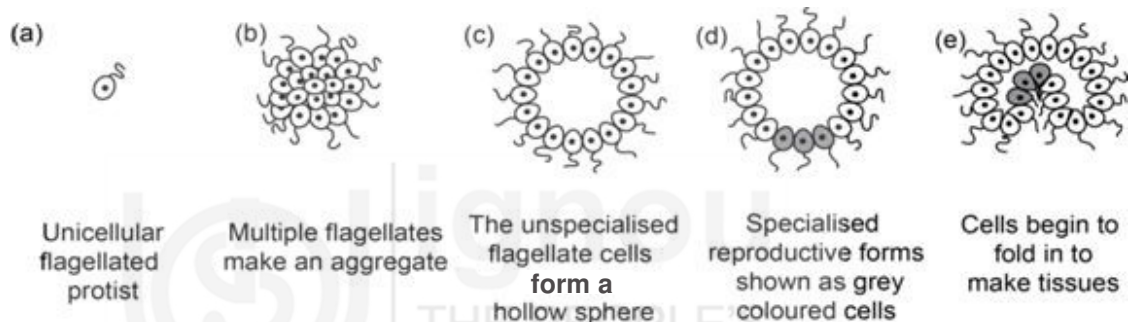


Fig. 2.12: Colonial flagellate hypothesis of the origin of Metazoa.

Metchnikoff (1887) revised the hypothesis suggesting that instead of invagination there must have been an ingress (wandering inside) of cells resulting in a solid organism, may be like the planula larva of the cnidarians and ctenophorans. This organism did not have a mouth and cnidarians and the extant ctenophores may have arisen from this form (Fig. 2.13).

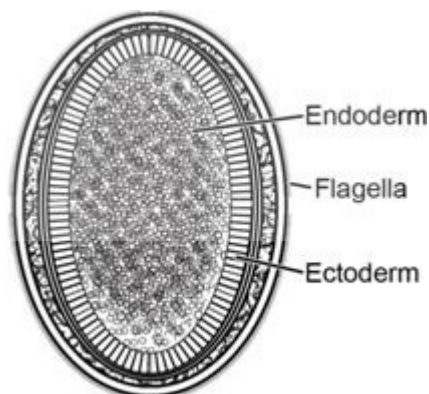


Fig. 2.13: Planula larva like ancestor.

Some of these planula like organisms might have settled at the bottom of the oceans and adopted a creeping form of locomotion developing a dorsal and ventral surface. A ventral mouth may have formed along with a start in cephalisation. This would have given rise to the earliest acoelomorphs and to the ancestors of all bilaterians. However, there are still many alternate views.

As more molecular evidences come to light, the origin of metazoan will become clearer.

2.4.2 Diversification and Phylogeny of Animals

In Section 2.3 we have discussed the grouping of animals into informal taxa that are intermediate between the phylum and animal kingdom by using characteristics of body design and architecture. Fig. 2.15 shows the diversification and phylogeny of living animal groups. Zoologists recognise about 36 phyla of living animals, of which only 15 major phyla are shown in our figure. The following inferences can be made about the relationships among the selected groups of animals shown in the figure:

1. All animals share a common ancestor and all extinct as well as extant animal lineages seem to have descended from it.
2. Among the extant animals Porifera branch out near the base of the tree. Molecular studies indicate that these must have been the first metazoans.
3. Eumetazoa are the animals with true tissue grade organisation. These can be divided into group Radiata including the Ctenophora and Cnidaria that are diploblastic having radial symmetry and group Bilateria which includes all the remaining eumetazoan phyla. These animals have bilateral symmetry and three germ layers (triploblastic).
4. Bilaterians can be acoelomates, pseudocoelomates and eucoelomates. They can be divided into **Protostomia** and **Deuterostomia** based on their embryonic development and formation of coelom. Protostomia are classified into two major groups **Lophotrochozoa** and **Ecdysozoa**. Lophotrochozoans include animals that possess a crown of tentacles that function in feeding called **lophophore** or have a distinct developmental stage called the **trochophore** as seen in Mollusca and Annelida (see Fig. 2.14).

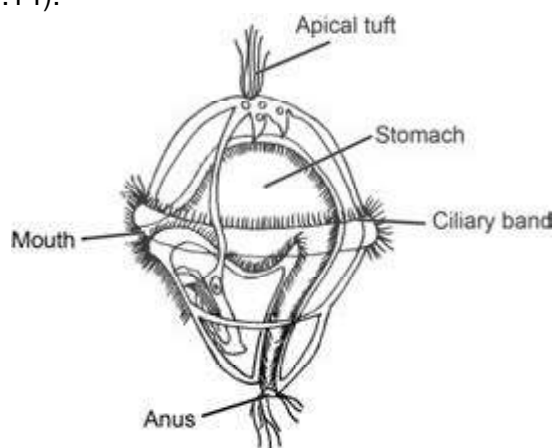


Fig. 2.14: Trochophore larva as seen in molluscs.

Ecdysozoans, include the nematods and arthropods that share a common feature of secreting an external skeleton. As the animal grows, it sheds the outer covering or moults. This process of shedding the old exoskeleton is known as **ecdysis**. Deuterostomia includes the echinoderms, hemichordates and chordates; all of these phyla consist of invertebrates except for one phylum Chordata that also includes the vertebrates i.e., animals with a backbone.

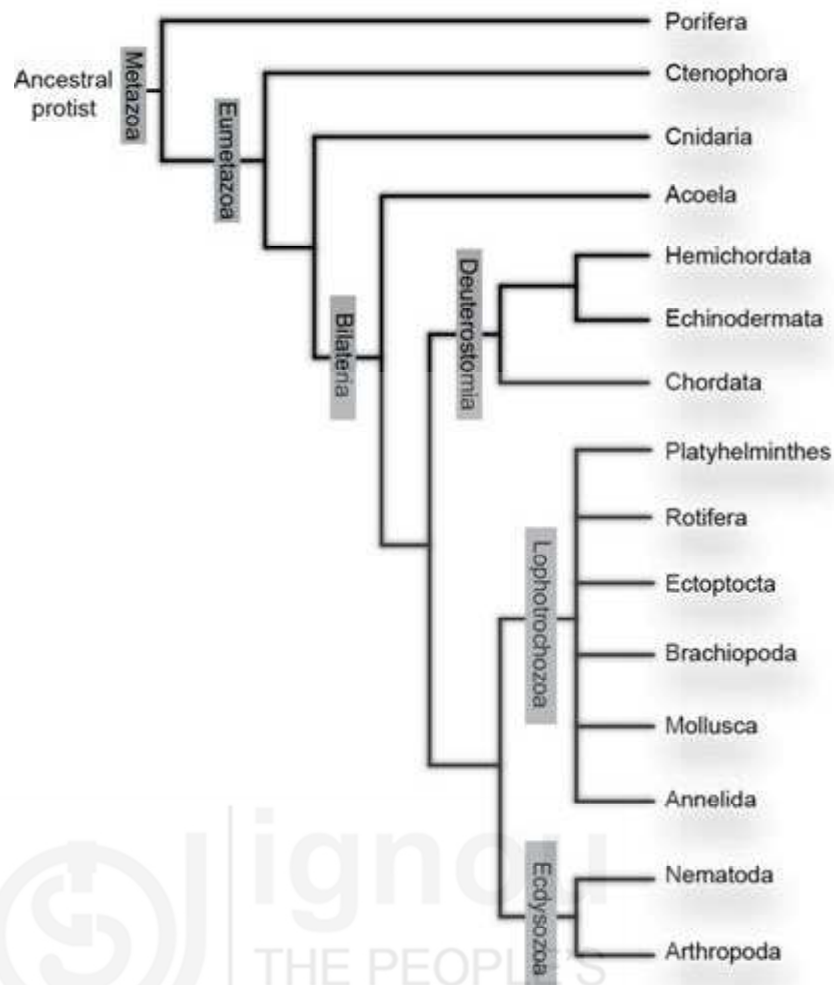


Fig. 2.15 : Phylogeny of major extant metazoan phyla (redrawn after Biology: A Global Approach).

At present the evidence in support of the relationship shown in Fig. 2.15 seems strong, but this is really a work in progress and as more evidence accumulates these phylogenies may change as science is an ongoing process of inquiry. In the following units we will explore the classification and characters of the major animal phyla along with their inter-relationships.

2.5 SUMMARY

In this Unit you have studied:

- The fundamental principles of taxonomy and systematics that are used to identify all species of biological organisms, access their evolutionary relationships and express these relationships in terms of classification systems. The immense diversity of organisms is arranged in units known as taxa according to their common features and evolutionary relationships.
- The binomial system of nomenclature of organisms and modern concept of species based on reproductive isolation, morphological features and sequence analysis of standard genes present in all animals of species. These species are grouped in hierarchy of increasingly inclusive

categories or taxa. The modern system of classification that is widely accepted is that all living organisms exist in three domains of Archaea, Bacteria and Eucarya. All animal taxa are placed in the domain Eucarya with other unicellular nucleate organisms fungi and plants.

- That every animal has an inherited body plan based on grade of organisation, body symmetry, number of embryonic germ layers and presence or absence of a body cavity. Majority of animals are bilaterally symmetrical (Bilateria) with a few groups showing radial symmetry (Radiata). Most animals are triploblastic except cnidarians and ctenophores that are diploblastic. Sponges do not have germ layers as they possess a cellular grade of organisation.
- That all animals except sponges have a gut cavity and most animals have a second cavity surrounding the gut which may be a coelom or a pseudocoelom. Triploblastic animals can be further grouped into protostomes and deuterostomes depending on their embryonic development. Protostomes can be further divided into lophotrochozoans or ecdysozoans based on their embryonic developmental patterns.
- That fossilized biochemical evidence has suggested that the common ancestor of all living animal species may have existed 770 mya. Molecular and c DNA studies as well as morphological and phylogenetic evidences support the most prevalent hypothesis on the origin of multicellular animals – that the choanoflagellates and metazoans are most closely related. They probably had a common ancestor which might have been a colonial flagellate in which the cells gradually became differentiated for different functions and became interdependent. However, the origin of multicellular animals is under debate.

2.6 TERMINAL QUESTIONS

1. Which animal group is considered to be the basal group? Explain giving reasons.
2. Make a flow chart to show how animals can be classified informally according to their level of organisation, symmetry, germ layers and developmental patterns.
3. Discuss the most widely accepted hypothesis for the origin of metazoans.
4. Define bilateral symmetry. What are the advantages that bilaterally symmetrical animals have over radially symmetrical animals?

2.7 ANSWERS

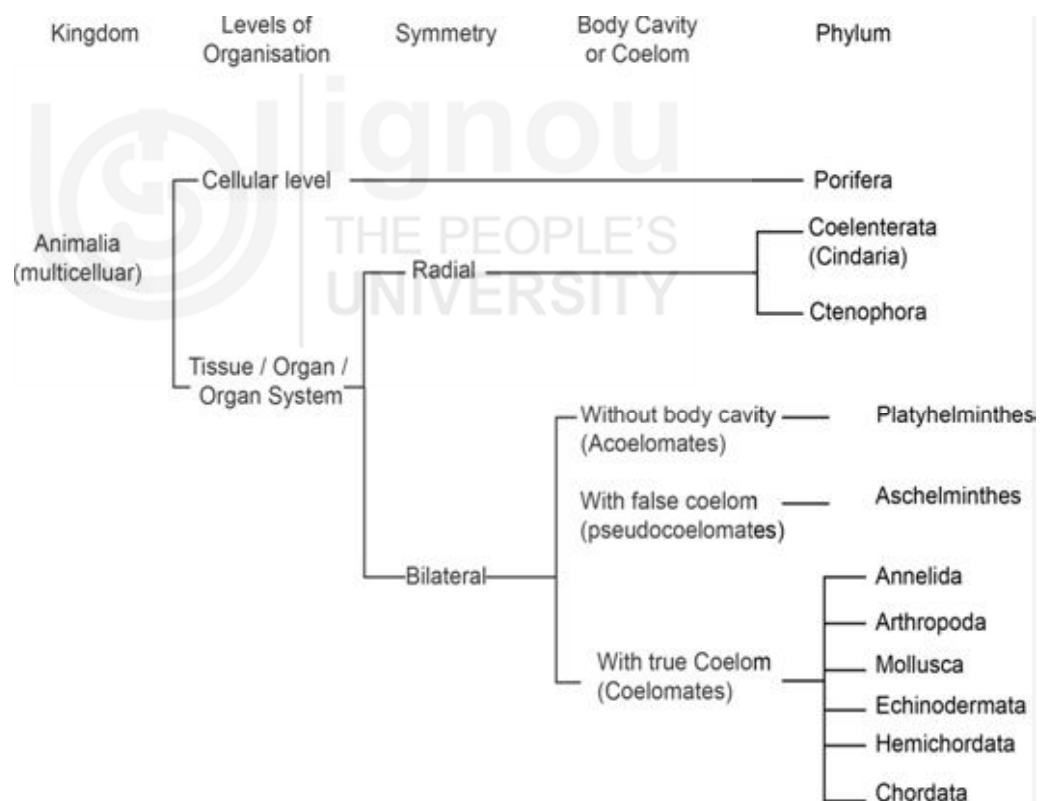
Self-Assessment Questions

1. HINT: Biological species uses the criterion that no reproduction can occur between different species. While phylogenetic concept of species uses the criterion of common ancestry. A possible definition combining the two concepts could be: A group of interbreeding individuals arising from a common ancestor that can produce viable and fertile offspring.

2. i) c; ii) b; iii) c; iv) d.
3. i) b;
ii) a) IV; b) I; c) II; d) III.
4. i) mesoderm; ii) pseudocoelomate; iii) enterocoelom;
iv) schizocoelom.
5. Protostomes: cleavage is spiral and determinate, blastopore forms mouth.
Deuterostomes: Cleavage is radial and indeterminate, blastopore never forms mouth but forms the anus and another opening forms the mouth.

Terminal Questions

1. Poriferans are considered the basal group of animals. Molecular studies suggest that they are the first metazoans. They have many similarities with colonial coanoflagellates. You can elaborate these similarities like collar cells, flagellated cells, no distinct cell layers in their larva etc.
2. Chart for classification of Animalia.



3. The most prevalent hypothesis is that they arose from colonial flagellated forms in which the cells gradually became more differentiated and interdependent. Elaborate the answer giving supporting argument.
4. Bilateral symmetry is seen in animals that can be divided into two mirror images if a plane runs through their anterior-posterior axis. Bilateral animals evolved cephalisation and could move in one direction. They were able to move faster than radial animals.

UNIT 3

PHYLUM PORIFERA

Structure

3.1	Introduction	3.3	Canal System
	Objectives		Asconoid Type
3.2	Porifera (Sponges)		Syconoid Type
	Characteristic Features		Leuconoid Type
	Classification	3.4	Summary
		3.5	Terminal Questions
		3.6	Answers

3.1 INTRODUCTION

In Unit 2 you have studied that the animals such as protists are unicellular eucaryotes which include protozoans and algae. You also learnt that multicellular organisms can be categorised according to the levels of body organisation. In this unit we shall study the simplest multicellular animals, the poriferans or sponges which are placed in Kingdom Animalia. Organisms in this phylum have different cell types for different functions but the cells are not organised into true tissues. Unlike most other metazoans, sponges lack nerves and true musculature. They do not have any formed organs or organ systems. Their cells are functionally independent to the extent that an entire sponge can be dissociated into its constituent cells in the laboratory and these cells can come together again and in some species reform the sponge.

Objectives

After studying this unit, you should be able to:

- ❖ recognise the characters of phylum Porifera;
- ❖ describe the characteristic features of different classes of the phylum;
- ❖ give example of various classes of phylum Porifera; and
- ❖ describe the canal system in sponges.

3.2 PORIFERA (SPONGES)

The word “porifera” has been derived from Latin words ‘porus’ (pore) and ‘fera’ (bearing), meaning pore-bearing organisms. Porifera or ‘sponges’ are multicellular

animals incapable of making movement as they are attached to the substratum like a plant (sessile). The group includes more than 5000 described species. Mostly marine, sponges show a wide variety of form and are found at all depths. Though they are generally vase like, they may be branched or irregular, cup-shaped, mushroom-shaped, varying in size from 1 mm to 1 meter.

3.2.1 Characteristic Features

As the name of the group indicates, the surface of the body presents a large number of minute pores called **ostia** (singular **ostium**). Through these ostia, water current enters the body cavity known as **spongocoel**. These pores actually lead into a system of channels (called canals) which, after permeating almost the whole body, open to the exterior by one or more large exhalant openings called **oscula** (singular **osculum**). This system of spaces connecting the inhalant pores or ostia with the exhalant oscula, is the **canal system**. The canal system may be simple as in the **asconoid** type or more complex as in **syconoid** and **leuconoid** types (Fig. 3.1). Through the canal system a continual stream of water is maintained by the action of the flagella. Thus the water enters the canal system through ostia and passes out through the oscula.

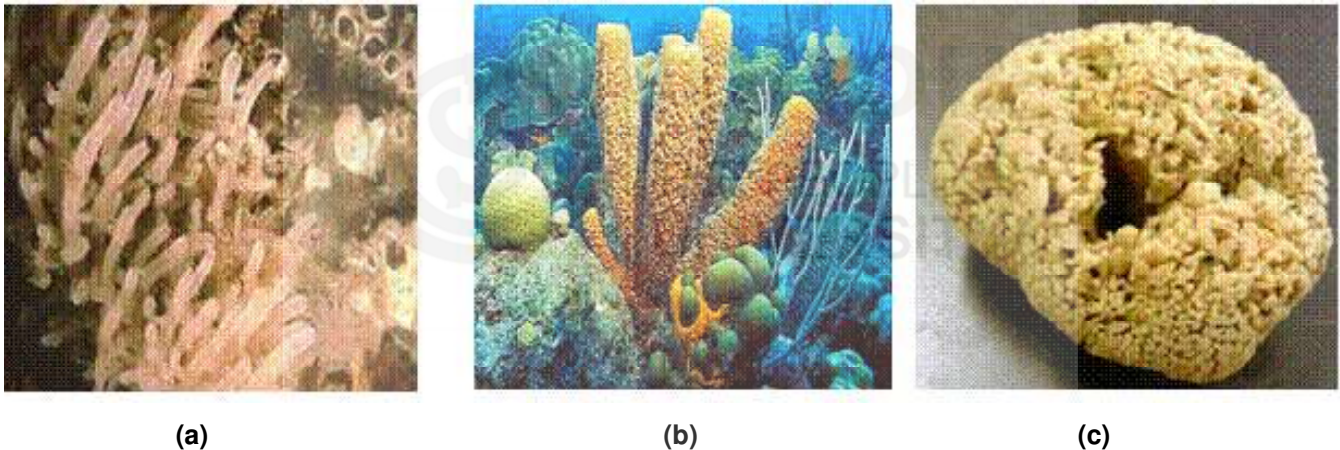


Fig. 3.1: Three types of sponge structure; a) *Leucosolenia* showing asconoid structure; b) *Sycon* showing syconoid structure; and c) *Euspongia* showing a complex leuconoid structure.

The sponge body is covered externally by an epithelial layer called pinacoderm. This layer is made up of flattened cells called **pinacocytes** (Fig. 3.2). These are thin leathery and tightly packed. Some of the pinacocytes are modified into **porocytes** by the formation of intracellular canal opening out through the ostium (Fig. 3.1). Some are modified as contractile myocytes arranged around oscula.

The chambers of the canal system are lined by ovoid, collar cells or **choanocytes** (Fig. 3.3), resembling in structure to choanoflagellate protozoans. These cells carry a flagellum surrounded by a contractile collar projecting into the sponge cavity. These cells are responsible for producing the water current of the canal system, and for food capture. Smaller food particles are engulfed by the choanocytes whereas the larger particles are passed on to archaeocytes or amoebocytes (Fig. 3.3), that are the principal sites of digestion.

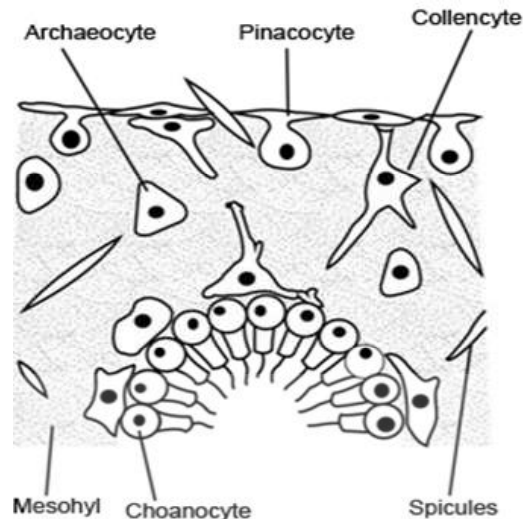


Fig. 3.2: Small section through sponge wall, showing four types of sponge cells. Pinacocytes are protective and contractile; choanocytes create water currents and engulf food particles; archaeocytes have a variety of functions; collencytes secrete collagen.

