



UNIT 1

DIVERSITY IN THE LIVING WORLD

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Animal Kingdom

Biology is the science of life forms and living processes. The living world comprises an amazing diversity of living organisms. Early man could easily perceive the difference between inanimate matter and living organisms. Early man deified some of the inanimate matter (wind, sea, fire etc.) and some among the animals and plants. A common feature of all such forms of inanimate and animate objects was the sense of awe or fear that they evoked. The description of living organisms including human beings began much later in human history. Societies which indulged in anthropocentric view of biology could register limited progress in biological knowledge. Systematic and monumental description of life forms brought in, out of necessity, detailed systems of identification, nomenclature and classification. The biggest spin off of such studies was the recognition of the sharing of similarities among living organisms both horizontally and vertically. That all present day living organisms are related to each other and also to all organisms that ever lived on this earth, was a revelation which humbled man and led to cultural movements for conservation of biodiversity. In the following chapters of this unit, you will get a description, including classification, of animals and plants from a taxonomist's perspective.



Ernst Mayr
(1904 – 2004)

Born on 5 July 1904, in Kempten, Germany, ERNST MAYR, the Harvard University evolutionary biologist who has been called 'The Darwin of the 20th century', was one of the 100 greatest scientists of all time. Mayr joined Harvard's Faculty of Arts and Sciences in 1953 and retired in 1975, assuming the title *Alexander Agassiz Professor of Zoology Emeritus*. Throughout his nearly 80-year career, his research spanned ornithology, taxonomy, zoogeography, evolution, systematics, and the history and philosophy of biology. He almost single-handedly made the origin of species diversity the central question of evolutionary biology that it is today. He also pioneered the currently accepted definition of a biological species. Mayr was awarded the three prizes widely regarded as the *triple crown* of biology: the *Balzan Prize* in 1983, the *International Prize for Biology* in 1994, and the *Crafoord Prize* in 1999. Mayr died at the age of 100 in the year 2004.



CHAPTER 1

THE LIVING WORLD

1.1 *Diversity in the Living World*

1.2 *Taxonomic Categories*

How wonderful is the living world ! The wide range of living types is amazing. The extraordinary habitats in which we find living organisms, be it cold mountains, deciduous forests, oceans, fresh water lakes, deserts or hot springs, leave us speechless. The beauty of a galloping horse, of the migrating birds, the valley of flowers or the attacking shark evokes awe and a deep sense of wonder. The ecological conflict and cooperation among members of a population and among populations of a community or even the molecular traffic inside a cell make us deeply reflect on – what indeed is life? This question has two implicit questions within it. The first is a technical one and seeks answer to what living is as opposed to the non-living, and the second is a philosophical one, and seeks answer to what the purpose of life is. As scientists, we shall not attempt answering the second question. We will try to reflect on – what is living?

1.1 DIVERSITY IN THE LIVING WORLD

If you look around you will see a large variety of living organisms, be it potted plants, insects, birds, your pets or other animals and plants. There are also several organisms that you cannot see with your naked eye but they are all around you. If you were to increase the area that you make observations in, the range and variety of organisms that you see would increase. Obviously, if you were to visit a dense forest, you would probably see a much greater number and kinds of living organisms in it. Each different kind of plant, animal or organism that you see, represents a species. The number of species that are known and described range between 1.7-1.8 million. This refers to **biodiversity** or the number and

types of organisms present on earth. We should remember here that as we explore new areas, and even old ones, new organisms are continuously being identified.

As stated earlier, there are millions of plants and animals in the world; we know the plants and animals in our own area by their local names. These local names would vary from place to place, even within a country. Probably you would recognise the confusion that would be created if we did not find ways and means to talk to each other, to refer to organisms we are talking about.

Hence, there is a need to standardise the naming of living organisms such that a particular organism is known by the same name all over the world. This process is called **nomenclature**. Obviously, nomenclature or naming is only possible when the organism is described correctly and we know to what organism the name is attached to. This is **identification**.

In order to facilitate the study, number of scientists have established procedures to assign a scientific name to each known organism. This is acceptable to biologists all over the world. For plants, scientific names are based on agreed principles and criteria, which are provided in International Code for Botanical Nomenclature (ICBN). You may ask, how are animals named? Animal taxonomists have evolved International Code of Zoological Nomenclature (ICZN). The scientific names ensure that each organism has only one name. Description of any organism should enable the people (in any part of the world) to arrive at the same name. They also ensure that such a name has not been used for any other known organism.

Biologists follow universally accepted principles to provide scientific names to known organisms. Each name has two components – the **Generic name** and the **specific epithet**. This system of providing a name with two components is called **Binomial nomenclature**. This naming system given by Carolus Linnaeus is being practised by biologists all over the world. This naming system using a two word format was found convenient. Let us take the example of mango to understand the way of providing scientific names better. The scientific name of mango is written as *Mangifera indica*. Let us see how it is a binomial name. In this name *Mangifera* represents the genus while *indica*, is a particular species, or a specific epithet. Other universal rules of nomenclature are as follows:

1. Biological names are generally in Latin and written in italics. They are Latinised or derived from Latin irrespective of their origin.
2. The first word in a biological name represents the genus while the second component denotes the specific epithet.
3. Both the words in a biological name, when handwritten, are separately underlined, or printed in italics to indicate their Latin origin.

4. The first word denoting the genus starts with a capital letter while the specific epithet starts with a small letter. It can be illustrated with the example of *Mangifera indica*.

Name of the author appears after the specific epithet, i.e., at the end of the biological name and is written in an abbreviated form, e.g., *Mangifera indica* Linn. It indicates that this species was first described by Linnaeus.

Since it is nearly impossible to study all the living organisms, it is necessary to devise some means to make this possible. This process is **classification**. Classification is the process by which anything is grouped into convenient categories based on some easily observable characters. For example, we easily recognise groups such as plants or animals or dogs, cats or insects. The moment we use any of these terms, we associate certain characters with the organism in that group. What image do you see when you think of a dog? Obviously, each one of us will see 'dogs' and not 'cats'. Now, if we were to think of 'Alsatians' we know what we are talking about. Similarly, suppose we were to say 'mammals', you would, of course, think of animals with external ears and body hair. Likewise, in plants, if we try to talk of 'Wheat', the picture in each of our minds will be of wheat plants, not of rice or any other plant. Hence, all these - 'Dogs', 'Cats', 'Mammals', 'Wheat', 'Rice', 'Plants', 'Animals', etc., are convenient categories we use to study organisms. The scientific term for these categories is **taxa**. Here you must recognise that taxa can indicate categories at very different levels. 'Plants' – also form a taxa. 'Wheat' is also a taxa. Similarly, 'animals', 'mammals', 'dogs' are all taxa – but you know that a dog is a mammal and mammals are animals. Therefore, 'animals', 'mammals' and 'dogs' represent taxa at different levels.