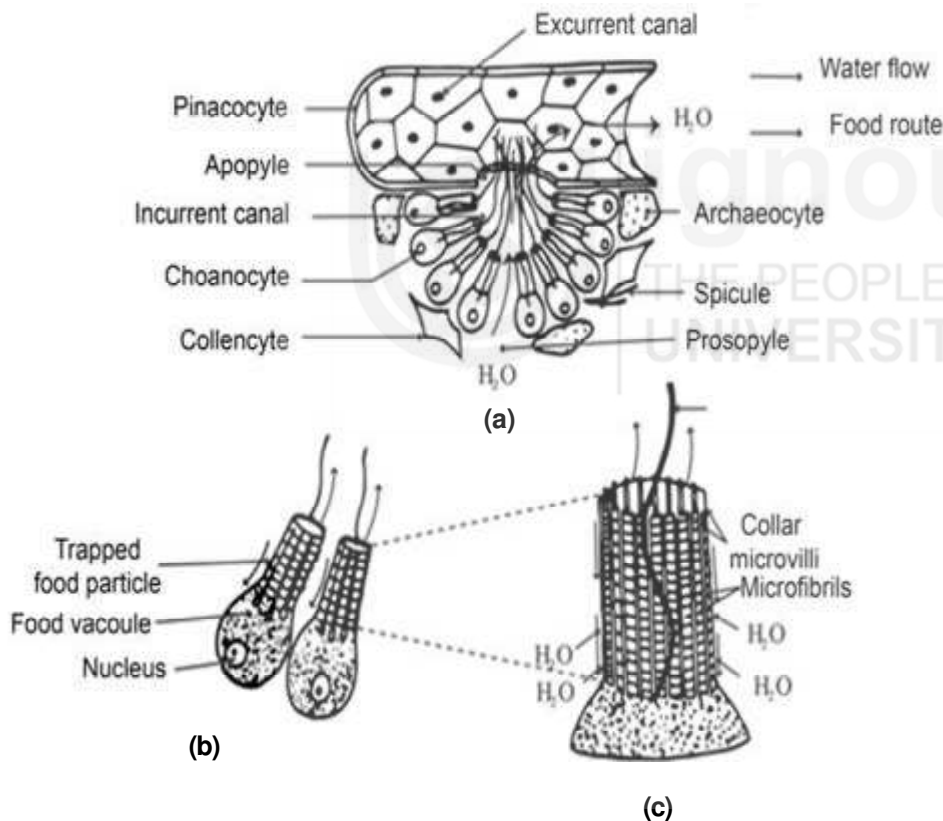


Fig. 3.3 : Food trapping by sponge cells: a) Cutaway section of canals showing cellular structure and direction of water flow; b) Two choanocytes; and c) structure of the collar. Small arrows indicate movement of food particles.

Between the epithelial layer and the choanocyte layer, is a gelatinous protein matrix called the **mesohyl** which contains amoeboid cells (archaeocytes) and skeletal elements. Archaeocytes are amoeboid cells that can move in the mesohyl and are modified to carry out different functions. They engulf food particles and are hence digestive in function. They carry the nutrition to other cells. Sclerocytes (Fig. 3.4) are specialised for secretion of tough skeletal

fibers, the spicules of the skeleton; spongocytes secrete a more flexible protein forming spongin fibres of the skeleton, collencytes and lophocytes secrete collagen.

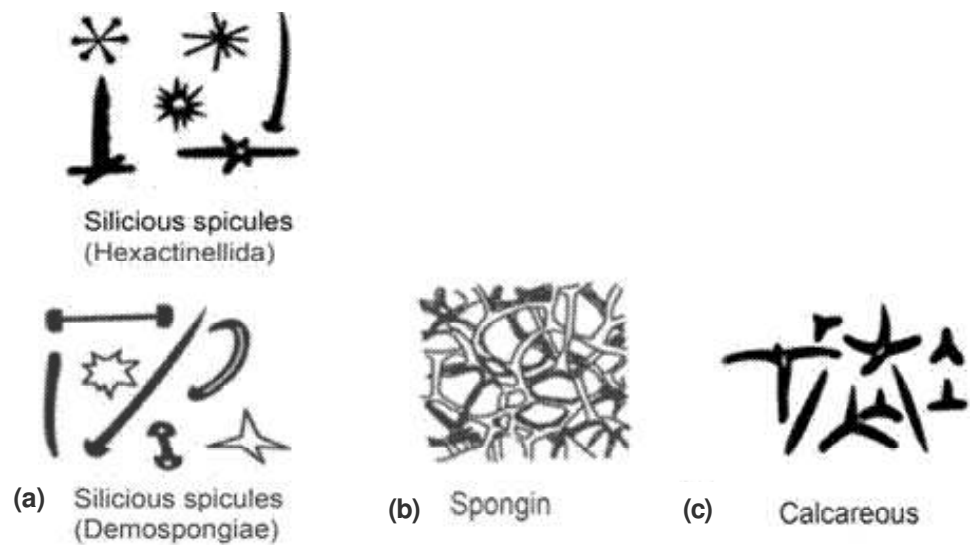


Fig. 3.4: a) Types of spicules found in sponges. There is amazing diversity, complexity, and beauty of form among the many types of spicules; b) Spongin fibres found in most sponges; c) Calcareous spicules.

The skeleton supporting the sponge body is mainly composed of spicules of various sizes and shapes. The spicules (Fig. 3.4) may be siliceous, or of calcium carbonate. The skeleton also consists of collagen and spongin. The spicules may have one, three, four or six rays. The structural variation of the spicules is of considerable importance in classification.

Most sponges are sequential hermaphrodites, meaning that each individual functions as both male and female, first as one sex and then the other. Sperms arise from choanocytes; oocytes arise either from choanocytes or archaeocytes. Cross fertilization occurs when the sperm from one individual that is functioning as male is attracted to another nearby individual functioning as female. The zygotes develop into flagellated larvae that are released from the parents and ultimately settle on a suitable substrate to develop into new individuals. In addition, internal buds or gemmules are formed from archaeocytes.

You have to clearly understand, in connection with histology of sponges, that the layers of the sponge body, namely, pinacoderm, mesohyal and choanocyte layer are not comparable to ectoderm, mesoderm and endoderm of higher animals.

3.2.2 Classification

Now that we have studied the characteristic features of Porifera, we shall discuss their classification giving examples of different classes.

The classification of phylum Porifera is based on type of canal system and chemical nature of spicules. Thus Porifera is divided into four classes: Calcarea, Hexactinellida, Demospongiae and Sclerospongiae.

1. **Class Calcarea:** These are characterised by the presence of spicules of calcium carbonate. Spicules are needle-shaped, or three- or four-rayed. All these sponges are marine, small, mostly less than 10 cm in height. These may be asconoid, syconoid or leuconoid. Examples : *Sycon* (Fig. 3.1b), *Leucosolenia* (Fig. 3.5).

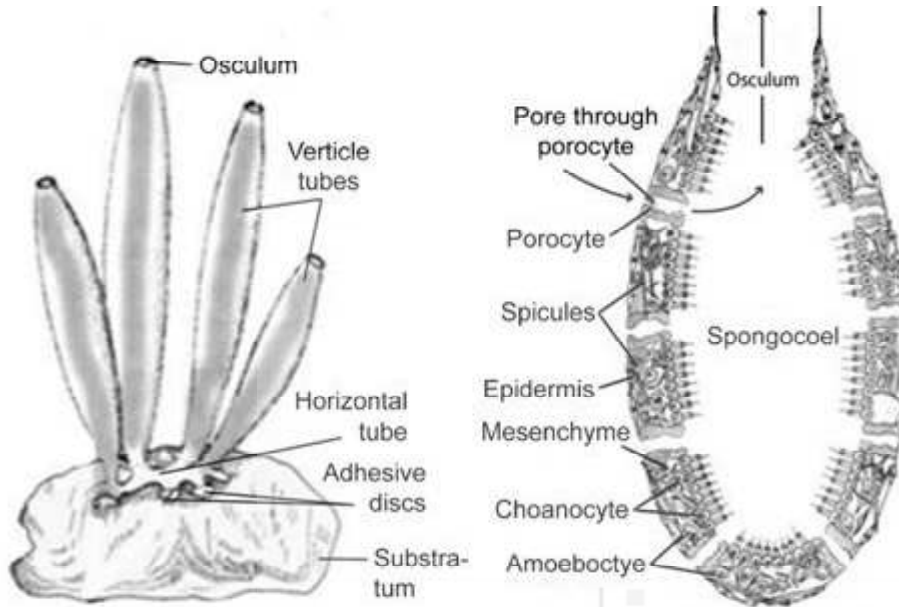


Fig. 3.5: *Leucosolenia*.

2. **Class Hexactinellida:** These are commonly known as glass sponges. Skeleton is made up of six-rayed siliceous spicules. Mostly deep sea sponges, radially symmetrical, with vase- or funnel-like bodies attached by stalks to substratum. Examples: *Euplectella* (Venus's flowerbasket) (Fig. 3.6), *Hyalonema* (Fig. 3.7). Mostly syconoid, 10-30 cm. No pinacocytes, but the outer layer is made up of net-like syncytium derived from interconnecting pseudopodia of amoebocytes.

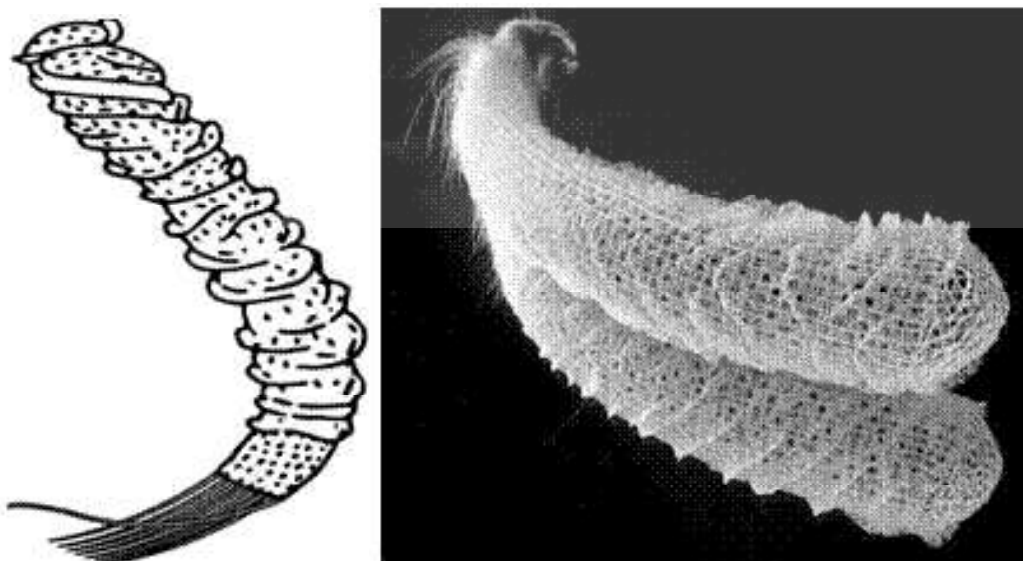


Fig. 3.6: *Euplectella*.

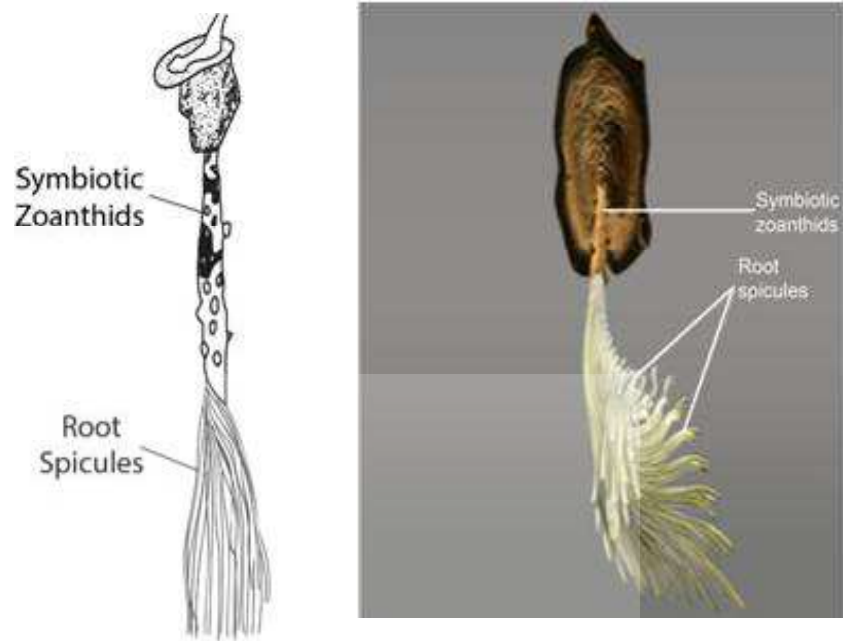


Fig. 3.7 : *Hyalonema*.

3. **Class Demospongiae:** This constitutes the largest class, with over 90% of all sponge species. The skeleton is made up of spicules of spongin or siliceous, or both; spicules not six-rayed. The bath sponges belong to the family Spongidae e.g., *Spongia* which has skeleton of spongin only. All Demospongiae are leuconoid. Some reach 1 m in size; usually brilliantly coloured. Some are fresh water e.g., *Spongilla* (Fig. 3.8), some bore into corals.

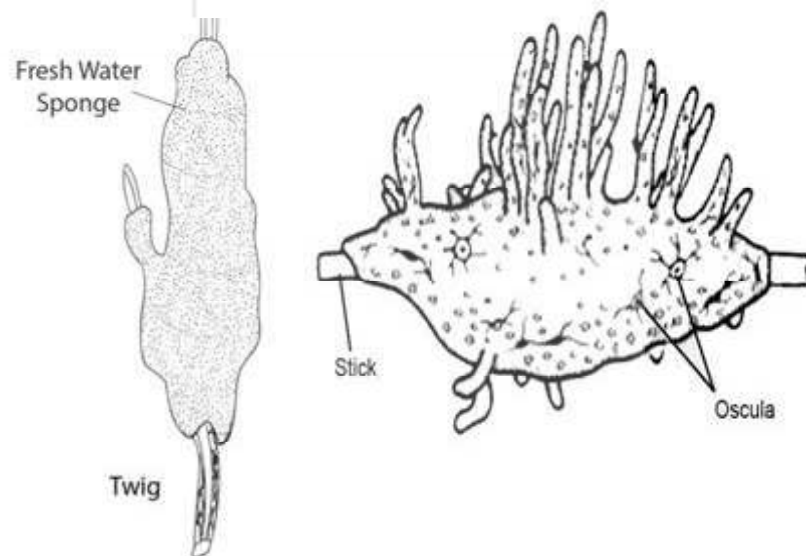


Fig. 3.8: *Spongilla*.

4. **Class Sclerospongiae:** These consist of a very small group of sponges which secrete a massive calcareous skeleton. Compound skeleton of siliceous spicules and spongin fibers is often present. The living tissue is limited to a thin superficial layer on the skeleton. All are leuconoid. They live hidden in crevices, caves and tunnels among coral reefs e.g. *Merlia* (Fig.3.9).

Fig. 3.9: *Merlia*.

3.3 CANAL SYSTEM

In sponges filter feeding is built around three anatomical designs such as *asconoid*, *syconoid*, or *leuconoid* type of canal systems that are as follows:

3.3.1 Asconoid Type

This is the simplest design with a hollow cylinder attached by its base to a substratum (Fig. 3.10 a). Body surface is covered by a single layer of flat cells of pinacoderm. The hollow interior, the atrium or spongocoel is lined by a layer of flagellated collar cells called choanoderm (collar skin). Cylinder wall is perforated by many ostia. At the upper, free end of the body there is a large opening, the osculum. The flagellated choanoderm creates a unidirectional water flow which enters the ostia, passes over the choanoderm enroute to the atrium, moves out through the osculum. This type of circulatory system of choanoderm, pores and chambers is called an *aquiferous system*. All asconoid sponges are small and have cylindrical or tubular bodies. The amount of water flow through the asconoid atrium depends on the flagellated choanoderm. Asconoid sponges include *Leucosolenia* and *Clathrina*.

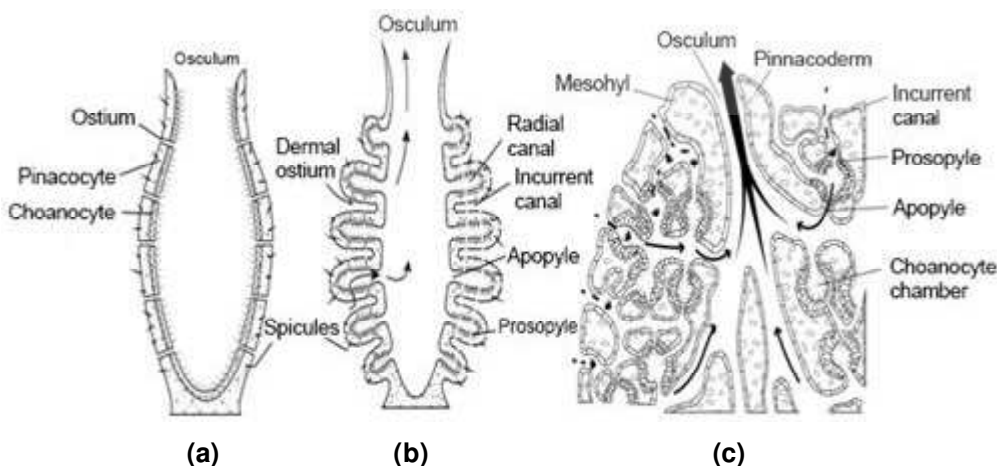


Fig. 3.10: a) Asconoid type canal system; b) Syconoid type canal system; c) Leuconoid type canal system.

3.3.2 Syconoid Type

The syconoid design (Fig. 3.10 b) increases surface area and reduces atrial volume by forming alternating inpockets and outpockets of the body wall. The out pockets of the choanoderm are called *choanocyte chambers* or *radial canals*. The inpockets of the pinacoderm are incurrent canals. Incurrent canals discharge into choanocyte chambers via numerous small openings known as prosopyles (means front gates). At the outer surface of the sponge, water may enter the incurrent canals directly or first pass through a narrow ostium formed by a secondary growth of tissue. Thus, water flow in the syconoid aquiferous system follows the route: ostia ® incurrent canals ® prosopyles ® choanocyte chambers ® atrium ® osculum. This new design of syconoid type decreases volume of atrium and increases the area of flagellated choanoderm. Therefore, syconoid sponges are generally larger in comparison with asconoid sponges. Syconoid sponges include *Grantia* and *Sycon*.

3.3.3 Leuconoid Type

As shown in Fig. 3.10c leuconoid design attains the largest body size ranging from a few centimeters to more than one meter. In leuconoid sponges water canal system is a complex net-work of water vessels which permeates a solid spongy body. It comprises spherical choanocyte chambers lying at the intersection of incurrent and excurrent canals (Fig. 3.10 c). Small diameter excurrent canals and quite often multiple oscula replace the comparatively voluminous atrium and single osculum of asconoid and syconoid sponges. Water enters a leuconoid sponge via surface ostia before flowing into incurrent canals (Fig. 3.10 c). From the incurrent canals, water passes through prosopyles into choanocyte chambers. Water moves out of each choanocyte chamber through an apopyle (back gate) and then flows through the excurrent canals that become progressively larger in diameter as they join with other excurrent canals. Large excurrent canals discharge water to the exterior via one or more oscula.

SAQ 1

Complete the following sentences inserting appropriate words in blanks:

- i) Porifera are cellular animals incapable of as they remain to the substratum like a
- ii) The sponge body is covered by an outer epithelial layer made up of
- iii) Sponges with skeleton made up of spicules of calcium carbonate belong to the class
- iv) Hexactinellida are characterised by the presence of spicules.
- v) The flagellated chamber of the canal system of sponges is lined by.....

3.4 SUMMARY

Let us summarise what we have learnt so far:

- Porifera are pore bearing multicellular animals that are incapable of making movement as they are attached to the substratum like a plant.
- Sponge body is covered externally by an epithelial layer called pinacoderm. The system of spaces connecting the inhalant pores or ostia with exhalent oscula is called canal system.
- Flagellated chambers of canal system are lined by ovoid, collar cells or choanocytes. Small food particles are engulfed by the choanocytes whereas the larger particles are passed on to archaeocytes or amoebocytes that are the principal sites of digestion.
- Phylum Porifera is divided into four classes such as, **Calcarea**, **Hexactinellida**, **Demospongiae** and **Sclerospongiae**.
- In sponges filter feeding is built around three anatomical designs like **Asconoid**, **Syconoid** or **Leuconoid type** of canal system.

3.5 TERMINAL QUESTIONS

1. Explain the characteristic features of sponges.
2. Describe canal system in Porifera.

3.6 ANSWERS

Self-Assessment Question

1. i) multicellular, movement, attached, plant
ii) pinacocytes
iii) calcarea
iv) six-rayed
v) choanocytes

Terminal Questions

1. As the name of the group indicates, the surface of the body presents a large number of minute pores called ostia. Through these ostia, water current enters the body cavity. Sponge body is covered externally by an epithelial layer called pinacoderm. The flagellated chambers of the canal system are lined by ovoid, collar cells or choanocytes resembling in structure like that of the choanoflagellate protozoans.
2. In sponges the filter feeding is built around three anatomical designs such as asconoid, syconoid and leuconoid canal system. Asconoid is the simplest design. Syconoid design increases surface area and reduces atrial volume by forming alternating inpockets and outpockets of the body wall. Whereas the leuconoid design attains the largest body size and in this water canal system there is a complex network of water vessels that permeates a solid spongy body.

PHYLUM CNIDARIA

Structure

4.1	Introduction	4.4	Polymorphism in Cnidaria
	Objectives		Polymorphism in Hydrozoa
4.2	Characteristic Features of Phylum Cnidaria	4.5	Summary
4.3	Classification of Phylum Cnidaria	4.6	Terminal Questions
		4.7	Answers

4.1 INTRODUCTION

In the last unit you have studied about phylum Porifera. All animals except sponges and a few other groups are eumatazoans (true animals) which is the group of animals with true tissues. You shall now study the organisation of animals placed in phylum Cnidaria, one of the oldest lineages which originated about 680 million years ago as shown by DNA analysis. Phylum Cnidaria, constituting Radiata, is some times referred to as coelenterates. They include more than 9000 living species, all aquatic, mostly marine but also some fresh-water forms. They are a successful group of animals, though of great structural and functional simplicity among metazoans. They include hydroids, jelly fishes, sea anemones, corals etc.

Objectives

After studying this unit, you should be able to:

- ❖ recognise characters of phylum Cnidaria;
- ❖ describe the characteristic features of different classes of animals placed in this phylum giving their examples;
- ❖ describe the basic organisation of the body of animals belonging to different classes of cnidarians; and
- ❖ explain the phenomenon of polymorphism in hydrozoa.

4.2 CHARACTERISTIC FEATURES OF PHYLUM CNIDARIA

Earlier zoologists have been more familiar with the name Coelenterata instead of Cnidaria, therefore, let's understand the difference between a coelenterate and a cnidarian. Earlier phylum Coelenterata included both cnidarians (hydra, jellyfish, sea anemone, corals) and ctenophores, later it was realised that they were quite different and could not be put together. Hence, the name Coelenterata was dropped and two phyla emerged – Cnidaria having jelly fish, anemone and corals and a minor phylum called Ctenophora.

Characteristic Features

1. All are aquatic animals.
2. All have radial symmetry.
3. Diploblastic, with an epidermis and a gastrodermis, and a less cellular or non-cellular, gelatinous mesoglea in between.
4. A gastrovascular cavity with a single opening, the mouth (usually called hypostome); tentacles encircling hypostome.
5. They have no coelom (body cavity), except for gastrovascular cavity, and no separate excretory or respiratory system.
6. Nerve net, (for diffuse conduction only), is present. Some sensory organs also occur.
7. No distinct muscle tissue, but an epithelio - muscular system is present.
8. Two forms of individuals - benthic polyps and pelagic medusae - occur. Polyps usually reproduce asexually by budding. Sexual reproduction in all medusae and some polyps, involving gametes. Cleavage holoblastic and indeterminate. A free swimming planula larva present.

Phylum Cnidaria has about 10,000 species. There are two forms of individuals in Cnidaria: the **polyp** and the **medusa**. Polyp is tubular, the oral end being free carrying a whorl of tentacles (called the proximate end), and the aboral end (called the distant end) attached to the substratum by the basal disc. The polyp is the sedentary, benthic form. The medusa is the free-swimming umbrella-like pelagic form, with mouth at the end of the manubrium on the sub-umbrellar side. Though polyp and medusa may appear to be quite different in form, they have basically the same plan with an outer layer of epidermis, and a gastrodermis lining the gastrovascular cavity, with a gelatinous layer of mesoglea in between them. The mesoglea in the medusa is, however, thicker (hence the term jelly fishes), and one form can be theoretically derived from the other, as could be easily understood from Fig. 4.1. The gastrovascular cavity serves as the alimentary canal, opening to the outside through only one opening, the mouth.

Body Wall

Structure of the body wall of cnidarians can be easily understood from a portion of the cross section of *Hydra* (Fig. 4.2). The outer epidermal layer is made up of five types of cells.

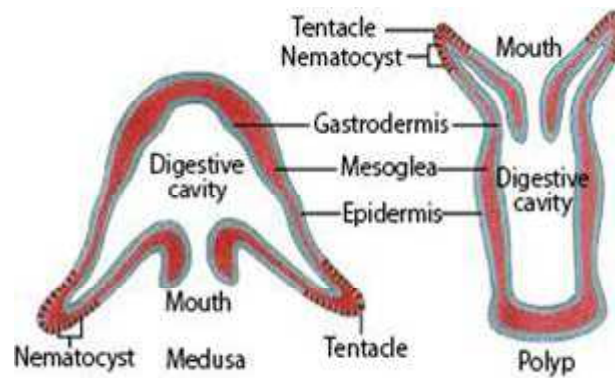


Fig. 4.1: Comparison of Medusa and Polyp.

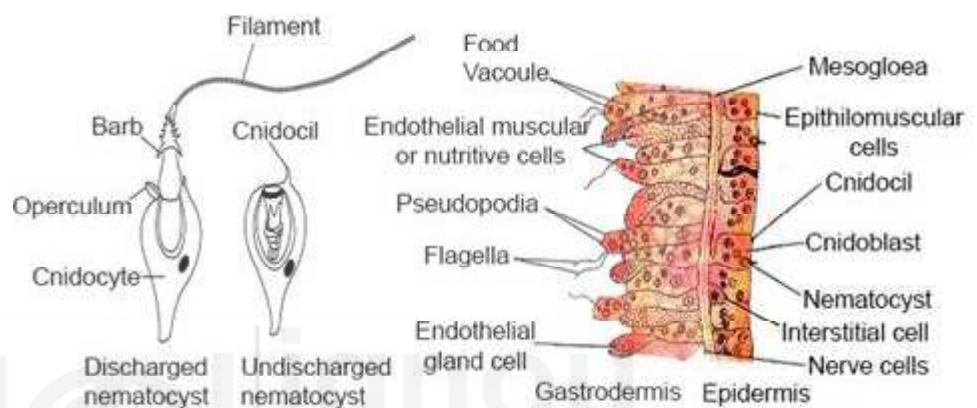


Fig. 4.2: At left, structure of a stinging cell. At right, portion of the body wall of a *Hydra*. Cnidocytes, which contain the nematocysts, arise in the epidermis from interstitial cells.



Fig. 4.3: Several types of nematocysts.

Epithelio muscular cells: These are columnar cells with basal contractile myofibrils extending parallel to the oro-aboral axis and are hence longitudinal fibers. Their contraction results in shortening the length of the animals.

Interstitial cells: These are undifferentiated cells found among the bases of the epitheliomuscular cells. These give rise to other types of cells.

Cnidocytes: During development these cnidocytes are called cnidoblasts. When fully formed the cnidocyte contains a stinging capsule called nematocyst containing a coiled tube (Fig. 4.3). This tube can be everted when discharged at will. At the base of the tube there are tiny sharp barbs. The capsule is covered with a lid i.e. the operculum. Cnidocyte also has a hair-like cnidocil, which acts as a trigger. The nematocyst contains a fluid of high osmotic pressure. When the prey touches the cnidocil, the permeability of the membrane covering the nematocyst changes and there is a sudden uptake of water into the nematocyst. This results in the eversion and discharge of the coiled tube, which is extended during the process. The coiled tube turns inside out like the sleeves of a shirt during the process. Once the nematocyst is discharged into the prey, the cnidocyte is absorbed and a new one is formed in its place. There are a variety of nematocysts in the cnidarians; they are important in classification of these animals. These structures are the weapons of offence and defence in the group; some are sticky and are used for food capture.

Mucous gland cells: There are gland cells which secrete mucous which is useful in protection, adhesion and for capture of the prey.

Sensory and nerve cells: The sensory cells are scattered among epidermal cells. Nerve cells are usually multipolar and their processes synapse with those of the sensory cells and of other nerve cells. They form a network in the epidermis.

Gastrodermis consists of i) Nutritive – muscular cells. These cells engulf food particles and digest them. They have also muscular processes at the base. These processes extend at right angles to the oro-aboral axis. Hence they are called circular muscle fibers, and their contraction results in decreasing the diameter of the body. ii) Gland cells secreting enzymes into the gastrovascular and iii) Mucus secreting cells.

4.3 CLASSIFICATION OF PHYLUM CNIDARIA

Depending mainly upon whether polyp or medusa is the dominant form in the life cycle, Cnidaria is divided into four classes 1) Hydrozoa; 2) Scyphozoa; 3) Cubozoa; and 4) Anthozoa.

1. **Class Hydrozoa:** They may be solitary or colonial forms. There are asexual polyps and sexual medusae, though one type may be suppressed. The feeding zooids (hydranths) do not have mesenteries. Medusa, when present, has a velum (the margin of the umbrella projecting inward in the form of a shelf). Animals may be either fresh water or marine.

Hydra (Fig. 4.4) is a common fresh water form, typically, being solitary and without a medusoid form. *Obelia* (Fig. 4.5) is a colonial form. It has feeding polyps with tentacles (gastrozooids or trophozooids), and reproductive zooids without tentacles, which bud off medusae (gonozooids). These individuals are connected to root-like hydrorhiza with a stalk-like hydrocaulus. The gonozooids bud off small medusae with epidermal gonads. The testes and ovaries are borne on different medusae (**gonochorism**). The medusae have light-sensitive ocelli, and statocysts which are sensitive to gravity (Fig. 4.6). *In Tubularia*, another colonial form, the gonozooids do not release medusae. The medusae remain attached to the gonozooids from where gametes are released. Then the gonozooids are called gonophores. Individuals belonging to the order siphonophora show highest degree of polymorphism. They form floating or swimming colonies made up of several types of modified medusae and polyps. *Physalia* (the Portuguese man of war) (Fig. 4.7) is such a colony with a big bright float and long tentacles arising from clusters of polyps modified differently for carrying out various functions. *Velella* (Fig. 4.8) with a small saucer shaped float (modified gastrozoid) carrying gonozooids and dactylazoids (club shaped polyps with gastrozoid) carrying gonozooids and dactylazoids (club shaped polyps with batteries of cnidocytes which are defensive in function) is another example.

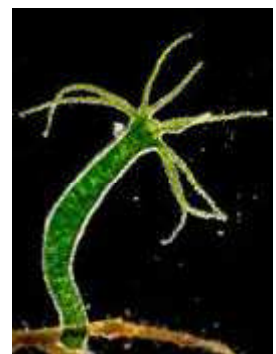


Fig. 4.4: *Hydra*.

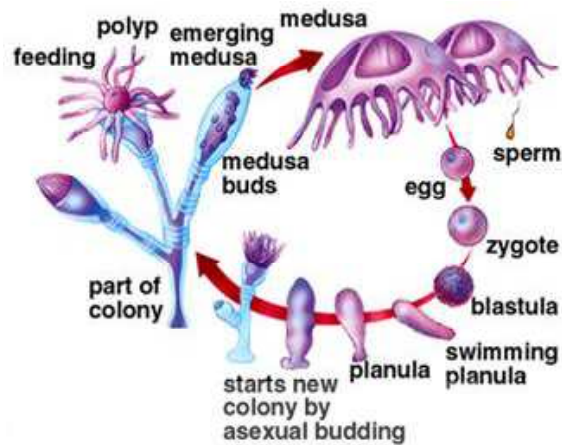


Fig. 4.5: Life cycle of *Obelia*, showing alternation of polyp (asexual) and medusa (sexual) stages. *Obelia* is a calyptoblastic hydroid; that is, its polyps as well as its stems are protected by continuations of the perisarc.

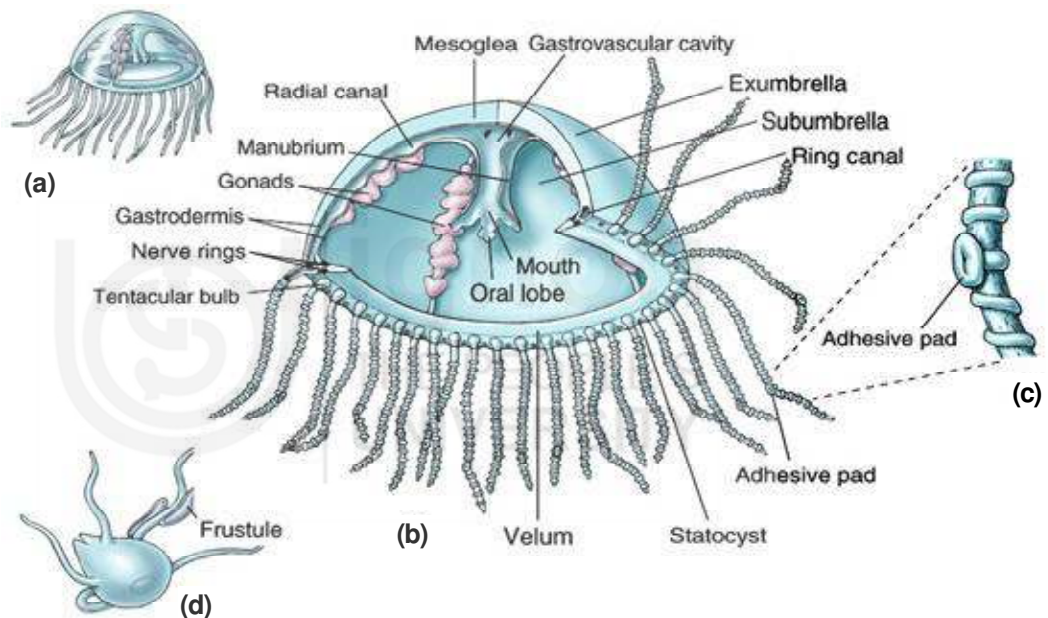


Fig. 4.6: Structure of *Gonionemus*. a) Medusa with typical tetramerous arrangement; b) Cutaway view showing morphology; c) Portion of a tentacle with its adhesive pad and ridges of nematocysts; d) Tiny Polyp.

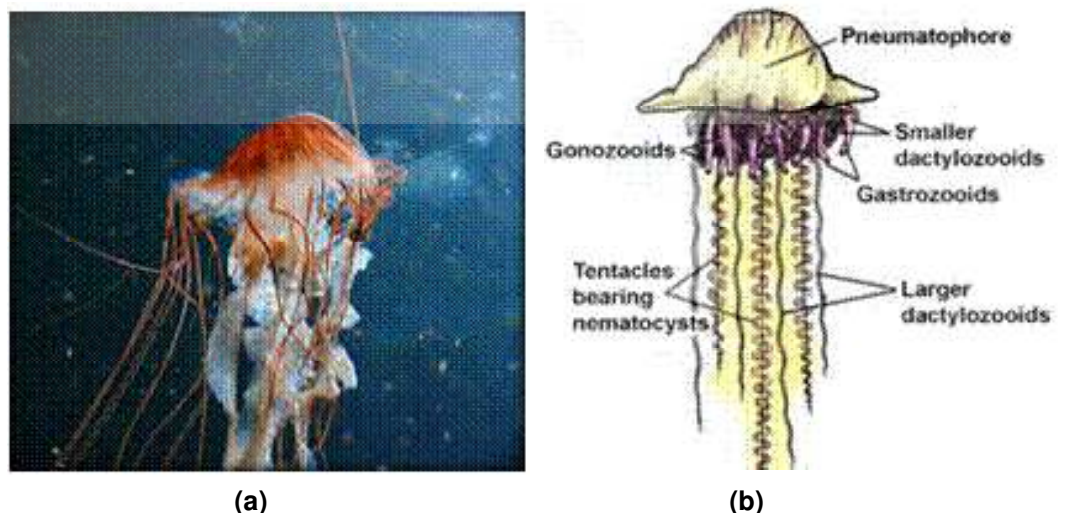


Fig. 4.7: *Physalia*: a) Natural view; b) Diagrammatic view.

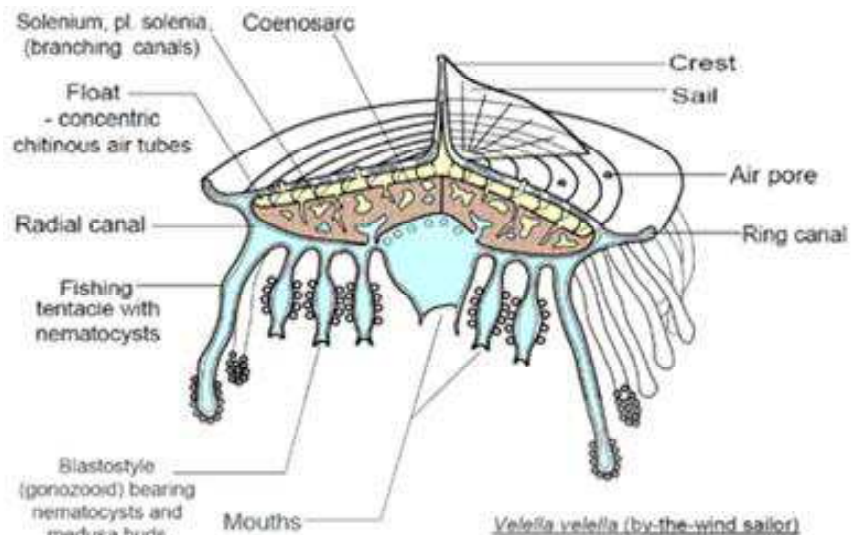


Fig. 4.8: *Velella* (by-the-wind sailor), a pelagic hydroid. These pelagic hydroids float near the surface, and the aboral surface bears a sail.

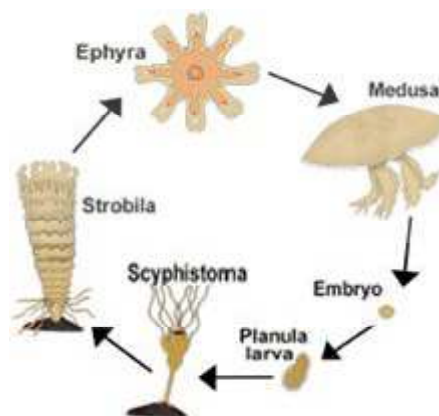
Colonial hydrozoans also include the hydrocorals (orders Milleporina and Stylasterina) secreting internal epidermal calcareous skeleton attaining considerable size. Since they have dactylozooids and can inflict painful sting, they are also called stinging corals.

2. **Class Scyphozoa:** These are solitary cnidarians, with polyp stage reduced or absent. Medusae do not have velum. Gelatinous mesoglea is very much enlarged. Margin of the umbrella has usually eight notches with sense organs. All are marine.

Aurelia is a typical example. Medusa is the dominant individual, 10–40 cm in diameter. The marginal club-shaped sense organs called rhopalia (Fig. 4.9) carry neuronal concentrations, statocysts and ocelli. Gonads are gastrodermal. Zygote develops into a planula larva which attaches to the substratum and develops into a polypoid scyphistoma (Fig. 4.9). The scyphistoma buds off ephyra larvae which are juvenile medusae. Another example is *Rhizostoma*.



(a)



(b)

Fig. 4.9: a) *Aurelia*; and b) Life cycle of *Aurelia*, a marine scyphozoan medusa.

3. **Class Cubozoa:** These are also solitary medusoid forms with reduced polyp stage. But the medusa is square in cross section. Tentacles or groups of tentacles hang from tough flattened pedalia which occur at the corners of the umbrella. All are marine. Example *Carybdea* (Fig. 4.10).

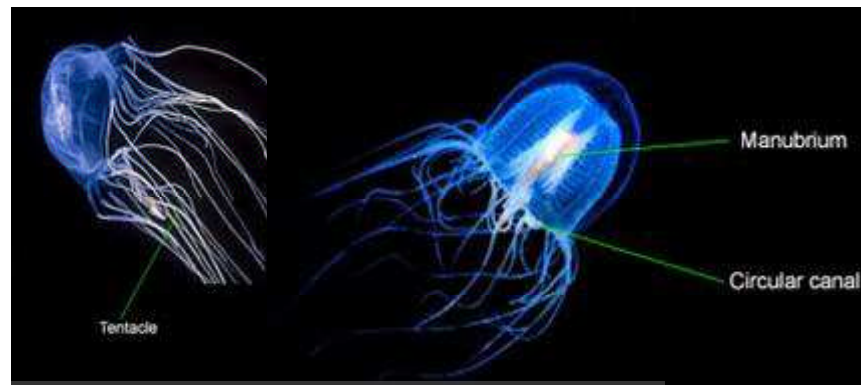


Fig. 4.10: *Carybdea*, a cubozoan medusa.