Hence, based on characteristics, all living organisms can be classified into different taxa. This process of classification is **taxonomy**. External and internal structure, along with the structure of cell, development process and ecological information of organisms are essential and form the basis of modern taxonomic studies.

Hence, characterisation, identification, classification and nomenclature are the processes that are basic to taxonomy.

Taxonomy is not something new. Human beings have always been interested in knowing more and more about the various kinds of organisms, particularly with reference to their own use. In early days, human beings needed to find sources for their basic needs of food, clothing and shelter. Hence, the earliest classifications were based on the 'uses' of various organisms.

Human beings were, since long, not only interested in knowing more about different kinds of organisms and their diversities, but also the relationships among them. This branch of study was referred to as **systematics**. The word systematics is derived from the Latin word 'systema' which means systematic arrangement of organisms. Linnaeus

used *Systema Naturae* as the title of his publication. The scope of systematics was later enlarged to include identification, nomenclature and classification. Systematics takes into account evolutionary relationships between organisms.

1.2 TAXONOMIC CATEGORIES

Classification is not a single step process but involves hierarchy of steps in which each step represents a rank or category. Since the category is a part of overall taxonomic arrangement, it is called the **taxonomic category** and all categories together constitute the **taxonomic hierarchy**. Each category, referred to as a unit of classification, in fact, represents a rank and is commonly termed as **taxon** (pl.: taxa).

Taxonomic categories and hierarchy can be illustrated by an example. Insects represent a group of organisms sharing common features like three pairs of jointed legs. It means insects are recognisable concrete objects which can be classified, and thus were given a rank or category. Can you name other such groups of organisms? Remember, groups represent category. Category further denotes rank. Each rank or *taxon*, in fact, represents a unit of classification. These taxonomic groups/categories are distinct biological entities and not merely morphological aggregates.

Taxonomical studies of all known organisms have led to the development of common categories such as kingdom, phylum or division (for plants), class, order, family, genus and species. All organisms, including those in the plant and animal kingdoms have species as the lowest category. Now the question you may ask is, how to place an organism in various categories? The basic requirement is the knowledge of characters of an individual or group of organisms. This helps in identifying similarities and dissimilarities among the individuals of the same kind of organisms as well as of other kinds of organisms.

1.2.1 Species

Taxonomic studies consider a group of individual organisms with fundamental similarities as a **species**. One should be able to distinguish one species from the other closely related species based on the distinct morphological differences. Let us consider *Mangifera indica*, *Solanum tuberosum* (potato) and *Panthera leo* (lion). All the three names, *indica*, *tuberosum* and *leo*, represent the specific epithets, while the first words *Mangifera*, *Solanum* and *Panthera* are genera and represents another higher level of taxon or category. Each genus may have one or more than one specific epithets representing different organisms, but having morphological similarities. For example, *Panthera* has another specific epithet called *tigris* and *Solanum* includes species like *nigrum* and

melongena. Human beings belong to the species *sapiens* which is grouped in the genus *Homo*. The scientific name thus, for human being, is written as *Homo sapiens*.

1.2.2 Genus

Genus comprises a group of related species which has more characters in common in comparison to species of other genera. We can say that genera are aggregates of closely related species. For example, potato and brinjal are two different species but both belong to the genus *Solanum*. Lion (*Panthera leo*), leopard (*P. pardus*) and tiger (*P. tigris*) with several common features, are all species of the genus *Panthera*. This genus differs from another genus *Felis* which includes cats.

1.2.3 Family

The next category, **Family**, has a group of related genera with still less number of similarities as compared to genus and species. Families are characterised on the basis of both vegetative and reproductive features of plant species. Among plants for example, three different genera *Solanum*, *Petunia* and *Datura* are placed in the family Solanaceae. Among animals for example, genus *Panthera*, comprising lion, tiger, leopard is put along with genus, *Felis* (cats) in the family Felidae. Similarly, if you observe the features of a cat and a dog, you will find some similarities and some differences as well. They are separated into two different families – Felidae and Canidae, respectively.

1.2.4 Order

You have seen earlier that categories like species, genus and families are based on a number of similar characters. Generally, order and other higher taxonomic categories are identified based on the aggregates of characters. Order being a higher category, is the assemblage of families which exhibit a few similar characters. The similar characters are less in number as compared to different genera included in a family. Plant families like Convolvulaceae, Solanaceae are included in the order Polymoniales mainly based on the floral characters. The animal order, Carnivora, includes families like Felidae and Canidae.

1.2.5 Class

This category includes related orders. For example, order Primata comprising monkey, gorilla and gibbon is placed in class Mammalia along with order Carnivora that includes animals like tiger, cat and dog. Class Mammalia has other orders also.

1.2.6 Phylum

Classes comprising animals like fishes, amphibians, reptiles, birds along with mammals constitute the next higher category called Phylum. All

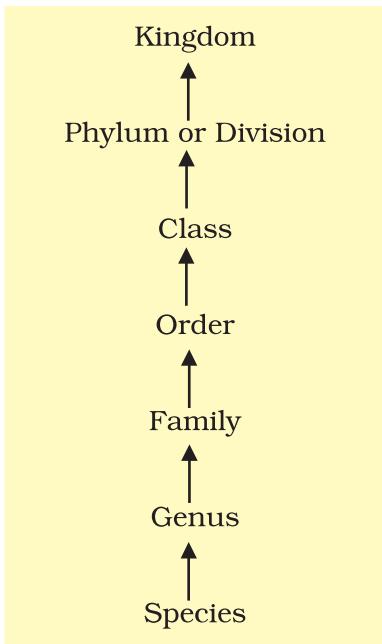


Figure 1.1 Taxonomic categories showing hierarchical arrangement in ascending order

these, based on the common features like presence of notochord and dorsal hollow neural system, are included in phylum Chordata. In case of plants, classes with a few similar characters are assigned to a higher category called Division.