4. **Class Anthozoa:** All are polyps. They are solitary or colonial. Mesenteries or septa subdivide the enteron. Septa bear nematocysts. Gonads are gastrodermal. All are marine.

The anthozoan polyps are larger and more complex (Fig. 4.11). The flattened oral disc bears tentacles and a slit like mouth. The mouth leads into a flattened stomodaeum. A ciliated groove called syphonoglyph and the flattened slit-like mouth give biradial symmetry to these animals. Mesenteries, which are folds of gastrodermis with mesoglea in between, extend into the gastrovascular cavity. *Complete* mesenteries extend between the outer wall of the column and the stomodaeum. *Incomplete* mesenteries, however, are not attached to the stomodaeum. The edges of the mesenteries become filamentous carrying cnidocytes and enzyme secreting cells. The septa may also have threads or acontia to kill the prey. Mesoglea in these animals is thick, cellular and fibrous. There are well-developed longitudinal retractor blocks of muscles on the mesenteries. Gonads also occur in the mesenteries. Fertilization and development result in a planula larva.

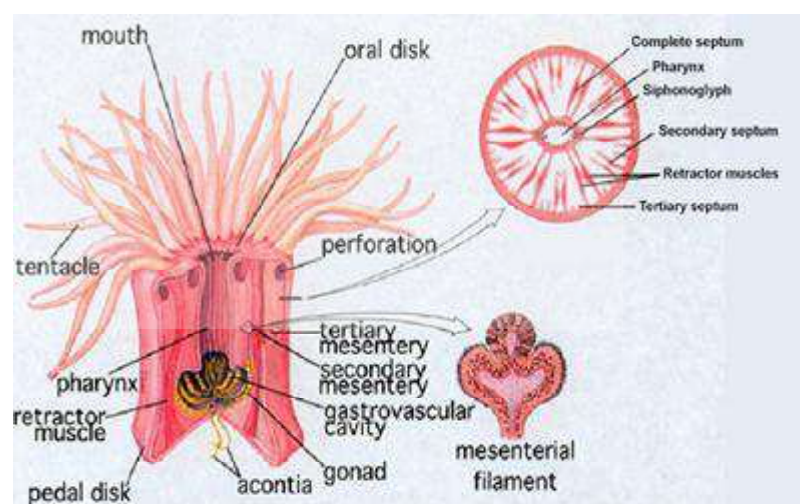


Fig. 4.11: Structure of the sea anemone. The free edges of the septa and the acontia threads are equipped with nematocysts to complete the paralysation of prey.

Examples: Sea anemones are common. They are solitary, occurring along the coast attached to rocks in the littoral region. *Metridium* and *Tealia* are typical examples. Other examples of the class are *Cerianthus*, *Renilla*

Gorgonia (Fig. 4.12), *Tubipora* (Fig. 4.13), *Antipathes* (Fig. 4.14), *Alcyonium* (Fig. 4.15).

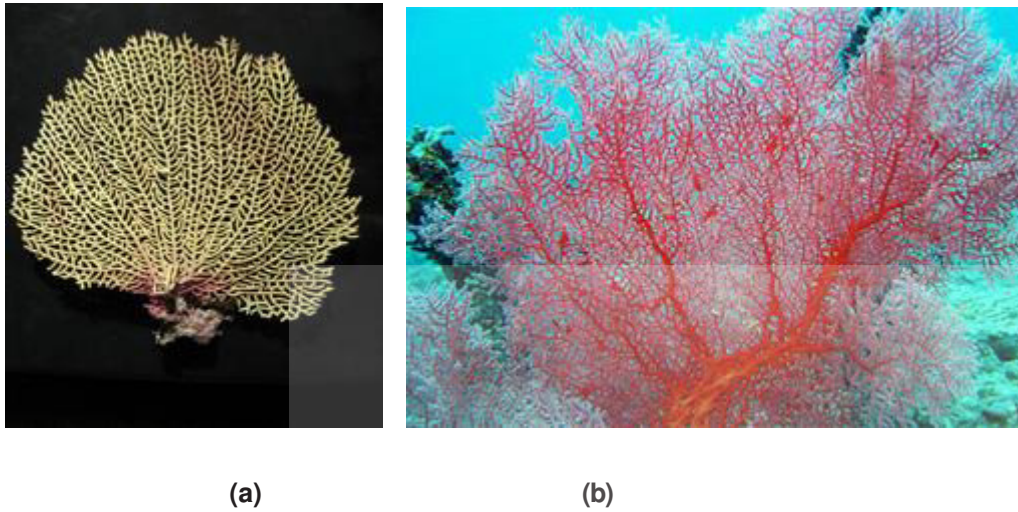


Fig. 4.12: *Gorgonia*: a) Dry specimen; and b) Natural.

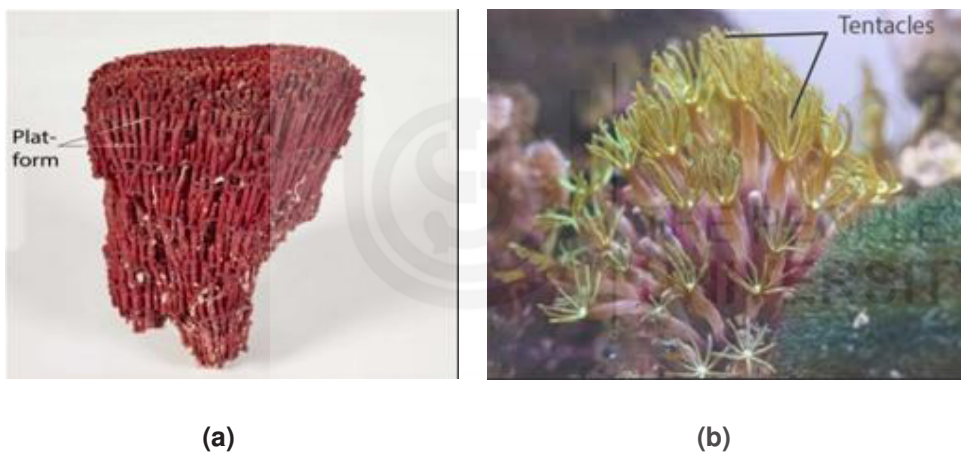


Fig. 4.13: *Tubipora*: a) Skeleton of entire colony; b) Natural polyp with tube and commencement of platform.

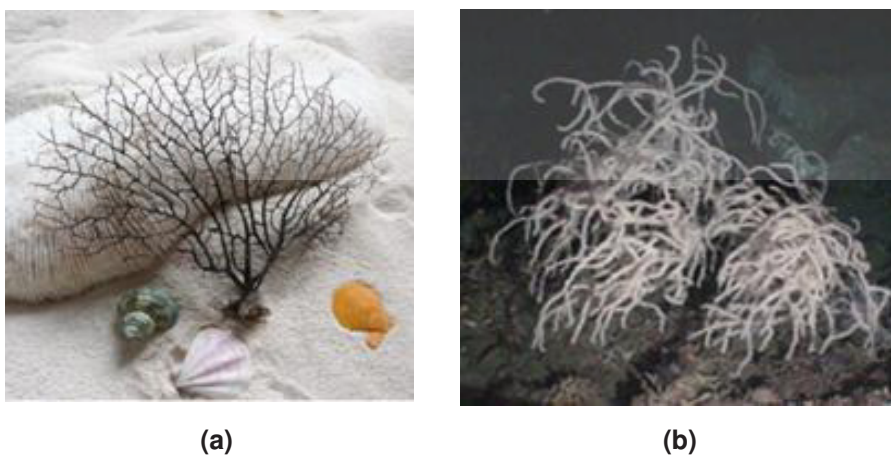


Fig. 4.14: a) Colony of *Antipathes*, a black or thorny coral (order Antipatharia, class Anthozoa).; b) The polyps of Antipatharia have six simple, nonretractile tentacles. The spiny processes in the skeleton are the origin of the common thorny corals.

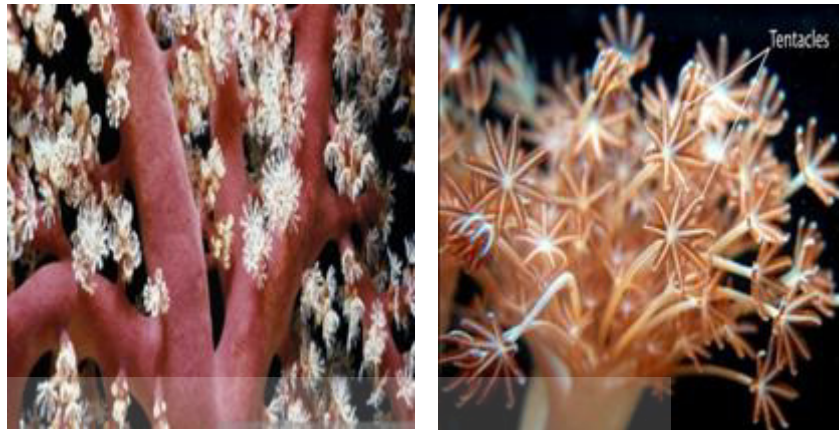


Fig. 4.15: Polyps of an alcyonarian coral (octocoral). Note the eight pinnate tentacles, and solenia. They have an endoskeleton of limy spicules often with a horny protein, which may be in the form of an axial rod.

Polyps may be solitary or colonial.

Polymorphism is a characteristic of many but not all colonial animals.

Obelia geniculata is most common. It is found attached to sea weeds, sunken ship wrecks, rocks and even on shells of other sea animals. It grows only upto 1-4 inches. It is light brown in colour and is commonly called as "Sea fur".

Some animals belonging to this class are colonial coral formers. In the true corals or stony scleractinian corals, polyps are connected with one another laterally and they sit upon calcareous cups they have secreted outside. The skeleton here is secreted by the epidermis of the base of the column below to living tissue rather than within. So it is an exoskeleton. The polyps can be withdrawn into the skeleton. The skeleton of the colonial corals becomes massive over the years, with the living tissue covering it as a sheet outside. Alcyonarians are usually referred to as octocorals as they have eight tentacles. They are also colonial, connected laterally in a branching form (Fig. 4.15). Here the amoebocytes of the mesoglea secrete the calcium carbonate skeleton, which is internal. *Corallium* is the precious red coral whose skeleton is used to make coral jewellery. The alcyonarians are soft corals, containing fewer spicules of calcium carbonate. Antipatherians form the thorny or black corals.

4.4 POLYMORPHISM IN CNIDARIA

Some animals are solitary, while others live in small groups, or in colonies. The colonies (groups) among animals can be of two types:

- 1) The individuals of the same species live together, they are structurally quite similar but perform different functions. (e.g., group of bees),
- 2) The individuals of a species get together, assume different forms (which is a unique property), perform different functions and collectively form one complete functional organism, these cannot survive individually. Both these types of colonies are also called "polymorphic colonies". The individuals of the colony are called zooids or castes.

As the name suggests **poly** means many and **morphs** means forms, that is many forms. Those species are called polymorphic whose individuals occur in different forms and perform different functions. This phenomenon is known as polymorphism. It is an amazing feature in the lives of a few animals. You will study this phenomenon in Cnidaria and Arthropoda as a number of animals of this group show this phenomenon distinctly.

In the following sub-section you will study about polymorphism in class Hydrozoa with specific example of *Obelia*.

4.4.1 Polymorphism in Hydrozoa

In general, all cnidarian forms fit into one of the two morphological types: (a) the hydra like polyp or hydroid form which is adapted for a sedentary existence and (b) an umbrella like medusa or jelly fish form which is adapted for a floating or free swimming life. (Fig. 4.16).

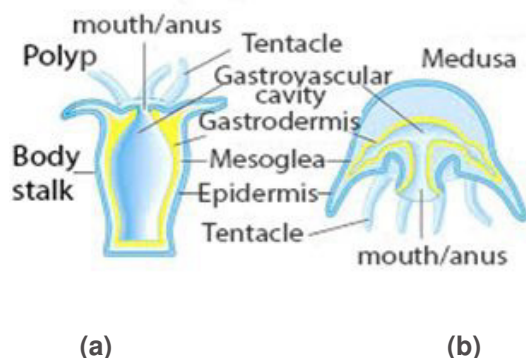


Fig. 4.16: a) A typical polyp having a tubular body with a mouth at one end surrounded by tentacles. The basal or aboral end is usually attached to the substratum by pedal disc or other device; b) A typical medusa which is bell shaped or umbrella shaped and has tetramerous symmetry (body parts arranged in fours). The mouth is usually on the concave side and tentacles extend from the rim of the umbrella. The medusa is usually free swimming.

Many hydroids of class Hydrozoa, exhibit polymorphism which is associated with their colonial organisation. Most hydroids are dimorphic or polymorphic, with at least two or sometimes, more, structurally and functionally different kinds of individuals within the same species. They are polyp during some part of their life.

Superficially the polyp and medusa may seem very different, but actually each has retained the sac like body plan basic to the phylum (Fig. 4.16). The medusa is essentially an unattached upside-down polyp with the tubular portion widened and flattened into a bell shape.

Both the polyp and medusa have the three body layers typical of cnidarians – (a) the outer ectoderm (b) the inner endoderm and (c) the middle jelly-like layer the mesoglea. The mesoglea is much thicker in the medusa, forming the bulk of the animal and making it more buoyant.

Let us now study polymorphism in detail in *Obelia*.

Obelia

Obelia is a marine, plant-like animal found attached to the substratum. It is a colonial and branching hydrozoan of the phylum Cnidaria (Fig. 4.17). It is widely distributed and lives as deep as 250 feet below sea level.



Fig. 4.17: *Obelia* Colony.

It is interesting to note that the *Obelia* colony, which appears like a small plant, is actually an animal which is made up of simple individuals living together and having different forms and functions. The colony results from asexual reproduction by budding, from the original zooid.

The *Obelia* colony is formed of three types of individuals (zooids):

- i) Nutritive zooid or hydranths or gastrozooids or trophozooid (feeding function)
- ii) Budding zooids or gonangia or blastostyle
- iii) Medusa or sexual zooid (the word medusa is singular; medusae is plural).

The *Obelia* colony is thus trimorphic (tri = three, morph = forms). The *Obelia* colony has a common stalk called hydrocaulus which gives rise to one or more stalks. The hydrocaulus is connected below to a root like stolon or hydrorhiza. The living cellular part of the hydrocaulus is the tubular coenosarc, composed of the three typical cnidarian layers. These layers surround the central coelenteron (gastrovascular cavity). The protective covering of the hydrocaulus is a non-living yellow, chitinous sheath secreted by the ectoderm called the perisarc (Fig. 4.18). Attached to the hydrocaulus are the individual polyps or zooids. All the zooids are attached to each other through the continuous enteron or gastrovascular cavity. Most of the zooids are feeding polyps called gastrozooids or hydranths.

Hydroids with a hydrotheca surrounding a polyp proper are said to be 'thecate' and those without the hydrotheca 'athecate'.

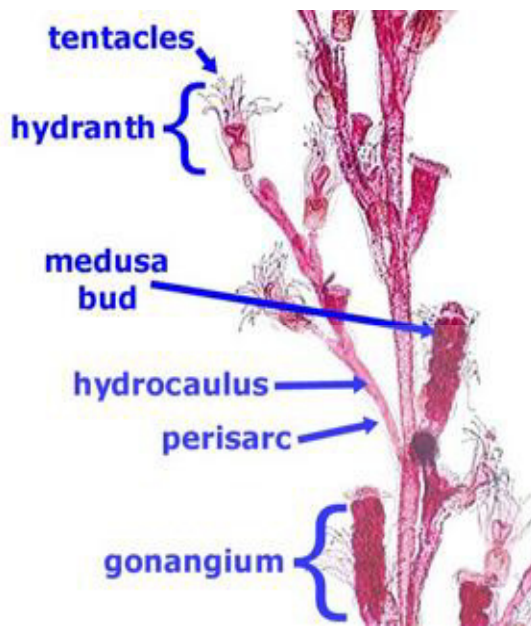


Fig. 4.18: *Obelia* colony, showing in detail the various zooids found in it.

POLYPOID FORMS

- i) **Gastrozoid or Hydranth** : Each *Obelia* colony has many hydranths or gastrozooids. Each hydranth is like a mini *Hydra*. It has a cylindrical, tube-like, 'bottle shaped' or vase-like body, with a terminal mouth which is surrounded by tentacles. Each zooid has an enteric cavity, which opens to the outside through the mouth. The zooid is attached to the hydrocaulus. This mini *Hydra* is enclosed in a cup shaped hydrotheca (Fig. 4.19). *Obelia* feeds on small aquatic animals such as worms, crustaceans and other arthropods. The tentacles of the hydranths help in catching the prey. The food is digested in the enteric or gastrovascular cavity. The nutrients are sent to the entire colony through the enteric canals.
- ii) **Gonangium (gonos = seed, angeion = vessel)** : In *Obelia*, the medusae are budded off from a reproductive polyp called gonangium. This polyp or zooid is club shaped and elongated. The immature gonangium often detaches itself from the parent *Obelia*, settles down and starts growing into a new *Obelia* colony. This is an asexual or vegetative way of reproduction. If the gonangium does not detach, then it only grows into a mature gonangium with a central mother blastostyle (Fig. 4.19 a) on which small growths or buds appear. These buds grow gradually in size and develop into male and female medusae or gonophores. This whole structure is covered by an extension of the perisarc, the transparent gonotheca (Fig. 4.19 b). This zooid has no tentacles and no mouth, it has instead a gonopore through which the medusae are set free.

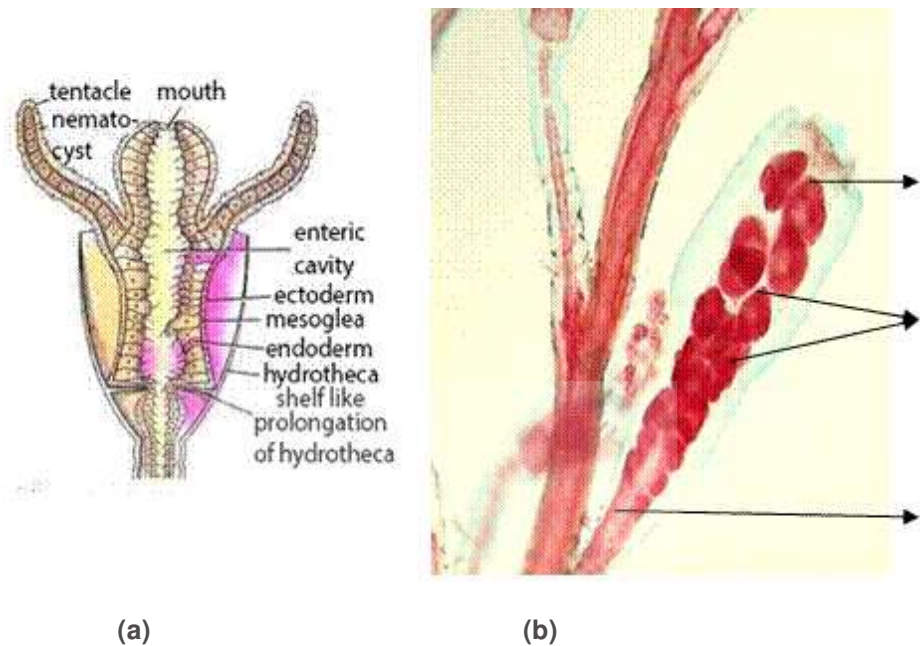


Fig. 4.19 : Different types of polyps, occurring in an *Obelia* colony
a) V.S. of Gastrozoid; b) Structure of a gonangium.

- iii) **Medusa:** The medusae are reproductive zooids and can be either male or female. Medusa reproduces sexually and is a sexual generation. Each medusa is a free swimming zooid of *Obelia* which on being mature, produces gametes (eggs or sperms). The medusa is umbrella-like in appearance. The outer convex side is called ex-umbrella and the inner concave side is sub-umbrella. The margin of the umbrella has a circlet of tentacles. For nutrition these medusae (Fig. 4.20) have a mouth and a gastric cavity. If the medusa is a male, it has four testes and if a female, four ovaries (Fig. 4.20).

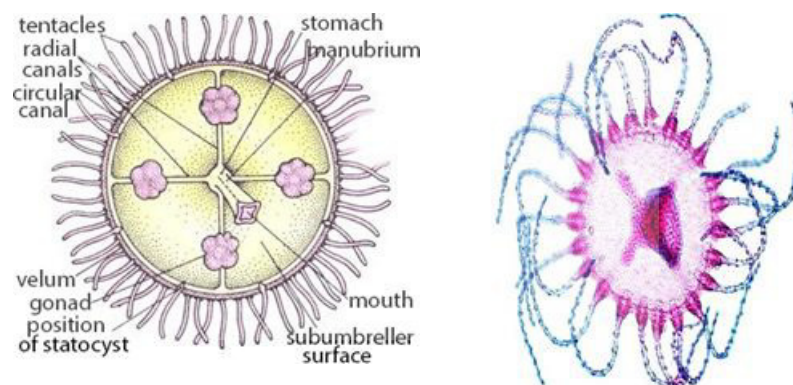


Fig. 4.20: Oral view of medusa of *Obelia*.