1.2.7 Kingdom

All animals belonging to various phyla are assigned to the highest category called Kingdom Animalia in the classification system of animals. The Kingdom Plantae, on the other hand, is distinct, and comprises all plants from various divisions. Henceforth, we will refer to these two groups as animal and plant kingdoms.

The taxonomic categories from species to kingdom have been shown in ascending order starting with species in Figure 1.1. These are broad categories. However, taxonomists have also developed sub-categories in this hierarchy to facilitate more sound and scientific placement of various taxa.

Look at the hierarchy in Figure 1.1. Can you recall the basis of arrangement? Say, for example, as we go higher from species to kingdom, the number of common characteristics goes on decreasing. Lower the taxa, more are the characteristics that the members within the taxon share. Higher the category, greater is the difficulty of determining the relationship to other taxa at the same level. Hence, the problem of classification becomes more complex.

Table 1.1 indicates the taxonomic categories to which some common organisms like housefly, man, mango and wheat belong.

TABLE 1.1 Organisms with their Taxonomic Categories

Common Name	Biological Name	Genus	Family	Order	Class	Phylum/ Division
Man	<i>Homo sapiens</i>	<i>Homo</i>	Hominidae	Primates	Mammalia	Chordata
Housefly	<i>Musca domestica</i>	<i>Musca</i>	Muscidae	Diptera	Insecta	Arthropoda
Mango	<i>Mangifera indica</i>	<i>Mangifera</i>	Anacardiaceae	Sapindales	Dicotyledonae	Angiospermae
Wheat	<i>Triticum aestivum</i>	<i>Triticum</i>	Poaceae	Poales	Monocotyledonae	Angiospermae

SUMMARY

The living world is rich in variety. Millions of plants and animals have been identified and described but a large number still remains unknown. The very range of organisms in terms of size, colour, habitat, physiological and morphological features make us seek the defining characteristics of living organisms. In order to facilitate the study of kinds and diversity of organisms, biologists have evolved certain rules and principles for identification, nomenclature and classification of organisms. The branch of knowledge dealing with these aspects is referred to as taxonomy. The taxonomic studies of various species of plants and animals are useful in agriculture, forestry, industry and in general for knowing our bio-resources and their diversity. The basics of taxonomy like identification, naming and classification of organisms are universally evolved under international codes. Based on the resemblances and distinct differences, each organism is identified and assigned a correct scientific/biological name comprising two words as per the binomial system of nomenclature. An organism represents/occupies a place or position in the system of classification. There are many categories/ranks and are generally referred to as taxonomic categories or taxa. All the categories constitute a taxonomic hierarchy.

EXERCISES

1. Why are living organisms classified?
2. Why are the classification systems changing every now and then?
3. What different criteria would you choose to classify people that you meet often?
4. What do we learn from identification of individuals and populations?
5. Given below is the scientific name of Mango. Identify the correctly written name.

Mangifera Indica

Mangifera indica

6. Define a taxon. Give some examples of taxa at different hierarchical levels.
7. Can you identify the correct sequence of taxonomical categories?
 - (a) Species → Order → Phylum → Kingdom
 - (b) Genus → Species → Order → Kingdom
 - (c) Species → Genus → Order → Phylum
8. Try to collect all the currently accepted meanings for the word 'species'. Discuss with your teacher the meaning of species in case of higher plants and animals on one hand, and bacteria on the other hand.
9. Define and understand the following terms:
(i) Phylum (ii) Class (iii) Family (iv) Order (v) Genus
10. Illustrate the taxonomical hierarchy with suitable examples of a plant and an animal.



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CHAPTER 2

BIOLOGICAL CLASSIFICATION

- [**2.1 Kingdom Monera**](#)
- [**2.2 Kingdom Protista**](#)
- [**2.3 Kingdom Fungi**](#)
- [**2.4 Kingdom Plantae**](#)
- [**2.5 Kingdom Animalia**](#)
- [**2.6 Viruses, Viroids and Lichens**](#)

Since the dawn of civilisation, there have been many attempts to classify living organisms. It was done instinctively not using criteria that were scientific but borne out of a need to use organisms for our own use – for food, shelter and clothing. Aristotle was the earliest to attempt a more scientific basis for classification. He used simple morphological characters to classify plants into trees, shrubs and herbs. He also divided animals into two groups, those which had red blood and those that did not.

In Linnaeus' time a **Two Kingdom** system of classification with **Plantae** and **Animalia** kingdoms was developed that included all plants and animals respectively. This system did not distinguish between the eukaryotes and prokaryotes, unicellular and multicellular organisms and photosynthetic (green algae) and non-photosynthetic (fungi) organisms. Classification of organisms into plants and animals was easily done and was easy to understand, but, a large number of organisms did not fall into either category. Hence the two kingdom classification used for a long time was found inadequate. Besides, gross morphology a need was also felt for including other characteristics like cell structure, nature of wall, mode of nutrition, habitat, methods of reproduction, evolutionary relationships, etc. Classification systems for the living organisms have hence, undergone several changes over the time. Though plant and animal kingdoms have been a constant under all different systems, the understanding of what groups/organisms be included under these kingdoms have been changing; the number and nature of other kingdoms have also been understood differently by different scientists over the time.

TABLE 2.1 Characteristics of the Five Kingdoms

Characters	Five Kingdoms				
	Monera	Protista	Fungi	Plantae	Animalia
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellulosic (Polysaccharide + amino acid)	Present in some	Present with chitin	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multicellular / loose tissue	Tissue / organ	Tissue / organ / organ system
Mode of nutrition	Autotrophic (chemosynthetic and photosynthetic) and Heterotrophic (saprophytic / parasitic)	Autotrophic (Photosynthetic) and Heterotrophic	Heterotrophic (Saprophytic / Parasitic)	Autotrophic (Photosynthetic)	Heterotrophic (Holozoic / Saprophytic etc.)

R.H. Whittaker (1969) proposed a **Five Kingdom Classification**. The kingdoms defined by him were named **Monera**, **Protista**, **Fungi**, **Plantae** and **Animalia**. The main criteria for classification used by him include cell structure, body organisation, mode of nutrition, reproduction and phylogenetic relationships. Table 2.1 gives a comparative account of different characteristics of the five kingdoms.

The three-domain system has also been proposed that divides the Kingdom Monera into two domains, leaving the remaining eukaryotic kingdoms in the third domain and thereby a six kingdom classification. You will learn about this system in detail at higher classes.