The presence of two body forms in the life history of *Obelia* and various other colonial cnidarians alternating between asexual and sexual generations, has been referred to as metagenesis or alternation of generation.

In *Obelia* and various other colonial cnidarians both the polyp and medusa are diploid and only the gametes are haploid. Thus the asexual polyp reproduces asexually by budding, and occasionally-produces buds or sexual medusa (also asexually) which may be male or female. This sexual medusa asexually

produces male or female gametes that fertilize and give rise to asexual colonies.

Obelia alternates between sexual and asexual phases of life. This is called metagenesis or alternation of generation. It can be explained by the Fig. 4.21 a and b.

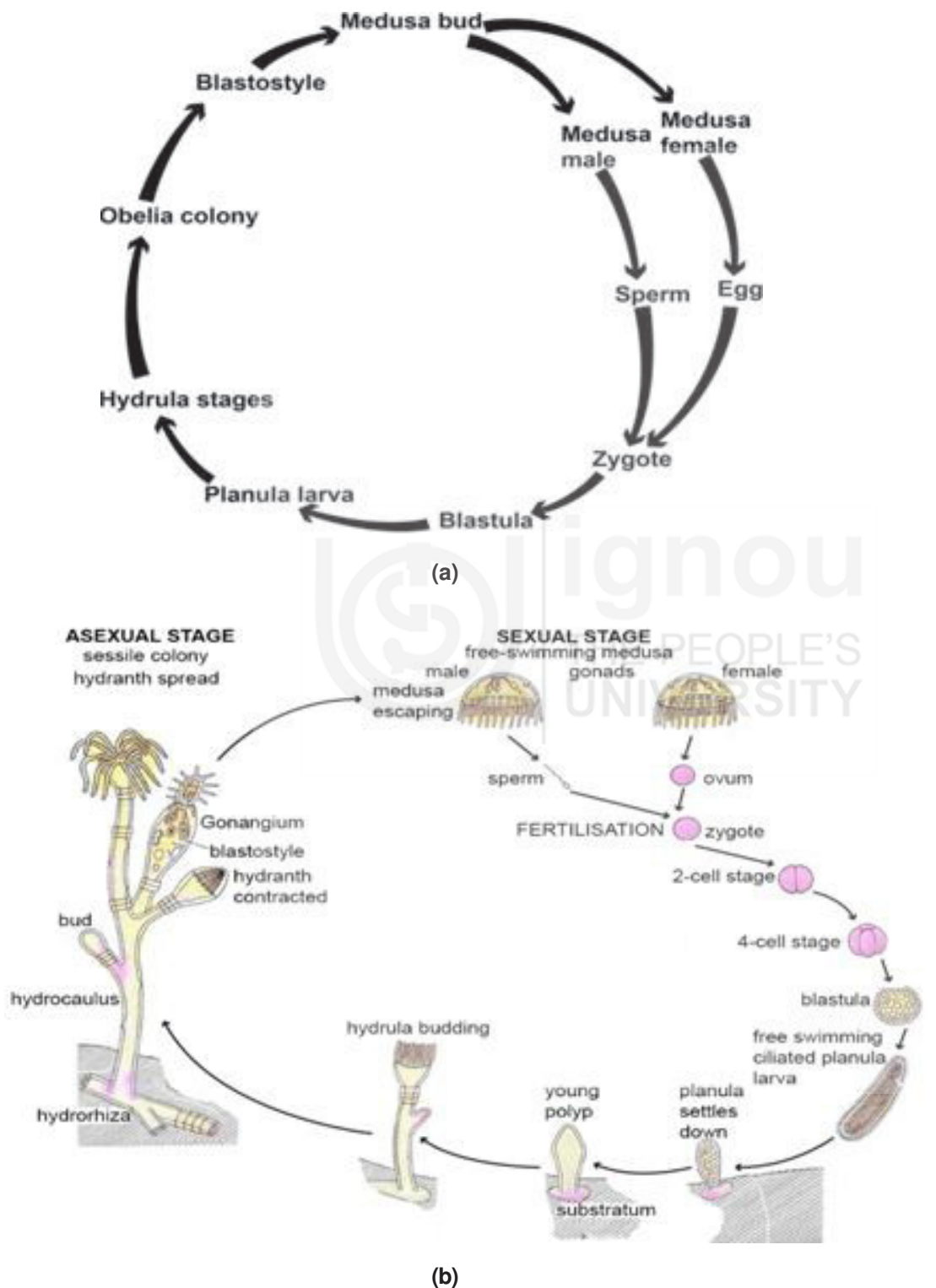


Fig. 4.21: Alternation of generation (metagenesis) in *Obelia* depicted by a) a flow chart; b) diagram of life cycle.

After going through this sub-section, you may have understood that *Obelia* is peculiar in the following ways:

-
- i) It is a colony of different individuals.
 - ii) These individuals are called zooids and have different forms and functions.
 - iii) The colony breeds asexually by budding and remains sessile during this phase.
 - iv) It reproduces asexually by forming male and female medusae, which are free swimming forms.
 - v) The medusae or the sexual individuals form gametes (eggs or sperms).
 - vi) The eggs and sperms fertilize to form zygote, which develops into a planula larva which in turn settles down and by budding (asexual method), gives rise to an asexual colony.
-

SAQ

Write true (T) or false (F) in the space provided against each statement.

- i) Cnidocyte has a hair like cnidocil which acts as a trigger. []
 - ii) Medusae are asexual zooids. []
 - iii) *Obelia* colony is bimorphic. []
 - iv) *Obelia* is a fresh water plant like animal found attached to substratum. []
 - v) Gonangium is a sexual way of reproduction. []
-

4.5 SUMMARY

Let us summarise what we have studied so far in this unit.

- There are two forms of individuals in Cnidaria: polyp and medusa.
- Polyp and medusa may appear quite different in form, they, however, have basically the same plan with an outer layer of epidermis and a gastrodermis lining the gastrovascular cavity, with a gelatinous layer of mesoglea in between them.
- Gastrovascular cavity serves as alimentary canal opening to the outside through only one opening, the mouth.
- Phylum Cnidaria is divided into four classes : Hydrozoa, Scyphozoa, Cubozoa and Anthozoa.
- Some cnidarians are solitary while others live in small groups or in colonies. Individuals of the colony are called zooids or castes.
- Many hydroids of class Hydrozoa exhibit polymorphism associated with their colonial organisation.
- *Obelia* colony is formed of three types of individual zooids, viz.
 - i) Nutritive zooids or hydranth or gastrozooids or trophozooids (feeding function)
 - ii) Budding zooids or gonangia or blastostyle and
 - iii) Medusae or sexual zooids.

4.6 TERMINAL QUESTIONS

1. Describe the characteristic features of Cnidarians.
2. What do you mean by polymorphism? Explain the functions of various polymorphic forms of Hydrozoa.

4.7 ANSWERS

Self-Assessment Question

- i) T, ii) F, iii) F, iv) F, v) T,

Terminal Questions

1. All are aquatic animals. They show radial or biradial symmetry around an oro-aboral axis but no head. They are diploblastic with an epidermis and a gastrodermis and gelatinous mesoglea in between. Gastrovascular cavity with a single opening, the mouth. Tentacles encircling the oral region. No coelom or excretory or respiratory system. Two forms of individuals – benthic polyp and pelagic medusa. Polyp reproduces asexually and medusa sexually.
2. Species whose individuals occur in different forms and perform different functions are called polymorphic and the phenomenon is known as polymorphism. Many hydroids of class Hydrozoa exhibit polymorphism which is associated with their colonial organisation. Most hydroids are dimorphic or polymorphic with structurally and functionally different kinds of individuals within the same species. *Obelia* is formed by three types of individuals (zooids) such as nutritive zooids, budding zooids or gonangia and medusa or sexual zooids.

PHYLUM PLATYHELMINTHES

Structure

5.1	Introduction Objectives	5.3	Life Cycle of <i>Taenia solium</i>
5.2	Platyhelminthes Characteristic Features Classification	5.4	Summary
		5.5	Terminal Questions
		5.6	Answers

5.1 INTRODUCTION

In the previous unit you have studied about phylum Cnidaria that includes animals that are diploblastic and whose body is made up of only two germ layers – the ectoderm and endoderm. The space in between the two germ layers is made up mostly of a jelly like substance, with very few cells. Now you will proceed to study triploblastic animals which have in addition to ectoderm and endoderm, a third germ layer – mesoderm. The first among these phyla is Phylum Platyhelminthes (from the Greek *platy*, meaning “flat” and *helminth*-, meaning “worm”), there are about 20,000 known species in this phylum.

Objectives

After studying this unit, you should be able to:

- ❖ recognise the characters of phylum Platyhelminthes which differentiate them from other phyla;
- ❖ describe the characteristic features of different classes of the phylum Platyhelminthes giving examples of each class;
- ❖ give basic idea of organisation of the body of animals belonging to different classes of phylum Platyhelminthes; and
- ❖ describe the life cycle of *Taenia solium*.

5.2 PLATYHELMINTHES

Animals included in phylum Platyhelminthes are soft bodied, bilaterally symmetrical animals popularly known as flat worms. The gelatinous mesoglea of the cnidarians is here replaced by a mesodermal, cellular, parenchyma, a type of packing tissue consisting of more cells and fibres than mesoglea, this has laid the foundation for a more complex organisation, with more organs and organ systems. These animals range in size from less than a millimeter to a few meters as in some tapeworms. They include free-living and parasitic species. Many live on land but some are fresh-water or marine, crawling on weeds and sediments.

5.2.1 Characteristic Features

1. Bilaterally symmetrical, with anterior and posterior ends.
2. Body dorsoventrally flattened.
3. Triploblastic – with three germ layers.
4. Acoelomate – no internal body cavity. The space between the organs is filled with a form of connective tissue called parenchyma derived from mesenchyme.
5. Digestive system absent in some; when present, has only the mouth but no anus.
6. Nervous system ladder-like, with simple sense organs.
7. Excretory system protonephridial type.
8. No respiratory, circulatory or skeletal systems.
9. Hermaphrodites, with complex reproductive system.
10. Eggs show spiral cleavage, which may be highly modified.
11. Development is usually direct in free living forms; in some there is a free-swimming larva (Muller's larva or Gotte's larva). In certain parasites development may be much complicated involving many larval stages in the life cycle.

Bilateral symmetry has evolved for the first time in this group of animals, and it has been maintained in all higher groups (Hence all these phyla are called Bilateria). This symmetry and the accompanying cephalisation have evolved side by side in response to progression in one direction – that end of the animal which is in front and during locomotion has become the head. Of necessity, sense organs are concentrated at that end. Another important feature of this group of animals is the appearance of a third cellular layer between epidermis and gastrodermis i.e. the parenchyma – instead of the gelatinous non-cellular mesoglea of the coelenterates.

Their flat shape increases their surface area which places the cells in close proximity to water in their environment or in their gut. Thus gas exchange and excretion of nitrogenous waste (ammonia) occurs through diffusion. Therefore, they do not have respiratory organs and their excretory organs are simple protonephridia with flame cells (Fig. 5.1). The flame cell is in fact made

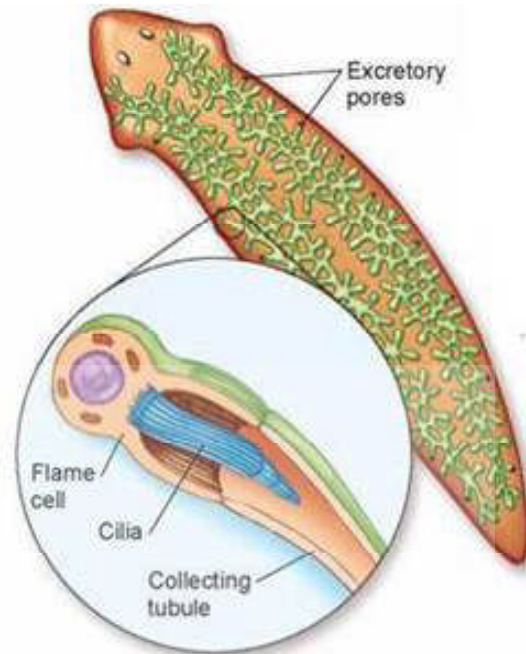


Fig. 5.1: Protonephridial system with details of a flame cell.

up of two cells: a cap cell and tubule cell. The cup-shaped cap cell has a tuft of flagella arising from the inner face of the cup and extending into its cavity beating like the flickering flame of a candle (hence flame cell). The cap cell and the tubule cell are fitted into one another by means of their finger like projections (interdigitations). At the interdigitations fenestrations (pores) occur. Beating of the flagella draws fluid into the lumen of the flame cell through the fenestrations and drives the flow into the lumen of the flame cell and further forward through the duct system. During this process, ions and various other molecules may be resorbed. Many such flame cells unite to form a duct system which may open out through nephridiopores. Though the system is often called excretory, it appears to be mainly osmoregulatory, as the system is reduced or even absent in marine forms. Nitrogenous wastes are actually removed by diffusion through the body surface.

Another feature in Platyhelminthes is the evolution of more elaborate and clear organ systems for the first time – protonephridial, digestive, reproductive, nervous, sensory etc. involving better integration of tissues and organs.

The gut of flatworms has only one opening i.e. the mouth. Naturally, most of these animals feed on tissues of other animals though some feed on algae. Most species are parasitic, with organs specialised for adhesion to the host. In gut parasites which are surrounded by partially digested food of host gut, alimentary canal is completely absent. But the surface of the platyhelminth parasite body is suitably modified for absorption of the surrounding digested food. Reproductive system is extensive in these animals, capable of producing large number of eggs.

5.2.2 Classification

Phylum Platyhelminthes is divided into four classes: Turbellaria, Monogenea, Trematoda and Cestoda.

- Class Turbellaria:** These are mostly free living and aquatic. Some are terrestrial, confined to humid areas. Body of these animals is covered with ciliated epidermal cells containing rhabdoids. Mouth is on the ventral side.

These animals range from a few millimeters to a few centimeters. They move by means of cilia covering the ventral side of the body gliding along a film of mucous that they secrete. Undulations of the body also help in locomotion of larger forms. In a transverse section (Fig. 5.2) you will see an outer covering of ciliated epidermal cells containing rod-like structures called rhabdoids. Cilia may be missing dorsally. If you disturb the animal the rhabdoids are ejected. So they are defensive in function. Rhabdoids may also form a mucous covering around the body. Beneath the epidermis you will see the circular, diagonal and longitudinal muscle fibres. These fibers are unstriated. You can also see mucous gland cells located in parenchyma. They open to the outside. A loose type of connective tissue, parenchyma, made up of aggregation of irregular cells, packs the space between internal organs. You will also see simple eyes on the head. Nerve tissue is concentrated as ganglia (brain) in the diverticula. Apart from possessing a well-developed reproductive system, the turbellarians have tremendous capacity for asexual reproduction especially by transverse binary fission. They also have extensive capacity for regeneration. Examples are *Dugesia (Planaria)* (Fig. 5.3), *Microstomum* (Fig. 5.4) and *Planocera*.

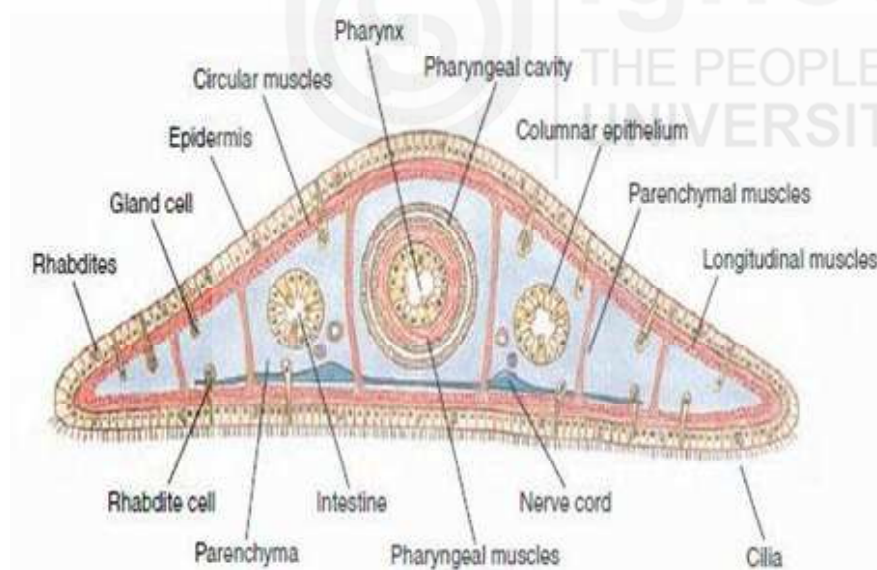


Fig. 5.2: Cross section of planarian through pharyngeal region, showing relationship of body structures.

- Class Monogenea:** Body of these animals is covered with a non-ciliated syncytium, the tegument. Their shape may be leaf like to cylindrical. They are parasitic, usually on the skin or gills of fish. For this, they have posterior attachment organs in the form of hooks, suckers, clamps. Their development is direct, with only one host. They have usually a free-swimming ciliated larva.

These are monogenetic flukes that is, they have only one host in their life cycle. Important differences from the turbellarians are that instead of the

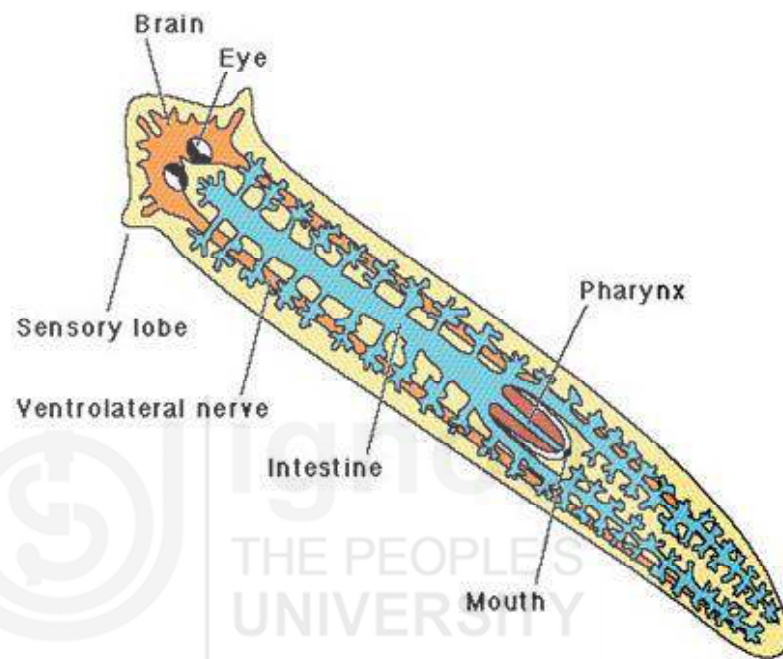
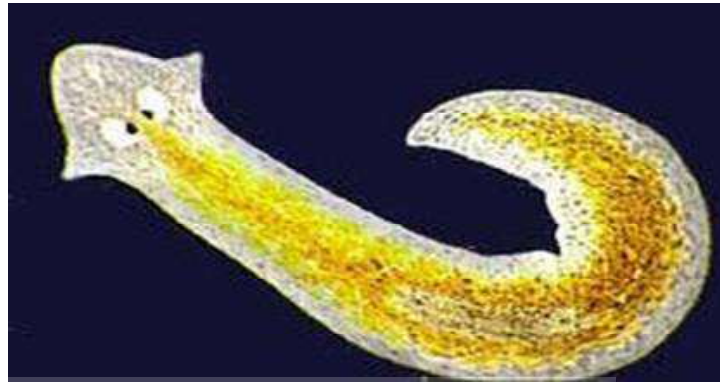


Fig. 5.3: *Dugesia* (Planaria).



Fig. 5.4: *Microstomum*.

ciliated epidermis, these have a non-ciliated syncytial tegument. You can also note a muscular pharynx for active ingestion of food from the host, i.e. the gut. The gut is branched into two. The adult has no sense organs. Examples *Gyrodactylus* (Fig. 5.5), *Polystoma* (Fig. 5.6), a parasite in the urinary bladder of frogs.

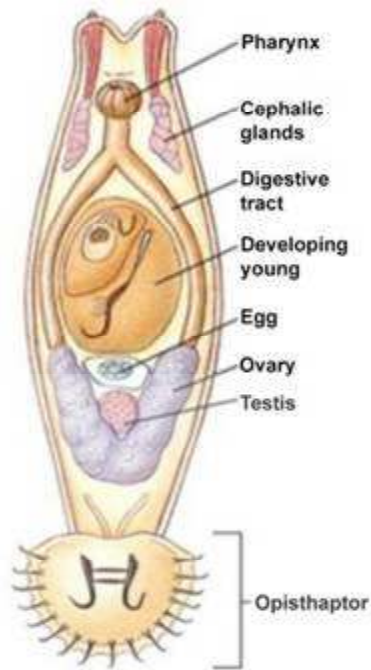


Fig. 5.5: *Gyrodactylus cylindriciformis*, ventral view.

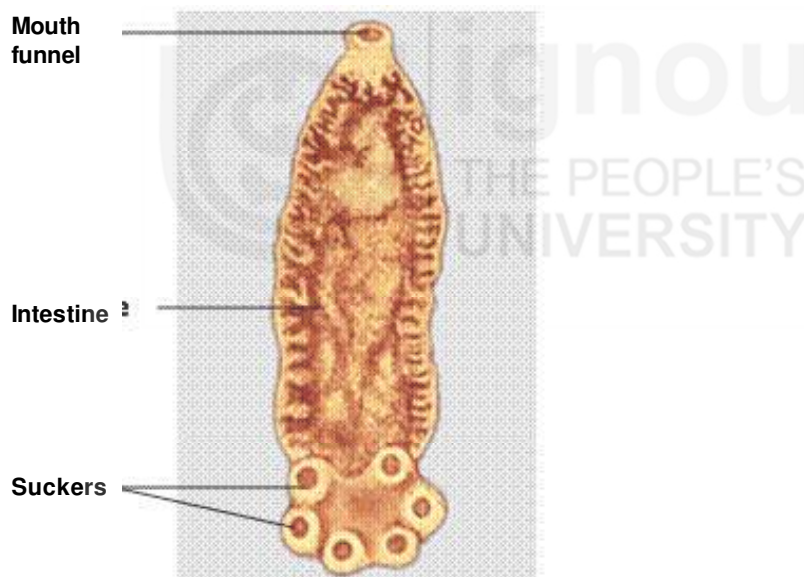
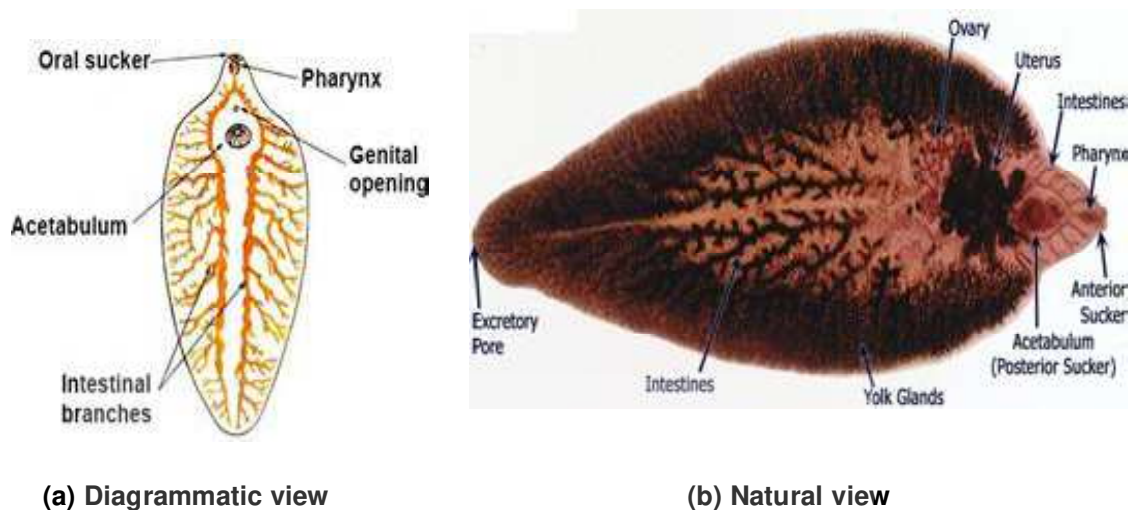


Fig. 5.6: *Polystoma*.

3. **Class Trematoda:** Body of these animals is also leaf-like to cylindrical-covered with non-ciliated syncytium i.e. the tegument. However, they have oral sucker and ventral sucker, but no hooks. Development is indirect. The definitive host (host in which sexual reproduction takes place; it is also known as final host) is a vertebrate. First host or the intermediate host in which asexual reproduction takes place, is a mollusc. Trematoda are also called digenetic flukes as they have two hosts in their life cycle.

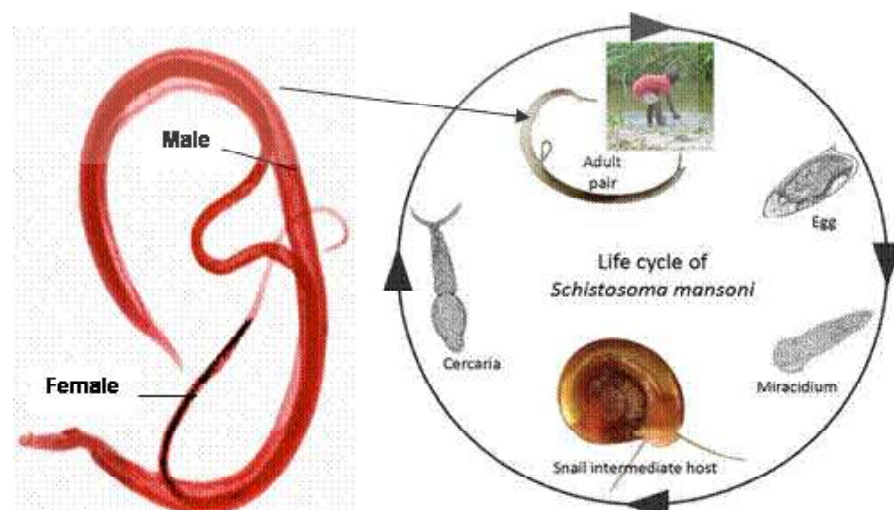
These digenetic flukes are endoparasitic, many of them causing diseases in humans and domestic animals. A typical example is *Fasciola* (Fig. 5.7).

Fasciola hepatica causes liver rot in sheep and other ruminants. The adult

Fig. 5.7: *Fasciola*.

lives in the bile duct of the liver. The eggs are passed along faeces, to the outside and on hatching, a ciliated larva, the **miracidium**, emerges out. The miracidium penetrates a snail which is the secondary host. In the snail, the miracidium becomes a **sporocyst**. Each sporocyst contains germinal masses, which by mitosis gives rise to a number of primary **rediae**. Each primary redia similarly gives rise to a large number of secondary rediae. The secondary redia gives rise to a number of **cercariae**. Thus you can see that each egg can give rise to a large number of progeny. The cercaria encysts on vegetation and it is now called **metacercaria**. The metacercariae along with vegetation are eaten up by the ruminant, in which it loses its cysts (comes out of the cyst) and grows into a young fluke, completing the life cycle.

Another example is *Schistosoma* (Fig. 5.8); the blood fluke. The species *S. mansoni*, *S. japonicum* and *S. haematobium* cause schistosomiasis in humans. You will note that schistosomes are peculiar in which they are gonochoristic (= dioecious i.e., having separate sexes), unlike other species of this phylum. The mature males and females are found in close association with one-another (Fig. 5.8). The male has a ventral groove into which is found the slender female.

Fig. 5.8: Life Cycle of *Schistosoma mansoni*.

4. **Class Cestoda:** These are the tape worms, parasitic in the digestive tracts of various vertebrates. In these animals also, body is covered with non-ciliated, syncitial tegument, but body is tape-like, with an anterior scolex carrying suckers and hooks for attachment to host tissues. Body is also divided into a number of proglottids. You will find that these worms have no digestive organs. Development is indirect, with two or more hosts.

A typical example is *Taenia* which lives in the gut of the host surrounded by the digested food material of the host; thus these animals have no mouth or gut, food can directly be absorbed through the highly modified tegument (Fig. 5.9). The scolex end buds off immature segments or proglottids which are added on (you may note that this is opposite to what occurs in annelids, which you will study later, in which segments are formed posteriorly, and they pass on anteriorly while maturing). Mature proglottids at the opposite end (gravid proglottids) are more or less, bags of eggs. The gravid proglottids containing large number of mature eggs are, ultimately shed off. The fully grown adult beef tape worm of the humans, *Taenia saginata*, having 700-1000 or more proglottids, may shed 3-10 proglottids daily, each containing 1,00,000 eggs. The proglottids passed out along with the stools, infect the vegetation which may be eaten up by grazing cattle. In the gut of the cattle, the eggs hatch and a larva with six hooks (oncosphere) emerges out. The oncosphere penetrates the intestinal wall into blood vessels, reaching through the blood stream, the voluntary muscles. Here they encyst forming bladder worms (cysticerci) with invaginated scolex. When infected beef is eaten by the human host, wall of their cyst dissolves, the scolex evaginates and it attaches to the intestinal wall, developing new proglottids, thus starting its own life cycle in the human host.

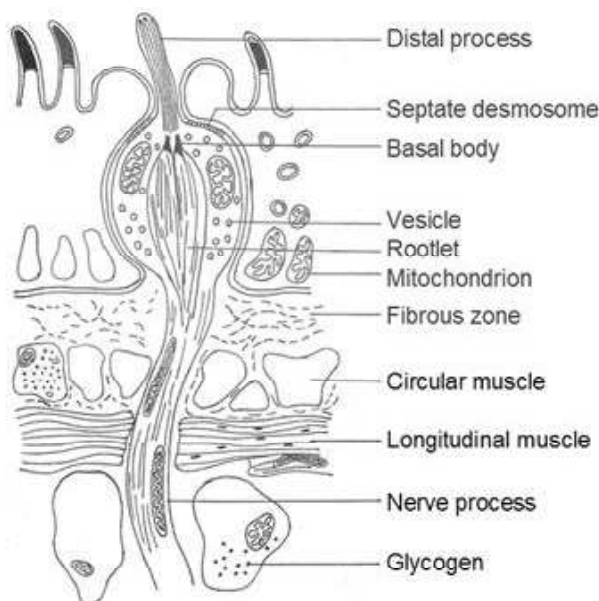


Fig. 5.9 : Schematic diagram of longitudinal section through a sensory ending in the tegument of *Taenia*.

Other examples of this class include the pork tape worm *Taenia solium* (Fig. 5.10) and the fish tape worm *Diphyllobothrium latum*.

Echinococcus granulosus (Fig. 5.11 a) is the dog tape worm; the juveniles of this are found in many species of mammals including man. Man, in this case, is an intermediate host. The juvenile stage is a peculiar kind of cysticercus known as hydatid cyst (Fig. 5.11 b). It grows for a long time attaining very large size. The main cyst having a unilocular chamber, may bud off daughter cysts within, each containing thousands of scolices. Each scolex can produce a tape worm when eaten by dog.

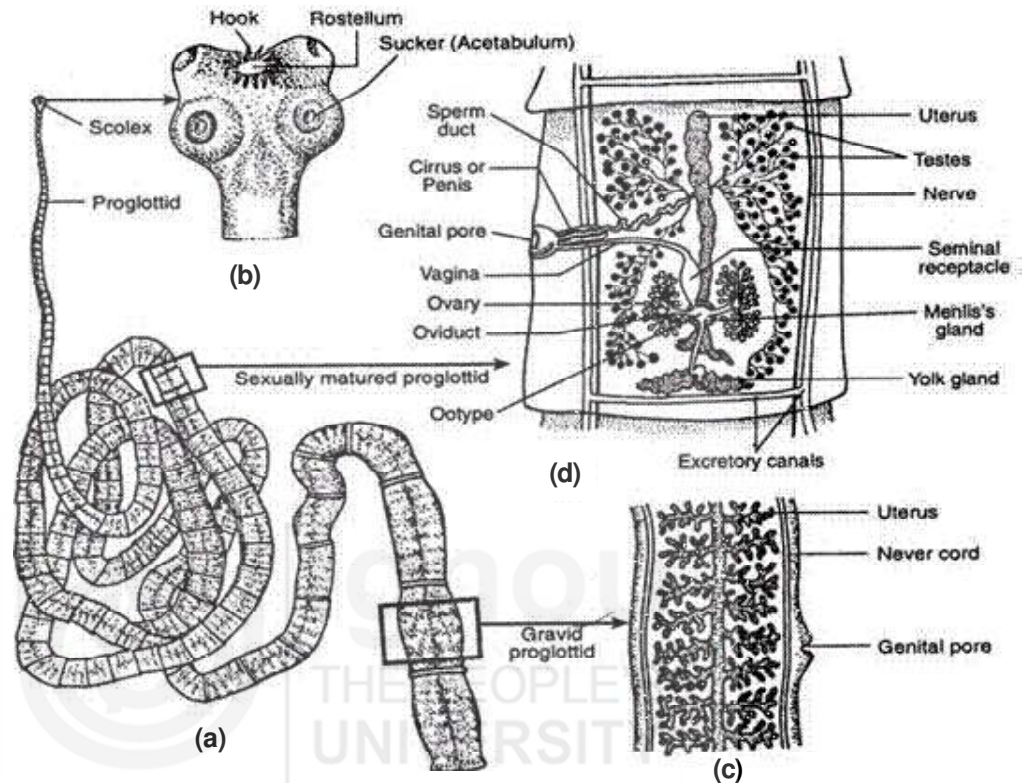


Fig. 5.10: *Taenia solium*: a) Entire specimen; b) Scolex of the same enlarged; c) A mature proglottid enlarged; and d) Gravid proglottid.

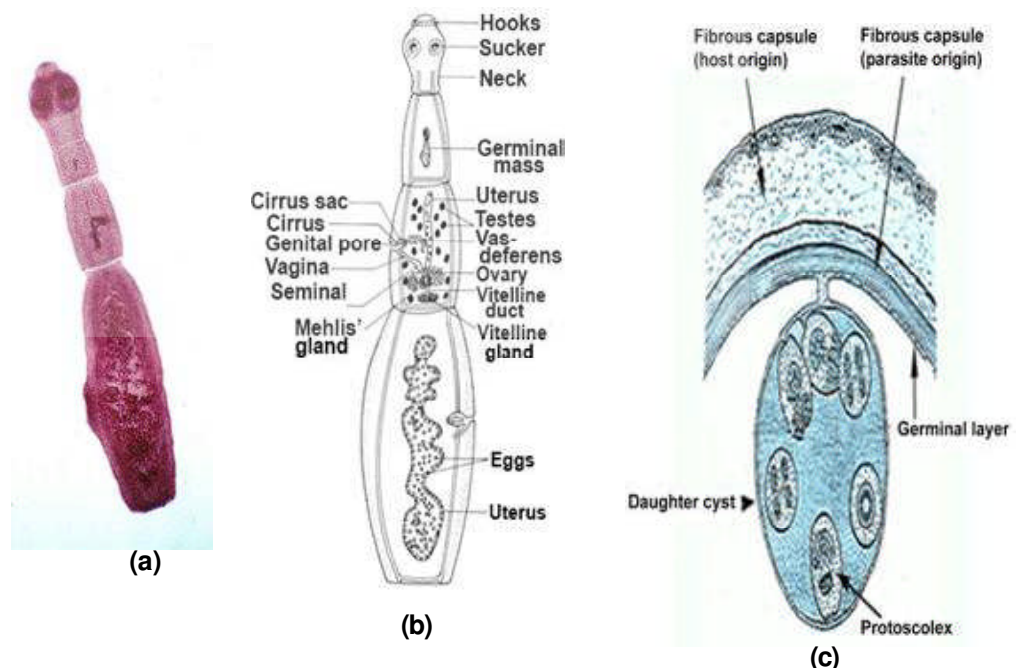


Fig. 5.11: *Echinococcus granulosus*: a) Stained specimen; b) Diagrammatic view; c) Hydatid cyst with different stages in development of scolices from germinative layer.

5.3 LIFE CYCLE OF *TAENIA SOLIUM*

Taenia solium is commonly called as the Pork Tapeworm and found in the small intestine of man and cosmopolitan in distribution (Fig. 5.12). *Taenia solium* is found in an endemic form in those countries where pork is consumed much as food. Its infection is quite common in China, Germany, India, Yugoslavia. Body of *Taenia* is elongated, flattened and ribbon like and differentiated into scolex, neck and strobilla. The scolex bears five suckers and two rows of retractile hooks. Each proglottid is hermaphrodite. The alimentary canal is absent. The life cycle is complicated and involves a primary host (man) and intermediate host (pig). The tapeworm keeps itself attached with the mucosa of alimentary canal with the help of hooks and absorbs the digested food of host's alimentary canal.

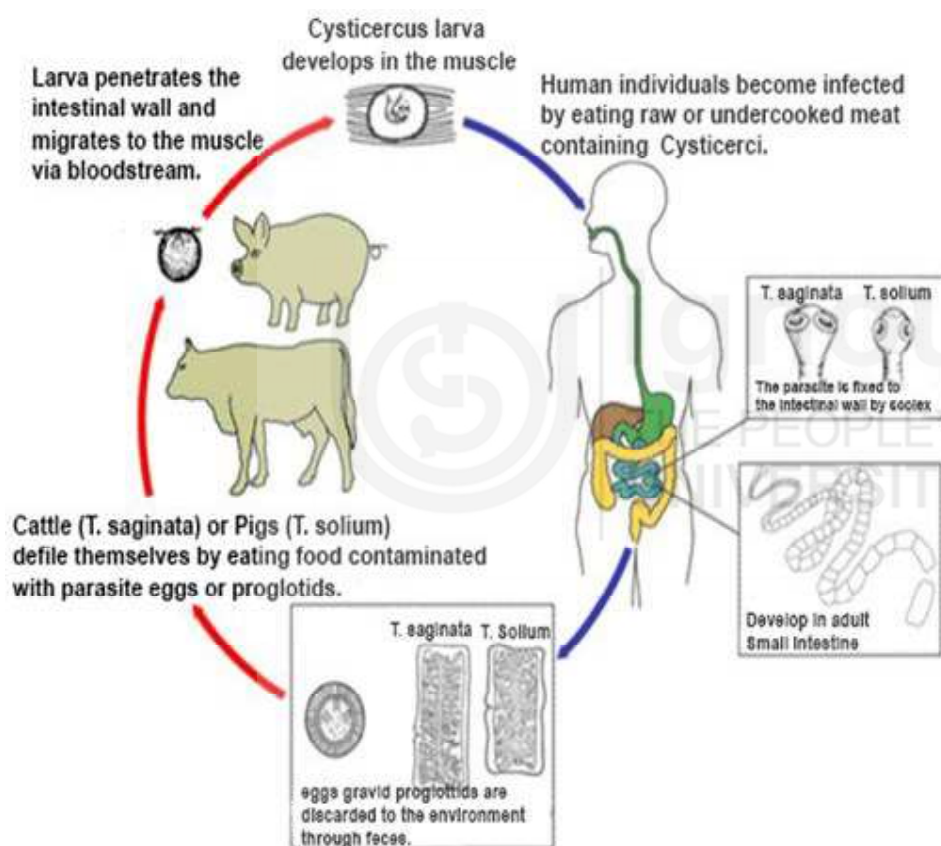


Fig. 5.12: Life cycle of *Taenia*.

Self-fertilization takes place within the same proglottid and the ripe proglottid containing fertilized eggs get detached from the body of tapeworm and pass out of the host's body in the form of chains in the faeces. Fertilized eggs, if taken by the pigs alongwith the faeces, reach the intestines of pigs where they hatch into hooked embryos, and penetrate through intestinal wall and get to the muscles of pig via blood stream. In the muscles, hooked embryos grow and form cysticercus larvae that are still covered with the bladder. If uncooked or undercooked pork is eaten by the human, the cysticercus larvae that are still covered with bladder reach the alimentary canal and develop here. The hooks and suckers on the scolex help them to get attached on the intestine of human to attain adult stage.

SAQ

Please attempt the following questions:

- Which of the words given in the parenthesis is correct?
Flame cells in platyhelminthes are in function.
(excretory/osmoregulatory)
- Name three important characters of Platyhelminthes for considering them more advanced than cnidarians.
- Arrange the character most appropriate to the class of Platyhelminthes against it.

Classes	Characters
a) Turbellaria	I. Presence of scolex
b) Monogenea	II. Presence of oral and ventral suckers, but no hooks
c) Trematoda	III. Presence of posterior hooks, suckers, clamps etc.
d) Cestoda	IV. Ciliated epidermal cells covering the body.

5.4 SUMMARY

Let us summarise what we have read so far.

- Animals placed under phylum Platyhelminthes are soft bodied, bilaterally symmetrical popularly known as flat worms.
- Triploblastic with three germ layers, viz., ectoderm, endoderm and mesoderm, No internal body cavity so they are acoelomate.
- Digestive system absent, excretory system is protonephridial type. No respiratory and circulatory system.
- Hermaphrodite with complex reproductive system.
- Platyhelminthes are placed in four classes: Turbellaria, Monogenea, Trematoda and Cestoda.
- Taenia solium* is a pork tapworm found in the intestine of humans. The life cycle is complicated and involves a primary host (humans) and intermediate host is pig.