Let us look at this five kingdom classification to understand the issues and considerations that influenced the classification system. Earlier classification systems included bacteria, blue green algae, fungi, mosses, ferns, gymnosperms and the angiosperms under 'Plants'. The character that unified this whole kingdom was that all the organisms included had a cell wall in their cells. This placed together groups which widely differed in other characteristics. It brought together the prokaryotic bacteria and the blue green algae (cyanobacteria) with other groups which were eukaryotic. It also grouped together the unicellular organisms and the multicellular ones, say, for example, *Chlamydomonas* and *Spirogyra* were placed together under algae. The classification did not differentiate between the heterotrophic group – fungi, and the autotrophic green plants, though they also showed a characteristic difference in their walls composition – the fungi had chitin

in their walls while the green plants had a cellulosic cell wall. When such characteristics were considered, the fungi were placed in a separate kingdom – Kingdom Fungi. All prokaryotic organisms were grouped together under Kingdom Monera and the unicellular eukaryotic organisms were placed in Kingdom Protista. Kingdom Protista has brought together *Chlamydomonas*, *Chlorella* (earlier placed in Algae within Plants and both having cell walls) with *Paramoecium* and *Amoeba* (which were earlier placed in the animal kingdom which lack cell wall). It has put together organisms which, in earlier classifications, were placed in different kingdoms. This happened because the criteria for classification changed. This kind of changes will take place in future too depending on the improvement in our understanding of characteristics and evolutionary relationships. Over time, an attempt has been made to evolve a classification system which reflects not only the morphological, physiological and reproductive similarities, but is also phylogenetic, i.e., is based on evolutionary relationships.

In this chapter we will study characteristics of Kingdoms Monera, Protista and Fungi of the Whittaker system of classification. The Kingdoms Plantae and Animalia, commonly referred to as plant and animal kingdoms, respectively, will be dealt separately in chapters 3 and 4.

2.1 KINGDOM MONERA

Bacteria are the sole members of the Kingdom Monera. They are the most abundant micro-organisms. Bacteria occur almost everywhere. Hundreds of bacteria are present in a handful of soil. They also live in extreme habitats such as hot springs, deserts, snow and deep oceans where very few other life forms can survive. Many of them live in or on other organisms as parasites.

Bacteria are grouped under four categories based on their shape: the spherical Coccus (pl.: cocci), the rod-shaped Bacillus (pl.: bacilli), the comma-shaped Vibrium (pl.: vibrio) and the spiral Spirillum (pl.: spirilla) (Figure 2.1).

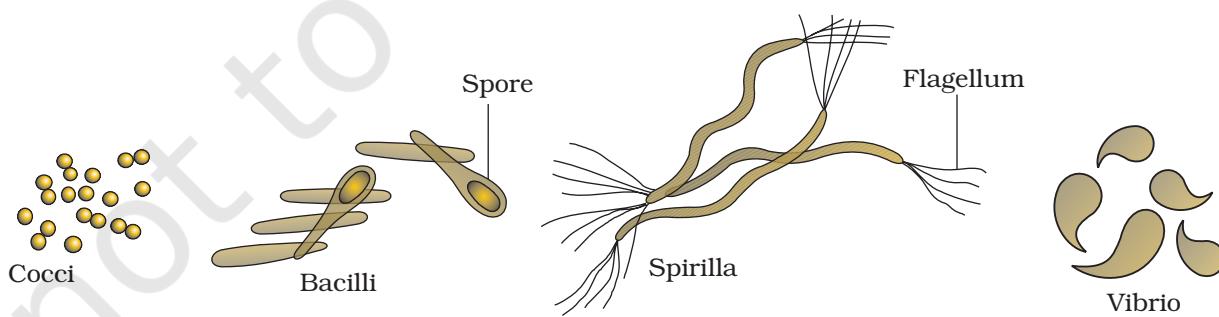


Figure 2.1 Bacteria of different shapes

Though the bacterial structure is very simple, they are very complex in behaviour. Compared to many other organisms, bacteria as a group show the most extensive metabolic diversity. Some of the bacteria are autotrophic, i.e., they synthesise their own food from inorganic substrates. They may be photosynthetic autotrophic or chemosynthetic autotrophic. The vast majority of bacteria are heterotrophs, i.e., they depend on other organisms or on dead organic matter for food.

2.1.1 Archaeabacteria

These bacteria are special since they live in some of the most harsh habitats such as extreme salty areas (halophiles), hot springs (thermoacidophiles) and marshy areas (methanogens). Archaeabacteria differ from other bacteria in having a different cell wall structure and this feature is responsible for their survival in extreme conditions. Methanogens are present in the gut of several ruminant animals such as cows and buffaloes and they are responsible for the production of methane (biogas) from the dung of these animals.

2.1.2 Eubacteria

There are thousands of different **eubacteria** or 'true bacteria'. They are characterised by the presence of a rigid cell wall, and if motile, a flagellum. The **cyanobacteria** (also referred to as blue-green algae) have chlorophyll *a* similar to green plants and are **photosynthetic autotrophs** (Figure 2.2). The cyanobacteria are unicellular, colonial or filamentous, freshwater/marine or terrestrial algae. The colonies are generally surrounded by gelatinous sheath. They often form blooms in polluted water bodies. Some of these organisms can fix atmospheric nitrogen in specialised cells called **heterocysts**, e.g., *Nostoc* and *Anabaena*. **Chemosynthetic autotrophic** bacteria oxidise various inorganic substances such as nitrates, nitrites and ammonia and use the released energy for their ATP production. They play a great role in recycling nutrients like nitrogen, phosphorous, iron and sulphur.

Heterotrophic bacteria are most abundant in nature. The majority are important decomposers. Many of them have a significant impact on human affairs. They are helpful in making curd from milk, production of antibiotics, fixing nitrogen in legume

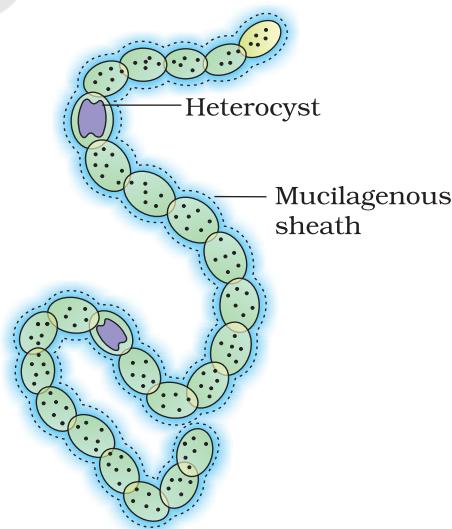


Figure 2.2 A filamentous blue-green algae – *Nostoc*

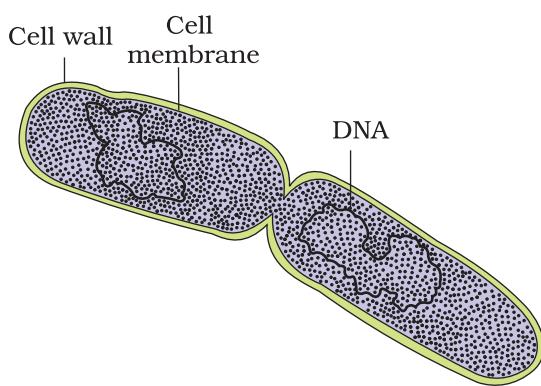


Figure 2.3 A dividing bacterium

roots, etc. Some are pathogens causing damage to human beings, crops, farm animals and pets. Cholera, typhoid, tetanus, citrus canker are well known diseases caused by different bacteria.

Bacteria reproduce mainly by fission (Figure 2.3). Sometimes, under unfavourable conditions, they produce spores. They also reproduce by a sort of sexual reproduction by adopting a primitive type of DNA transfer from one bacterium to the other.

The **Mycoplasma** are organisms that completely lack a cell wall. They are the smallest living cells known and can survive without oxygen. Many mycoplasma are pathogenic in animals and plants.

2.2 KINGDOM PROTISTA

All single-celled eukaryotes are placed under **Protista**, but the boundaries of this kingdom are not well defined. What may be 'a photosynthetic protistan' to one biologist may be 'a plant' to another. In this book we include Chrysophytes, Dinoflagellates, Euglenoids, Slime moulds and Protozoans under Protista. Members of Protista are primarily aquatic. This kingdom forms a link with the others dealing with plants, animals and fungi. Being eukaryotes, the protistan cell body contains a well defined nucleus and other membrane-bound organelles. Some have flagella or cilia. Protists reproduce asexually and sexually by a process involving cell fusion and zygote formation.

2.2.1 Chrysophytes

This group includes diatoms and golden algae (desmids). They are found in fresh water as well as in marine environments. They are microscopic and float passively in water currents (plankton). Most of them are photosynthetic. In diatoms the cell walls form two thin overlapping shells, which fit together as in a soap box. The walls are embedded with silica and thus the walls are indestructible. Thus, diatoms have left behind large amount of cell wall deposits in their habitat; this accumulation over billions of years is referred to as 'diatomaceous earth'. Being gritty this soil is used in polishing, filtration of oils and syrups. Diatoms are the chief 'producers' in the oceans.

2.2.2 Dinoflagellates

These organisms are mostly marine and photosynthetic. They appear yellow, green, brown, blue or red depending on the main pigments present in their cells. The cell wall has stiff cellulose plates on the outer surface. Most of them have two flagella; one lies longitudinally and the other transversely in a furrow between the wall plates. Very often, red dinoflagellates (Example: *Gonyaulax*) undergo such rapid multiplication that they make the sea appear red (red tides). Toxins released by such large numbers may even kill other marine animals such as fishes.

2.2.3 Euglenoids

Majority of them are fresh water organisms found in stagnant water. Instead of a cell wall, they have a protein rich layer called pellicle which makes their body flexible. They have two flagella, a short and a long one. Though they are photosynthetic in the presence of sunlight, when deprived of sunlight they behave like heterotrophs by predating on other smaller organisms. Interestingly, the pigments of euglenoids are identical to those present in higher plants. Example: *Euglena* (Figure 2.4b).

2.2.4 Slime Moulds

Slime moulds are saprophytic protists. The body moves along decaying twigs and leaves engulfing organic material. Under suitable conditions, they form an aggregation called plasmodium which may grow and spread over several feet. During unfavourable conditions, the plasmodium differentiates and forms fruiting bodies bearing spores at their tips. The spores possess true walls. They are extremely resistant and survive for many years, even under adverse conditions. The spores are dispersed by air currents.

2.2.5 Protozoans

All protozoans are heterotrophs and live as predators or parasites. They are believed to be primitive relatives of animals. There are four major groups of protozoans.

Amoeboid protozoans: These organisms live in fresh water, sea water or moist soil. They move and capture

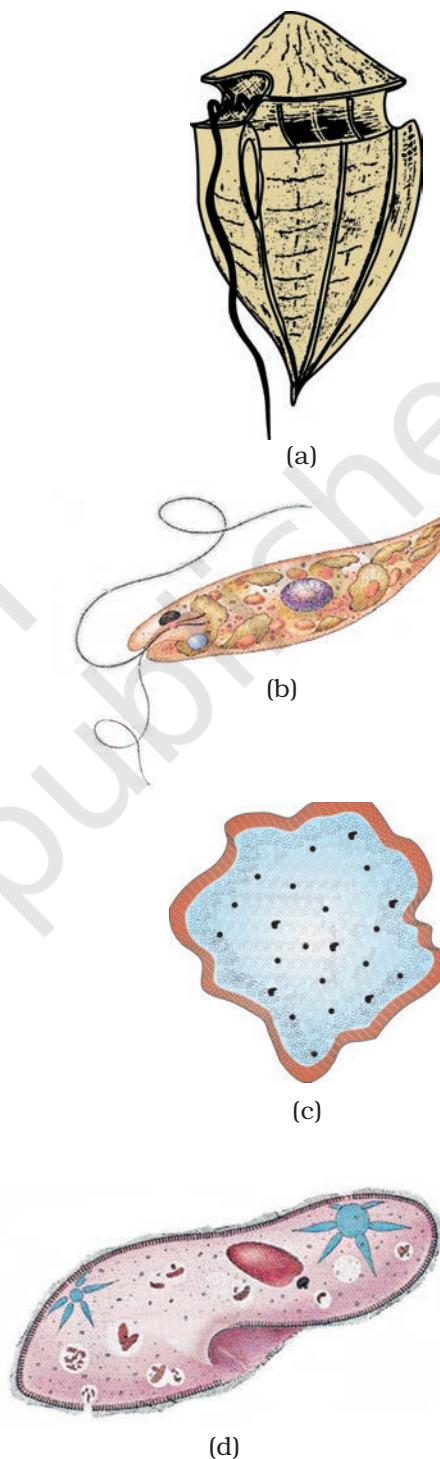


Figure 2.4 (a) *Dinoflagellates*
 (b) *Euglena*
 (c) *Slime mould*
 (d) *Paramoecium*

their prey by putting out pseudopodia (false feet) as in *Amoeba*. Marine forms have silica shells on their surface. Some of them such as *Entamoeba* are parasites.