5.5 TERMINAL QUESTIONS

- Describe the salient features of Phylum Platyhelminthes.
- Draw and explain the life cycle of *Taenia solium*.

5.6 ANSWERS

Self-Assessment Question

- i) Osmoregulatory
- ii) a) Bilateral symmetry accompanied by cephalisation
b) Triploblastic nature with cellular parenchyma
c) Presence of many organ systems.
- iii) a) - IV, b) - III, c) - II, d) - I.

Terminal Questions

- 1. Refer to Subsection 5.2.1.
- 2. Refer to Section 5.3.



PHYLUM NEMATODA

Structure

6.1	Introduction Objectives	6.4	Parasitic Adaptations in <i>Ascaris lumbricoides</i>
6.2	Nematoda Characteristic Features Classification of Phylum Nematoda	6.5	Summary
6.3	Life Cycle of <i>Ascaris lumbricoides</i>	6.6	Terminal Questions
		6.7	Answers

6.1 INTRODUCTION

Phylum Nematoda is also known as Nemathelminthes. As we have studied earlier, these are animals that have a false cavity between ectoderm and endoderm which is called pseudocoel; why this is false cavity, because the ectoderm and endoderm are not lined by the mesoderm. This lining is a characteristic feature of the true coelom, the body cavity of coelomates. The pseudocoelomates comprise the minor phyla i.e., Gastrotricha, Kinorhyncha, Loricifera, Priapulida, Nematomorpha, Acanthocephala, Entoprocta, Rotifera and major phylum Nematoda. These were initially put together, but since these groups are polyphyletic – they have originated from different ancestors – they comprise separate phyla. Recall from Unit 2 that Phylum Nematoda along with Arthropoda and these minor phyla make up a large group – Ecdyzoa and they all excrete an external skeleton which is shed by a process known as ecdysis or moulting. In the present unit we will be studying only Phylum Nematoda.

Objectives

After studying this unit, you should be able to:

- ❖ recognise the characters of phylum Nematoda;
- ❖ describe the characteristic features of different classes of animals placed under this phylum along with their examples;
- ❖ give a basic idea of organisation of the body of pseudocoelomate animals;
- ❖ explain the life history of round worm in *Ascaris lumbricoides*; and
- ❖ discuss the various parasitic adaptations in *Ascaris lumbricoides*.

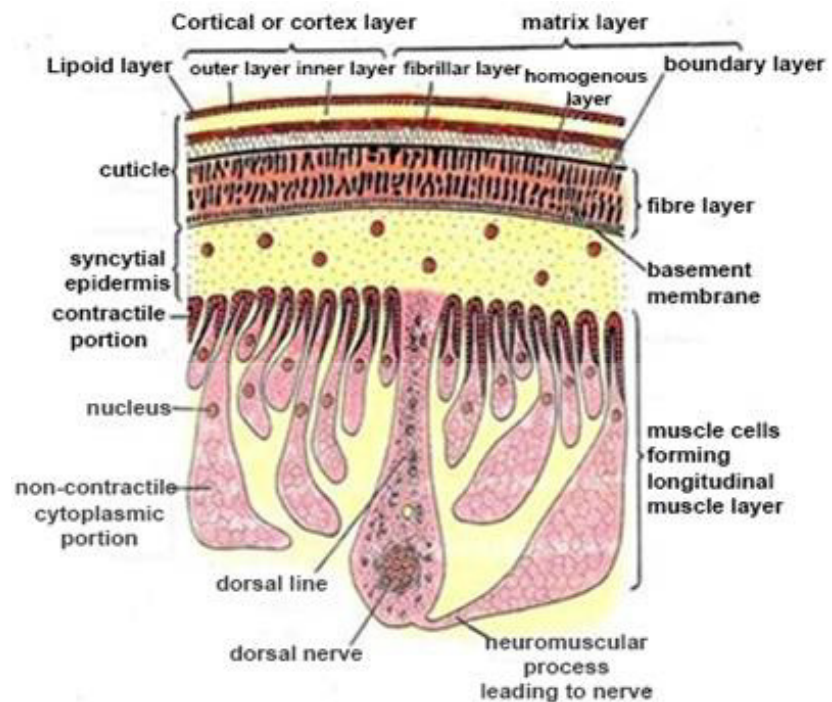
6.2 NEMATODA

Animals belonging to Phylum Nematoda are popularly known as round worms. A highly successful group of animals with about 12,000 species known, but unknown species estimated so far outnumber these (about 5,00,000!). They are found free in the soil in all types of aquatic environment, in animals and plants, as parasites. They are also known to cause diseases in them. However, there is very little structural diversity among them, all being built on the same fundamental plan.

6.2.1 Characteristic Features

1. Vermiform body bilaterally symmetrical, but with tendency for radial symmetry along longitudinal axis. Cross sectional area circular; no segmentation or appendages.
2. A tough and complex cuticle is present.
3. Body has more than two cell-layers; tissues and organs present.
4. Circular muscles absent in the body wall.
5. Body cavity is pseudocoel, with body fluid at high pressure.
6. Gut extending from the mouth at the anterior end to anus which is sub-terminal. Muscular pharynx.
7. One ventral, one dorsal and two lateral epidermal chords with longitudinal muscles arranged in the four quadrants in between.
8. Longitudinal nerves in the dorsal and ventral epidermal chords, with direct contact with muscle cells.
9. Muscles of the body wall are peculiar features.
10. No circulatory system. No flame cells or nephridia. No cilia or flagella. Excretory tubules in one or a limited number of renette cells.
11. Highly determinate type of cleavage. Development direct.
12. A very unique characteristic feature that they show is **Eutely** i.e., as they mature from young to adult, growth involves increase in cell-size rather than cell number.

The cuticle of nematodes is characteristic of the group. It is non-living and many layered, with spiral fibres of one layer crossing those of the others (Fig. 6.1 a). This type of cuticular organisation affords considerable strength to withstand high hydrostatic pressure of the fluid within the body cavity.



(a)

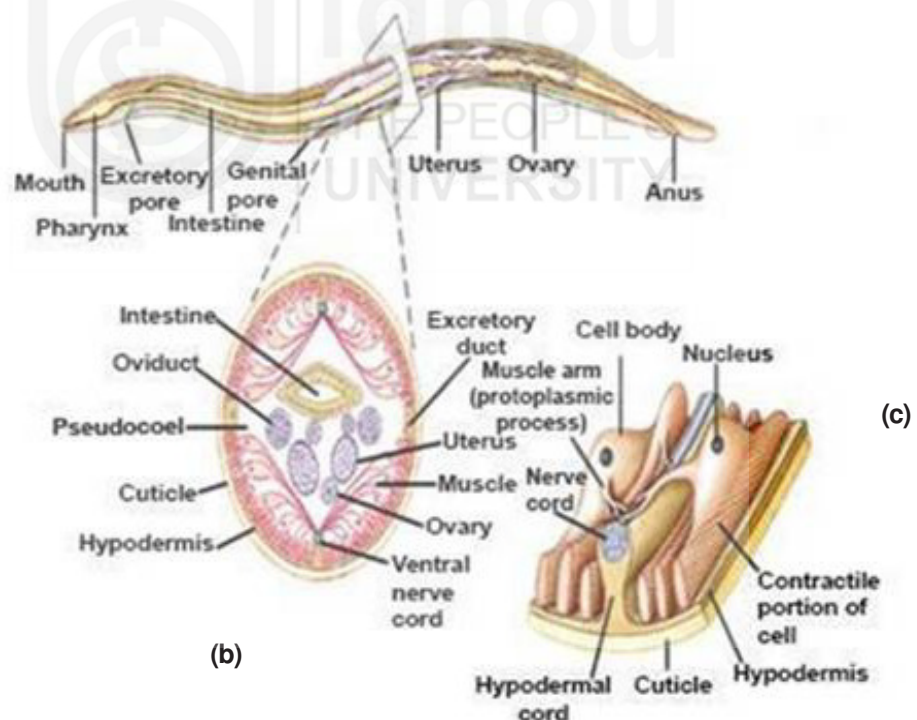


Fig. 6.1: a) Structure of the nematode cuticle. The cuticle consists of an outer striated layer, an inner homogeneous layer and a complex of fibrous layers; b & c, Structure of a nematode as illustrated by *Ascaris* female; b) Cross section; c) Single muscle cell; muscle arm extends to dorsal or ventral nerve.

A cross section of the body wall (Fig. 6.1 b) shows epidermal layer beneath the cuticle. There are four longitudinal strands of chords in the epidermis: one mid-ventral, one mid-dorsal and two lateral. The dorsal and the ventral chords

contain the longitudinal nerve trunks: the lateral chords contain the excretory canal. The muscle fibres are peculiar in this phylum. They form neuromotor units. The contractile elements of these rest on the epidermis (Fig. 6.1c). An innervation process proceeds from the muscle cell to the nerve chord. It enables simultaneous contraction of all muscle cells. You may note here that the system of muscle fibres sending process to the nerve fibre is unusual. It is the nerve fibre which usually sends process to the muscle fibres.

The alimentary canal is made up mostly of the non-muscular intestine. The pharynx has, however, a muscular functioning to pump food into the gut. Rectum is short leading out through the anus. The body cavity is almost completely filled by the paired reproductive organs (Fig. 6.2), sexes are separate. Fertilization is internal. The eggs when laid, are either zygotes, or even embryos at early stages of development. They are extremely resistant.

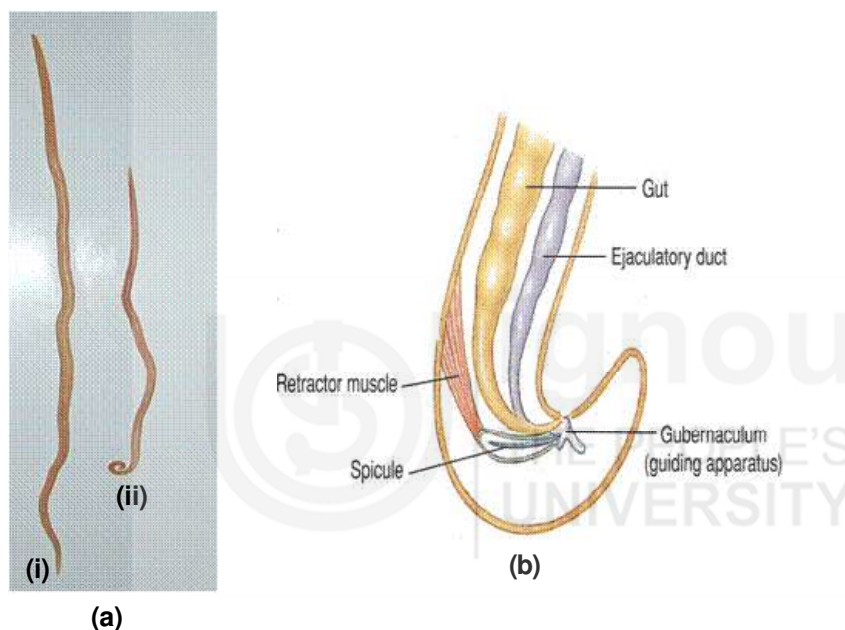


Fig. 6.2: a) i) Female *Ascaris*; ii) Male *Ascaris*; b) Tip of Male *Ascaris*.

6.2.2 Classification of Phylum Nematoda

The phylum is divided into two classes based on the presence or absence of phasmids that are minute paired sensory organs (chemoreceptors) located posteriorly to the anus:

1. **Class Secernentea (Phasmidia)** : Almost all are terrestrial. Many are important parasites. Most free-living species live in soil. Amphids are sensory and pore like, located on lateral lips. Phasmids are present. Epidermal cells are uni or multinucleated. Excretory glands or excretory canals are present. Examples: *Ascaris* (Fig 6.2), *Ancylostoma* (Fig. 6.3), *Enterobius* (Fig. 6.4), *Wuchereria*, *Rhabditis*.
2. **Adenophorea (Aphasmidia)** The group is polyphyletic. Most are free-living, some are parasitic. Free-living species include some terrestrial and almost all freshwater and marine nematodes. Various shaped amphids located behind lips. Lack phasmids, epidermal cells are uninucleate. Excretory glands are present. No excretory canals. Examples: *Trichinella* (Fig. 6.5).

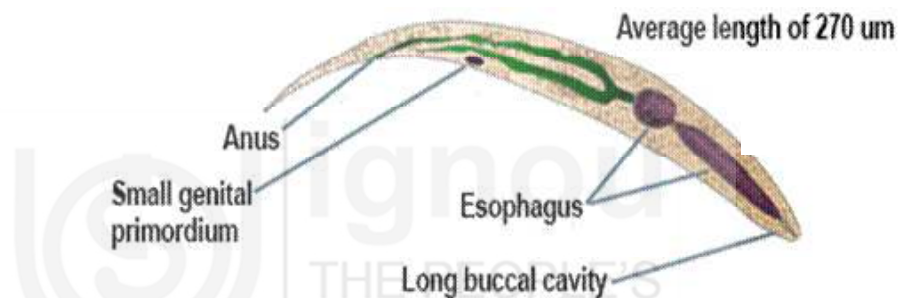
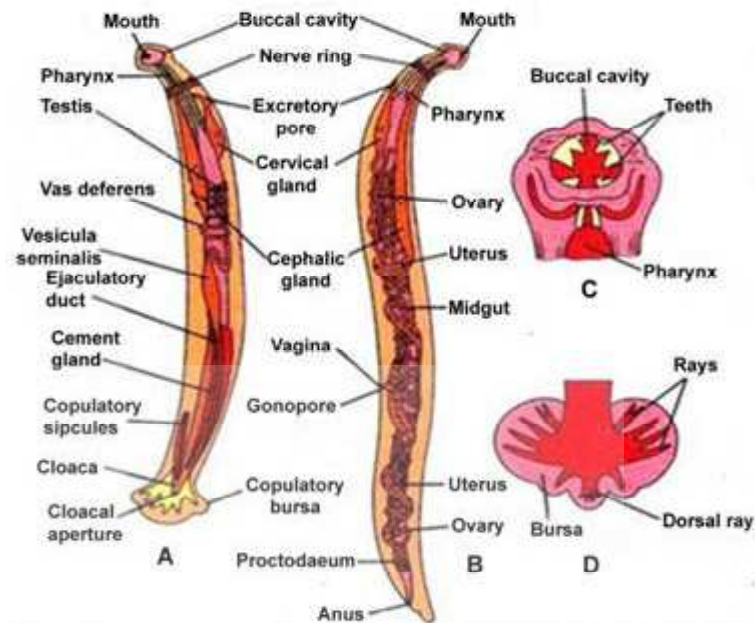


Fig. 6.3: A) Male *Ancylostoma duodenale*; B) Female *Ancylostoma duodenale*; C) Anterior end; D) Posterior end; and E) First stage rhabdiform.

Some well known examples of parasitic nematodes are *Ascaris lumbricoides* i.e. the human intestinal round worm. *Ascaris megalocephala* is found in the intestine of horses. An *Ascaris* female may lay about 2,00,000 eggs per day, which pass out along the stools of the host. The eggs remain alive for years, in the soil. They gain entry into the host alimentary canal through

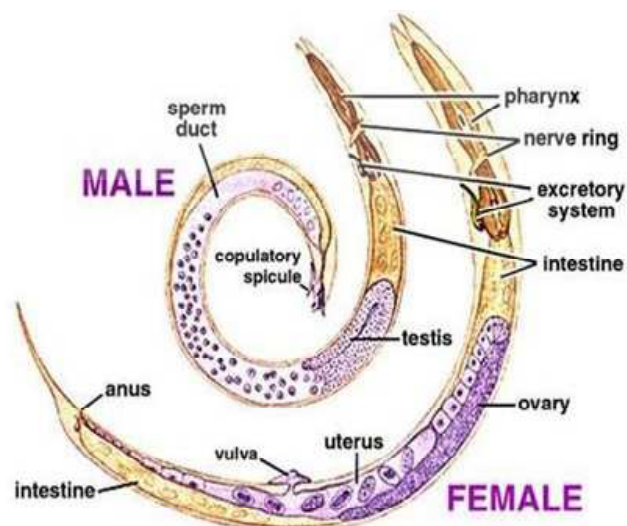


Fig. 6.4: *Enterobius vermicularis*.

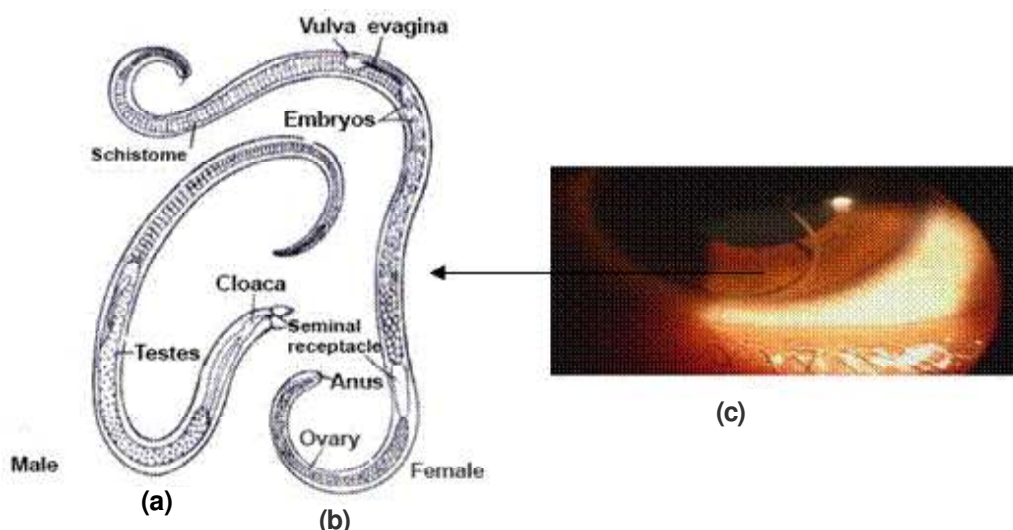


Fig. 6.5: a) Male; and b) Female *Trichinella spiralis*; c) Eye worm in cornea.

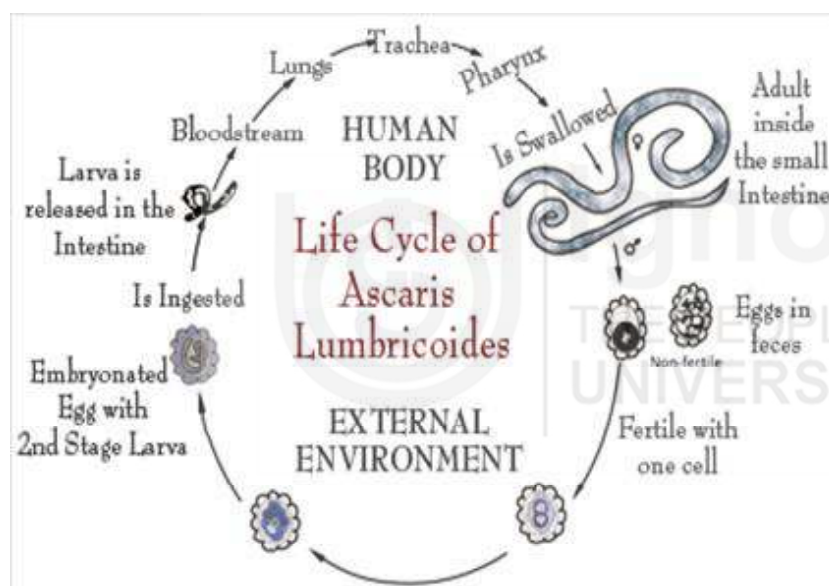


Fig. 6.6: Life cycle of *Ascaris*.

contaminated food and there the tiny juveniles come out of the eggs (Fig. 6.6.). Then they burrow through the intestinal wall and enter the veins and lymph vessels, from where they are carried to the heart and from there to the lungs. There they penetrate the alveoli and enter the trachea. If infestation is severe they may cause pneumonia at this stage. When they reach pharynx they may be swallowed, passing through the stomach and maturing in about two months after ingestion of eggs. In the intestine they feed on intestinal contents and cause various symptoms, including intestinal blockade, if present in large numbers.

The hook worm *Ancylostoma duodenale* (Fig. 6.3) is a parasite of man. The anterior end curves dorsally in the form of a hook. By means of large plates in their mouth they lacerate the intestinal mucosa of the human host and pump blood into intestine, as a result of which the host becomes anaemic. Eggs pass out through faeces and juveniles hatch out in the soil. They burrow

through the human skin to blood, reaching lungs and ultimately intestine, as in *Ascaris*.

Other examples include the pinworm (Fig. 6.4). *Enterobius vermicularis*, the trichina worm *Trichinella spiralis* (Fig. 6.5) and *Brugiamalayi* living in the lymphatic system causing obstruction and inflammation. The females of the filarial worm release small microfilariae into blood and lymphatic system. These enter the mosquito through blood. In the mosquito they undergo development upto infective stage. Then they escape mosquito and enter another human host through the mosquito bite.