Flagellated protozoans: The members of this group are either free-living or parasitic. They have flagella. The parasitic forms cause diseases such as sleeping sickness. Example: *Trypanosoma*.

Ciliated protozoans: These are aquatic, actively moving organisms because of the presence of thousands of cilia. They have a cavity (gullet) that opens to the outside of the cell surface. The coordinated movement of rows of cilia causes the water laden with food to be steered into the gullet. Example: *Paramoecium* (Figure 2.4d).

Sporozoans: This includes diverse organisms that have an infectious spore-like stage in their life cycle. The most notorious is *Plasmodium* (malarial parasite) which causes malaria, a disease which has a staggering effect on human population.

2.3 KINGDOM FUNGI

The fungi constitute a unique kingdom of heterotrophic organisms. They show a great diversity in morphology and habitat. You must have seen fungi on a moist bread and rotten fruits. The common mushroom you eat and toadstools are also fungi. White spots seen on mustard leaves are due to a parasitic fungus. Some unicellular fungi, e.g., yeast are used to make bread and beer. Other fungi cause diseases in plants and animals; wheat rust-causing *Puccinia* is an important example. Some are the source of antibiotics, e.g., *Penicillium*. Fungi are cosmopolitan and occur in air, water, soil and on animals and plants. They prefer to grow in warm and humid places. Have you ever wondered why we keep food in the refrigerator? Yes, it is to prevent food from going bad due to bacterial or fungal infections.

With the exception of yeasts which are unicellular, fungi are filamentous. Their bodies consist of long, slender thread-like structures called hyphae. The network of hyphae is known as mycelium. Some hyphae are continuous tubes filled with multinucleated cytoplasm – these are called coenocytic hyphae. Others have septae or cross walls in their hyphae. The cell walls of fungi are composed of chitin and polysaccharides.

Most fungi are heterotrophic and absorb soluble organic matter from dead substrates and hence are called **saprophytes**. Those that depend on living plants and animals are called **parasites**. They can also live as **symbionts** – in association with algae as **lichens** and with roots of higher plants as **mycorrhiza**.

Reproduction in fungi can take place by vegetative means – fragmentation, fission and budding. Asexual reproduction is by spores

called conidia or sporangiospores or zoospores, and sexual reproduction is by oospores, ascospores and basidiospores. The various spores are produced in distinct structures called fruiting bodies. The sexual cycle involves the following three steps:

- (i) Fusion of protoplasms between two motile or non-motile gametes called **plasmogamy**.
- (ii) Fusion of two nuclei called **karyogamy**.
- (iii) Meiosis in zygote resulting in haploid spores.

When a fungus reproduces sexually, two haploid hyphae of compatible mating types come together and fuse. In some fungi the fusion of two haploid cells immediately results in diploid cells ($2n$). However, in other fungi (ascomycetes and basidiomycetes), an intervening dikaryotic stage ($n + n$, i.e., two nuclei per cell) occurs; such a condition is called a **dikaryon** and the phase is called **dikaryophase** of fungus. Later, the parental nuclei fuse and the cells become diploid. The fungi form fruiting bodies in which reduction division occurs, leading to formation of haploid spores.

The morphology of the mycelium, mode of spore formation and fruiting bodies form the basis for the division of the kingdom into various classes.

2.3.1 Phycomycetes

Members of phycomycetes are found in aquatic habitats and on decaying wood in moist and damp places or as obligate parasites on plants. The mycelium is aseptate and coenocytic. Asexual reproduction takes place by zoospores (motile) or by aplanospores (non-motile). These spores are endogenously produced in sporangium. A zygosporangium is formed by fusion of two gametes. These gametes are similar in morphology (isogamous) or dissimilar (anisogamous or oogamous). Some common examples are *Mucor* (Figure 2.5a), *Rhizopus* (the bread mould mentioned earlier) and *Albugo* (the parasitic fungi on mustard).

2.3.2 Ascomycetes

Commonly known as sac-fungi, the ascomycetes are mostly multicellular, e.g., *Penicillium*, or rarely unicellular, e.g., yeast (*Saccharomyces*). They are saprophytic, decomposers, parasitic or coprophilous (growing on dung). Mycelium



(a)



(b)



(c)

Figure 2.5 Fungi: (a) *Mucor*
(b) *Aspergillus* (c) *Agaricus*

is branched and septate. The asexual spores are conidia produced exogenously on the special mycelium called conidiophores. Conidia on germination produce mycelium. Sexual spores are called ascospores which are produced endogenously in sac like ascii (singular ascus). These ascii are arranged in different types of fruiting bodies called ascocarps. Some examples are *Aspergillus* (Figure 2.5b), *Claviceps* and *Neurospora*. *Neurospora* is used extensively in biochemical and genetic work. Many members like morels and truffles are edible and are considered delicacies.

2.3.3 Basidiomycetes

Commonly known forms of basidiomycetes are mushrooms, bracket fungi or puffballs. They grow in soil, on logs and tree stumps and in living plant bodies as parasites, e.g., rusts and smuts. The mycelium is branched and septate. The asexual spores are generally not found, but vegetative reproduction by fragmentation is common. The sex organs are absent, but plasmogamy is brought about by fusion of two vegetative or somatic cells of different strains or genotypes. The resultant structure is dikaryotic which ultimately gives rise to basidium. Karyogamy and meiosis take place in the basidium producing four basidiospores. The basidiospores are exogenously produced on the basidium (pl.: basidia). The basidia are arranged in fruiting bodies called basidiocarps. Some common members are *Agaricus* (mushroom) (Figure 2.5c), *Ustilago* (smut) and *Puccinia* (rust fungus).

2.3.4 Deuteromycetes

Commonly known as imperfect fungi because only the asexual or vegetative phases of these fungi are known. When the sexual forms of these fungi were discovered they were moved into classes they rightly belong to. It is also possible that the asexual and vegetative stage have been given one name (and placed under deuteromycetes) and the sexual stage another (and placed under another class). Later when the linkages were established, the fungi were correctly identified and moved out of deuteromycetes. Once perfect (sexual) stages of members of deuteromycetes were discovered they were often moved to ascomycetes and basidiomycetes. The deuteromycetes reproduce only by asexual spores known as conidia. The mycelium is septate and branched. Some members are saprophytes or parasites while a large number of them are decomposers of litter and help in mineral cycling. Some examples are *Alternaria*, *Colletotrichum* and *Trichoderma*.

2.4 KINGDOM PLANTAE

Kingdom Plantae includes all eukaryotic chlorophyll-containing organisms commonly called plants. A few members are partially heterotrophic such as the insectivorous plants or parasites. Bladderwort and Venus fly trap are examples of insectivorous plants and *Cuscuta* is a parasite. The plant cells have an eukaryotic structure with prominent chloroplasts and cell wall mainly made of cellulose. You will study the eukaryotic cell structure in detail in Chapter 8. Plantae includes algae, bryophytes, pteridophytes, gymnosperms and angiosperms.

Life cycle of plants has two distinct phases – the diploid sporophytic and the haploid gametophytic – that alternate with each other. The lengths of the haploid and diploid phases, and whether these phases are free-living or dependent on others, vary among different groups in plants. This phenomenon is called **alternation of generation**. You will study further details of this kingdom in Chapter 3.

2.5 KINGDOM ANIMALIA

This kingdom is characterised by heterotrophic eukaryotic organisms that are multicellular and their cells lack cell walls. They directly or indirectly depend on plants for food. They digest their food in an internal cavity and store food reserves as glycogen or fat. Their mode of nutrition is holozoic – by ingestion of food. They follow a definite growth pattern and grow into adults that have a definite shape and size. Higher forms show elaborate sensory and neuromotor mechanism. Most of them are capable of locomotion.

The sexual reproduction is by copulation of male and female followed by embryological development. Salient features of various phyla are described in Chapter 4.

2.6 VIRUSES, VIROIDS, PRIONS AND LICHENS

In the five kingdom classification of Whittaker there is no mention of lichens and some acellular organisms like viruses, viroids and prions. These are briefly introduced here.

All of us who have suffered the ill effects of common cold or 'flu' know what effects viruses can have on us, even if we do not associate it with our condition. Viruses did not find a place in classification since they are not considered truly 'living', if we understand living as those organisms that have a cell structure. The viruses are non-cellular organisms that are characterised by having an inert crystalline structure outside the living cell.

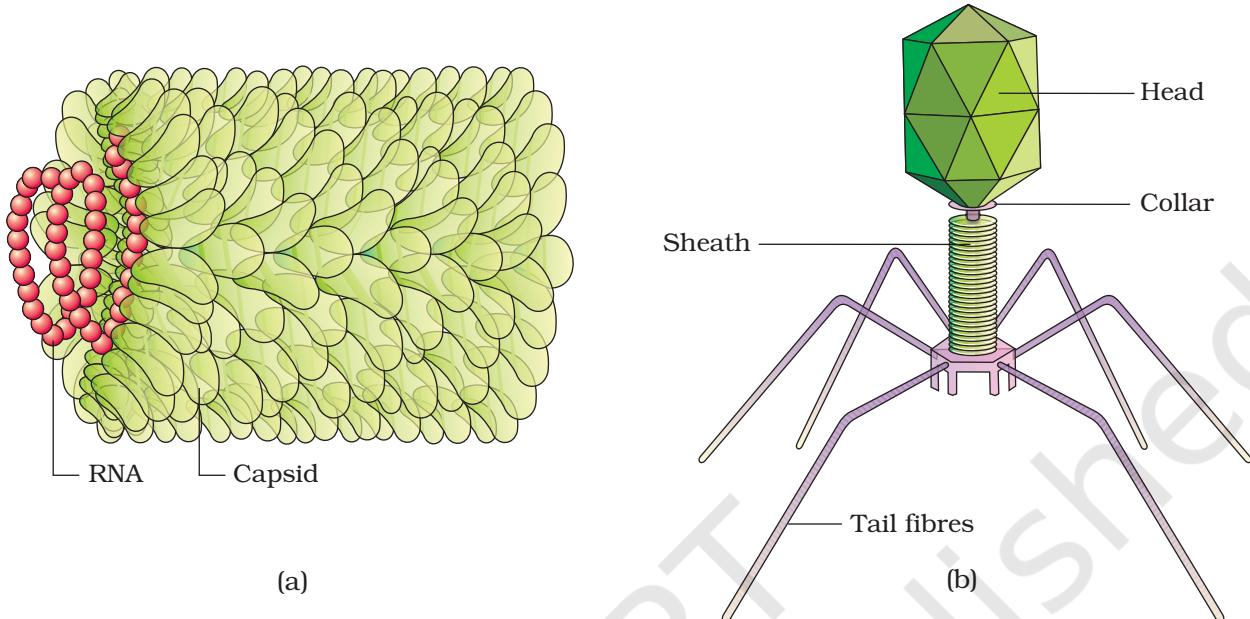


Figure 2.6 (a) Tobacco Mosaic Virus (TMV) (b) Bacteriophage

Once they infect a cell they take over the machinery of the host cell to replicate themselves, killing the host. Would you call viruses living or non-living?

Virus means venom or poisonous fluid. Dmitri Ivanowsky (1892) recognised certain microbes as causal organism of the mosaic disease of tobacco (Figure 2.6a). These were found to be smaller than bacteria because they passed through bacteria-proof filters. M.W. Beijerinck (1898) demonstrated that the extract of the infected plants of tobacco could cause infection in healthy plants and named the new pathogen "virus" and called the fluid as *Contagium vivum fluidum* (infectious living fluid). W.M. Stanley (1935) showed that viruses could be crystallised and crystals consist largely of proteins. They are inert outside their specific host cell. Viruses are obligate parasites.

In addition to proteins, viruses also contain genetic material, that could be either RNA or DNA. No virus contains both RNA and DNA. A virus is a nucleoprotein and the genetic material is infectious. In general, viruses that infect plants have single stranded RNA and viruses that infect animals have either single or double stranded RNA or double stranded DNA. Bacterial viruses or bacteriophages (viruses that infect the bacteria) are usually double stranded DNA viruses (Figure 2.6b). The protein coat called capsid made of small subunits called capsomeres, protects the nucleic acid. These capsomeres are arranged in helical or polyhedral geometric forms. Viruses cause diseases like mumps, small pox, herpes and influenza. AIDS in humans is also caused by a virus. In plants, the symptoms can be mosaic formation, leaf rolling and curling, yellowing and vein clearing, dwarfing and stunted growth.