6.3 LIFE CYCLE OF *ASCARIS LUMBRICOIDES*

Ascaris is commonly known as *roundworm* inhabiting the human's small intestine and more commonly infests children. This endoparasite completes its life cycle without intermediate host. *Ascaris lumbricoides* is light yellow to light pink in colour. The body is elongated, cylindrical and pointed at both the ends. The female is about 20 to 40 centimeter and male is about 15 to 30 centimeter in length. Mouth is situated at the anterior and guarded by three lips. Alimentary canal of the *Ascaris* consists of foregut, midgut and hindgut. This parasite carries out its respiration anaerobically.

Copulation of *Ascaris* takes place inside the intestine of the humans. Fertilized ovum undergoes maturation division and is released in the intestine of the host from where they pass out with faeces. Under favourable conditions the eggs develop into the rhabdoid larvae, an infective stage. This reaches the intestine of human by ingestion of contaminated food or water. The egg shells are dissolved and juveniles hatch out. These juveniles penetrate the intestine and enter the hepatic portal system and from here they reach the liver, heart and finally lungs where they develop into 3rd larval stage that is followed by 4th larval stage. The fourth stage larvae get to the pharynx through trachea and then get to attain adult stage. Average life span of *Ascaris* is 9 to 12 months in humans (see Fig. 6.6).

6.4 PARASITIC ADAPTATIONS IN *ASCARIS LUMBRICOIDES*

The survival of a parasite in the body of host depends upon its ability to adapt to surrounding environment at the site of infection that is, microenvironment. Certain morphological, anatomical and physiological changes occur in the parasite to adapt to this microenvironment and because of these, the parasite survives in the host. Such changes which facilitate a parasite to adapt to parasitic mode of life in the host itself are called *parasitic adaptations*.

Different parasitic adaptations are as follows:

1. Body shape and size of the parasite depends upon the space available at the site of infection. Body of *Ascaris* is elongated, cylindrical and tapered at both ends which happen to be an important adaptation for moving in a small narrow space.
2. Locomotory structures are almost absent in the parasitic forms as they need not move in search of food.

3. If a parasite in the body occurs without attaching to the surrounding tissues, it gets carried away to a non-specific site or to the exterior of the body, in which case, survival is not possible. Therefore, to remain at the specific site of infection they attach to the surrounding tissues in the intestine. For this *Ascaris* has a mouth bound by three lips that help it to attach to the membrane of the host intestine.
4. To protect itself from the harmful effects of digestive enzymes of the host, the parasite's body surface is covered with cuticle. Physiological studies demonstrate that *Ascaris* secretes enzyme inhibitors which provide protection to the worm from host's digestive enzymes.
5. *Ascaris lumbricoides* live as facultative anaerobes as the availability of oxygen is very less or no oxygen is available for them. They can carry on aerobic respiration if oxygen is available and anaerobic respiration in the absence of oxygen.
6. The reproductive potential of a parasite is very high. A single female of *Ascaris* may lay about 2,00,000 eggs per day which exit the body of the host with the faeces. In spite of numerous risks during development, high reproductive potential ensures the continuation of the parasitic race. A large production of eggs is an adaption to parasitic mode of life.
7. The developing eggs are resistant to adverse environmental conditions and may remain viable in soil for 20 years. It is also a adaptation to parasitic mode of life.
8. According to physiological studies *Ascaris* secretes enzyme inhibitors which provide protection to round worm from the host's digestive enzymes.
9. Due to presence of the parasites, the host's immunological system gets activated producing antibodies to eliminate parasites. However, parasites elude the action of antibodies generally by a process of molecular mimicry, in which the parasites are covered by molecules that are similar to that of the host. These are considered by host's antibodies as self molecules and antibodies fail to counteract.

SAQ

Fill in the blanks with appropriate word given in the parenthesis:

- i) The of nematode is characteristic of the group (epidermis/cuticle).
 - ii) The hookworm *Ancylostoma duodenate* is a parasite of (cat/humans).
 - iii) The of the filarial worm release small microfilariae into blood and lymphatic system (male/female).
 - iv) *Ascaris megalcephala* is found in the intestine of (goat/horse).
 - v) *Ascaris lumbricoides* lives as anaerobe as the availability of oxygen is very less (obligative/ facultative).
-

6.5 SUMMARY

Let us summarise what we have learnt so far:

- Animals placed in phylum Nematoda are popularly known as round worms. They are found in soil in animals and plants as parasites or free living.
- Vermiform body, bilaterally symmetrical, cross sectional area circular, no segmentation or appendages. A complex cuticle present.
- No circulatory system. No flame cells or nephridia, muscular pharynx.
- *Ascaris lumbricoides* is a common parasite in the human small intestine. The parasite carries out its respiration anaerobically. Copulation of *Ascaris* takes place inside the intestine of human host. Average life span of *Ascaris* is 9-12 months in humans.
- The survival of parasite in the body of host depends upon its ability to adapt to surrounding environment at the site of infection. Such changes which facilitate a parasite to adapt to parasitic mode of life in the host itself are called parasitic adaptations.

6.6 TERMINAL QUESTIONS

1. Discuss the salient features of phylum Nematoda.
2. What is parasitic adaptation? Explain the adaptations that have taken place in *Ascaris lumbricoides*.

6.7 ANSWERS

Self-Assessment Question

i) Cuticle, ii) humans, iii) female, iv) horse, v) facultative.

Terminal Questions

1. Refer to Subsection 6.2.1.
2. Refer to Section 6.4.

CREDITS FOR PHOTOS AND DIAGRAMS

UNIT 1 ANIMAL LIKE PROTISTS: PROTOZOANS

- Fig. 1.1:** Based on Campbell et al Biology A Global Approach; 10th ed. Pearson Education Ltd.
- Fig. 1.2:** photo source for *Trichonympha* <http://www.microscopy-uk.org.uk/mag/indexmag.html?http://www.microscopy-uk.org.uk/mag/artmar03/rhtermite.html>
- Fig. 1.3:** a) *Trypanosoma gambiense* Photo Credit: Content Providers: CDC/Dr. Myron G. Schultz -This media comes from the Centers for Disease Control and Prevention's Public Health Image Library (PHIL)

b) *Leishmania donovani* source: <https://www.studyblue.com/notes/note/n/parasite-quizzes/deck/15026424>
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- Fig. 1.8:** Protist Information Server, URL: <http://protist.i.hosei.ac.jp/>
- Fig. 1.9:** a) <http://www.markwebber.org/images/plankton05/pages/Unawatuna-marine-IV-Globigerina%20sp-2745-2-Sept%2010-05.html>

b) Source: <https://wordsinmocean.com/2012/05/16/does-phosphate-thin-foram-shells/>
- Fig. 1.10:** Source: radiolarian.org
- Fig. 1.11:** a) Plasmodial slime mold *Leocarpus fragilis*, (By Aorg1961 - Own work, GFDL, <https://commons.wikimedia.org/w/index.php?curid=9613693>) b) Cellular slime mold *Dictyostelium* (source: dictyexpress.org)

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b) *Entamoeba histolytica* cysts.
(By DPD CDC http://www.dpd.cdc.gov/dpdx/images/ParasiteImages/A-F/Amebiasis/E_histol_trophs_F.JPG, Public Domain) <https://commons.wikimedia.org/w/index.php?curid=741354>).
- Fig. 1.14:** a) *Nucearia* sp User:NEON_ja - Own work, CC BY-SA 2.5, <https://commons.wikimedia.org/w/index.php?curid=1702884>)
- Fig. 1.19:** (source: <https://www.youtube.com>)
- Fig. 1.21:** Electron micrographs (Source and public domain notice at <http://remf.dartmouth.edu/imagesindex.html>).

UNIT 2 ANIMAL CLASSIFICATION AND ARCHITECTURE

- Fig. 2.1:** Modified from Pearson Education
- Fig. 2.14:** <http://en.wikipedia.org/wiki/File:ColonialFlagellateHypothesis.png>

UNIT 3 PHYLUM PORIFERA

- Fig. 3.1:** (*Leucosolenia* (Source: <http://www.unterwasserweltostsee.de/html/rohrenkalkschwamm.html>),
Sycon (Source: <http://www.biozoomer.com/2014/04/sycon-sponge-reproduction.html>),
Euspongia (Source: <https://quizlet.com/16656082/test>)
- Fig. 3.6:** (Source: www.pinterest.com/pin/519884350705840762)
- Fig. 3.8:** (Source www.biologydiscussion.com/invertebrate-zoology/sponges/11-representative-types-of-sponges/28552)
- Fig. 3.9:** (Source: www.whyevolutionistrue.wordpress.com/2012/11/29/the-amazing-mimicry-of-frogfish/)

UNIT 4 PHYLUM CNIDARIA

- Fig. 4.1:** (Source: www.cnidaria2.wikispaces.com)
- Fig. 4.2:** (source: www.biologydiscussion.com/invertebrate-zoology/phylum-coelenterata/internal-structure-of-hydra-with-diagram/28580)
- Fig. 4.3:** (Source: www.sites.google.com/a/pennington.org/box-jellyfish/description)

- Fig. 4.4:** (Source: www.schaechter.asmblog.org/.a/6a00d8341c5e1453ef016767926740970b-popup)
- Fig. 4.5:** (Source: [http://highereducation.com/sites/dl/free/0073212040/63802/05811.jpg](http://www.http://highereducation.com/sites/dl/free/0073212040/63802/05811.jpg))
- Fig. 4.6:** (Source: www.keyword-suggestions.com/Z2VudXMgZ29uaW9uZW11cw)
- Fig. 4.7:** (Source: <https://s-media-cache-ak0.pinimg.com/236x/9f/2c/21/9f2c21fe892ec27e47b57516fb8bf9cd.jpg>;
(Source: www.biologydiscussion.com/invertebrate-zoology/17representative-types-of-coelenterata-zoology/28769)
- Fig. 4.8:** (Source: www.medusas.org/medusas-velero;
(Source: www.art4search.com/jellyfish-diagram-with-labeled-parts-chat-patrickneyman)
- Fig. 4.9:** (Source: www.discoverlife.org/mp/20p?see=I_JP13&res=640;
(Source: www.oregonexpat.files.wordpress.com/2013/02/jelly-life-cycle.jpg?w=252&h=250)
- Fig. 4.10:** (Source: www.toplistenz.com/wp-content/uploads/2016/08/Box-Jellyfish.jpg)
- Fig. 4.11:** (Source: www.maryanakruk.files.wordpress.com/2014/03/sea_anemone_structure.jpg)
- Fig. 4.12:** (Source: <http://www.biolib.cz/IMG/GAL/14093.jpg>)
(Source: www.aquariumdomain.com/images/corals/orangeTreeGorgonian1.jpg)
- Fig. 4.13:** (Source: <https://encryptedtbn3.gstatic.com/images?q=tbn:ANd9GcRx8QtY21Sz7qs6u667GGBon5y7ciXBnwY1TqRsC5MNeGp72FB2ow>)
- Fig. 4.14:** (Source: www.aliexpress.com/item-img/Antipathes-dichotoma-Pallas-Natural-sea-cycas-Gorgonians-Juneberry-Tieshu-willow-aquarium-wedding-home-decoration-20-35cm/1882457614.html?spm=2114.10010108.1000017.2.4tkExp#)
(Source: <http://www.magicporthole.org/news/OCEANA-35092.jpg>)
- Fig. 4.15:** (Source: www.gettyimages.com.au/detail/photo/branched-alcyonarian-coral-with-polyps-high-res-stock-photography/128119010)
- Fig. 4.16:** (Source: www.slideplayer.com/slide/4887108)

- Fig. 4.17:** (Source: [www. http://siera104.com/images/bio/cndaria/Obelia.jpg](http://siera104.com/images/bio/cndaria/Obelia.jpg))
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- Fig. 4.19:** (Source: [www.kullabs.com/uploads/cccc_\(2\).jpg](http://www.kullabs.com/uploads/cccc_(2).jpg))
(Source: www.hccfl.edu)
- Fig. 4.20:** (Source: cdn.biologydiscussion.com/wp-content/uploads/2016/04/clip_image012-7.jpg; Source: classconnection.s3.amazonaws.com/212/flashcards/692292/jpg/obelia_medusa.ashx.jpg)
- Fig. 4.21:** (Source: http://cdn.biologydiscussion.com/wpcontent/uploads/2016/05/clip_image008-78.jpg);
(Source: [www.kullabs.com/uploads/clip_image024_thumb-2_\(2\).jpg](http://www.kullabs.com/uploads/clip_image024_thumb-2_(2).jpg))

UNIT 5 PHYLUM PLATYHELMINTHES

- Fig. 5.1:** (Source: www.schoolbag.info/biology/living/living.files/image784.jpg)
- Fig. 5.2:** (Source: classconnection.s3.amazonaws.com/600/flashcards/2690600/jpg/fig003-143BDBB5DE801450425.jpg)
- Fig. 5.3:** (Source: users.monash.edu.au/~murray/AIMS-R-users/images/Dugesia.jpg);
Source: www.biologycorner.com/resources/flatworm.gif)
- Fig. 5.5:** (Source: www.es.slideshare.net/karina2260/phyllum-platelmintes)
- Fig. 5.7:** (Source: www.impe-qn.org.vn/impe-qn/vn/upload/info/image/1472713833352_image007.jpg);
(Source: www.savalli.us/BIO385/Diversity/05.Platyhelminthes Images/Sheep FlukeL.jpg)
- Fig. 5.8:** (Source: i.dailymail.co.uk/i/pix/2015/01/13/24ABA24B00000578-0-image-a-571421171233533.jpg);
(Source: scan.myspecies.info/sites/scan.myspecies.info/files/Lifecycle2_AE_7_3_2014.jpg)
- Fig. 5.9:** (Source: http://cronodon.com/images/Cestode_sensory.jpg)
- Fig. 5.10:** (Source: cdn.biologydiscussion.com/wp-content/uploads/2016/08/image-327.png)

Fig. 5.11: (Source: www.vdsstream.wikispaces.com/file/view/Echinococcus-multilocularis-adult.jpg/576105013/Echinococcus-multilocularis-adult.jpg;

(Source: rowdysites.msudenver.edu/~churchcy/BIO3270/Images/Worms/Echinococcusps.jpg)

Fig. 5.12: (Source: www.web.stanford.edu/class/humbio103/ParaSites2006/Taenia_solium/Images/Taenia_LifeCycle.gif)

Unit 6 PHYLUM NEMATODA

Fig. 6.1: (Source: cdn.biologydiscussion.com/wp-content/uploads/2016/04/clip_image007-15.jpg;

(Source: www.lifescitpjhs.wikispaces.com/file/view/nematode-body.jpg/572864849/800x564/nematode-body.jpg)

Fig. 6.2: (Source: www.upload.wikimedia.org/wikipedia/commons/thumb/4/46/Asuum_male_and_female.jpg/800px-Asuum_male_and_female.jpg)

Fig. 6.3: (Source: cdn.biologydiscussion.com/wp-content/uploads/2016/04/clip_image005-22.jpg);

(Source: parasitologyillustrated.com/images/parasitology%20website%20images/Nematodes/necator/hookworm%20rhabditiform%20larva.png)

Fig. 6.4: (Source: sharonapbio-taxonomy.wikispaces.com/file/view/nematode.jpg/50864359/nematode.jpg)

Fig. 6.5: (Source: <http://www.southampton.ac.uk/~ceb/Diagnosis/Vol7.h44.jpg>;

(Source: i.dailymail.co.uk/i/pix/2015/12/30/10/2FADED5D00000578-3378664-A_disgusting_video_shows_a_doctors_looking_into_an_unidentified_-a-23_1451470839737.jpg)

Fig. 6.6: (Source: ruby.fgcu.edu/courses/davidb/50249/web/Trichuristrichiura133.jpg)

Fig. 6.7: (Source: <http://www.medindia.net/patients/patientinfo/images/life-cycle-of-ascaris-lumbricoides.jpg>)

GLOSSARY

Acoelomate	: an animal without a coelom or body cavity.
Alveolate	: a group of protozoans having pits or sacs under their plasma membrane, eg., apicomplexans and ciliates.
Atoll Coral	: a ring shaped reef enclosing an open lagoon.
Axostyle	: sheet of microtubules found in some microbial eucaryotes that arise from the base of flagella and continues out of the membrane into forming the core of the flagella. It helps in movement of the flagella.
Bilateria	: group of animals that show bilateral symmetry. The body can be divided into two mirror halves if a plane runs through the anterior-posterior axis.
Blastopore	: an opening in the archenteron that typically develops into the anus in deuterostomes and mouth in the protostomes.
Bud	: the smaller of two progeny cells resulting from fission.
Cepahalisation	: formation of a anterior head region with concentration of nervous tissue both during evolution and during development of the embryo.
Cnidocil	: a short, stiff, bristle like cilium that is borne on a cnidocyte, a cnidarian's cell that contains an eversible thin, long and sharp tube, the cnida.
Coelenteron	: the body cavity and gut of cnidarians and ctenophores. Gastrovascular cavity; archenteron.
Coelom	: body cavity in triploblastic animals lined by a mesodermally derived epithelium (peritoneum).
Colony	: an association of unicellular or multicellular organisms of the same species; individuals may be separate from or connected to other members of the colony and there may be some division of labour among them and sharing of resources.
Cuticle	: a tough but flexible non-mineral covering of an organism that provides protection.
Dactylozoid	: a finger-shaped, defensive hydrozoan polyp.
Determinate Cleavage	: a type of embryonic development in protostomes in which the fate of each cell is fixed very early in development.

Deuterostomia	: a group of bilateral animals in which the anus develops first from the blastopore.
Dimorphism	: existence within a species of two distinct forms, according to colour, sex, size, organ structure and so on. Occurrence of two-kinds of zooids in a colonial organism.
Dioecious	: having separate sexes; i.e. some individuals of the species contain male reproductive system and other individuals contain the female system.
Ecdyzoa	: one of the three main lineages of bilaterian animals; many of whom show moulting in their life stages.
Enterocoely	: a process by which some animal embryos develop in which the coelom is developed by outpocketing of the embryonic gut.
Epidermis	: the outer, non vascular layer of skin of ectodermal origin; in invertebrates a single layer of ectodermal epithelium.
Eutely	: condition of a body composed of genetically fixed, constant number of cell or nuclei in all adult members of species as in rotifers, acanthocephalans and nematodes.
Fringing reef	: reef that extends seaward directly from the shore.
Gel	the part of the pseudopodium that is composed of stiffened cytoplasm.
Gonophore	: a hydroid reproductive bud that bears the germ cells and may become a free swimming medusa or a variously modified sessile medusa i.e. medusoid.
Gonopore	: the external genital pore found in many invertebrates.
Gonozooid	: a hydrozoan reproductive polyp which is often reduced, lacking mouth and tentacles and bears gonophores. A sexually reproductive zooid of thaliaceans.
Hermaphroditic	: having both male and female reproductive systems in the same individual.
Hydranth	: nutritive zooids of hydroid colony.
Hydroid	: the polyp form of cnidarian as distinguished from medusa form. Any cnidarian of the class Hydrozoa, order Hydroida.

Hydroskeleton	: a mass of turgid fluid or plastic parenchyma enclosed within a muscular wall or within one of the body spaces that provide support or rigidity to an organism or one of its part, necessary for antagonistic muscle action; for example, parenchyma in acoelomates and perivisceral fluid in pseudocoelomates serve as hydrostatic skeleton.
Indeterminate cleavage:	a type of embryonic development in deuterostomes where each cell produced by early cleavage has the capacity to develop into an individual embryo.
Lophophore	: a crown of ciliated tentacles surrounding the mouth and used for feeding in some animals.
Lophotrochozoa	: one of the three main lineages of bilateral animals. These animals have a lophophore and a larval stage; the trochophore.
Medusa	: a jelly fish, or the free-swimming stage in the life of cycle of cnidarians.
Radiata	: group of animals that show radial symmetry in which the body does not have a right and left side but can be divided into two halves by any plane that passes through its central axis.
Schizocoel	: a type of development in coelomate animals where the body cavity is formed by the splitting of the embryonic mesodermal tissue.
Sedentary	: stationary, sitting inactive; staying in one place.
Siliceous	: containing silica.
Spicule	: one of the minute calcareous or siliceous skeletal bodies found in sponges, radiolarians, soft corals and sea cucumbers.
Spongin	: fibrous, collagenous material making up the skeletal network of horny sponges.

SUGGESTED READINGS

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Course Coordinator

Animal Diversity (Acoelomates, Coelomates, Anaminotes, Aminota)

Course Code: BZYCT-131

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To,

The Course Coordinator
Animal Diversity (Acoelomates, Coelomates, Anaminotes, Aminota)
Course Code: BZYCT-131
School of Sciences
Indira Gandhi National Open University
Maidan Garhi,
New Delhi-110068

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