Viroids : In 1971, T.O. Diener discovered a new infectious agent that was smaller than viruses and caused potato spindle tuber disease. It was found to be a free RNA; it lacked the protein coat that is found in viruses, hence the name viroid. The RNA of the viroid was of low molecular weight.

Prions : In modern medicine certain infectious neurological diseases were found to be transmitted by an agent consisting of abnormally folded protein. The agent was similar in size to viruses. These agents were called prions. The most notable diseases caused by prions are bovine spongiform encephalopathy (BSE) commonly called mad cow disease in cattle and its analogous variant Cr-Jacob disease (CJD) in humans.

Lichens : Lichens are symbiotic associations i.e. mutually useful associations, between algae and fungi. The algal component is known as **phycobiont** and fungal component as **mycobiont**, which are autotrophic and heterotrophic, respectively. Algae prepare food for fungi and fungi provide shelter and absorb mineral nutrients and water for its partner. So close is their association that if one saw a lichen in nature one would never imagine that they had two different organisms within them. Lichens are very good pollution indicators – they do not grow in polluted areas.

SUMMARY

Biological classification of plants and animals was first proposed by Aristotle on the basis of simple morphological characters. Linnaeus later classified all living organisms into two kingdoms – Plantae and Animalia. Whittaker proposed an elaborate five kingdom classification – Monera, Protista, Fungi, Plantae and Animalia. The main criteria of the five kingdom classification were cell structure, body organisation, mode of nutrition and reproduction, and phylogenetic relationships.

In the five kingdom classification, bacteria are included in Kingdom Monera. Bacteria are cosmopolitan in distribution. These organisms show the most extensive metabolic diversity. Bacteria may be autotrophic or heterotrophic in their mode of nutrition. Kingdom Protista includes all single-celled eukaryotes such as Chrysophytes, Dinoflagellates, Euglenoids, Slime-moulds and Protozoans. Protists have defined nucleus and other membrane bound organelles. They reproduce both asexually and sexually. Members of Kingdom Fungi show a great diversity in structures and habitat. Most fungi are saprophytic in their mode of nutrition. They show asexual and sexual reproduction. Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes are the four classes under this kingdom. The plantae includes all eukaryotic chlorophyll-containing organisms. Algae, bryophytes, pteridophytes, gymnosperms and angiosperms are included in this group. The life cycle of plants exhibit alternation of generations – gametophytic and sporophytic generations. The heterotrophic eukaryotic, multicellular organisms lacking a cell wall are included in the Kingdom Animalia. The mode of nutrition of these organisms is holozoic. They reproduce mostly by the sexual mode. Some acellular organisms like viruses and viroids as well as the lichens are not included in the five kingdom system of classification.

EXERCISES

1. Discuss how classification systems have undergone several changes over a period of time?
2. State two economically important uses of:
 - (a) heterotrophic bacteria
 - (b) archaebacteria
3. What is the nature of cell-walls in diatoms?
4. Find out what do the terms 'algal bloom' and 'red-tides' signify.
5. How are viroids different from viruses?
6. Describe briefly the four major groups of Protozoa.
7. Plants are autotrophic. Can you think of some plants that are partially heterotrophic?
8. What do the terms phycobiont and mycobiont signify?
9. Give a comparative account of the classes of Kingdom Fungi under the following:
 - (i) mode of nutrition
 - (ii) mode of reproduction
10. What are the characteristic features of Euglenoids?
11. Give a brief account of viruses with respect to their structure and nature of genetic material. Also name four common viral diseases.
12. Organise a discussion in your class on the topic – Are viruses living or non-living?



CHAPTER 3

PLANT KINGDOM

- [3.1 Algae](#)
- [3.2 Bryophytes](#)
- [3.3 Pteridophytes](#)
- [3.4 Gymnosperms](#)
- [3.5 Angiosperms](#)

In the previous chapter, we looked at the broad classification of living organisms under the system proposed by Whittaker (1969) wherein he suggested the Five Kingdom classification viz. Monera, Protista, Fungi, Animalia and Plantae. In this chapter, we will deal in detail with further classification within Kingdom Plantae popularly known as the 'plant kingdom'.

We must stress here that our understanding of the plant kingdom has changed over time. Fungi, and members of the Monera and Protista having cell walls have now been excluded from Plantae though earlier classifications placed them in the same kingdom. So, the cyanobacteria that are also referred to as blue green algae are not 'algae' any more. In this chapter, we will describe Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms under Plantae.

Let us also look at classification within angiosperms to understand some of the concerns that influenced the classification systems. The earliest systems of classification used only gross superficial morphological characters such as habit, colour, number and shape of leaves, etc. They were based mainly on vegetative characters or on the androecium structure (system given by Linnaeus). Such systems were **artificial**; they separated the closely related species since they were based on a few characteristics. Also, the artificial systems gave equal weightage to vegetative and sexual characteristics; this is not acceptable since we know that often the vegetative characters are more easily affected by environment. As against this, **natural classification systems** developed, which were based on natural affinities among the organisms and consider,

not only the external features, but also internal features, like ultra-structure, anatomy, embryology and phytochemistry. Such a classification for flowering plants was given by George Bentham and Joseph Dalton Hooker.

At present **phylogenetic classification systems** based on evolutionary relationships between the various organisms are acceptable. This assumes that organisms belonging to the same taxa have a common ancestor. We now use information from many other sources too to help resolve difficulties in classification. These become more important when there is no supporting fossil evidence. **Numerical Taxonomy** which is now easily carried out using computers is based on all observable characteristics. Number and codes are assigned to all the characters and the data are then processed. In this way each character is given equal importance and at the same time hundreds of characters can be considered. **Cytotaxonomy** that is based on cytological information like chromosome number, structure, behaviour and **chemotaxonomy** that uses the chemical constituents of the plant to resolve confusions, are also used by taxonomists these days.

3.1 ALGAE

Algae are chlorophyll-bearing, simple, thalloid, autotrophic and largely aquatic (both fresh water and marine) organisms. They occur in a variety of other habitats: moist stones, soils and wood. Some of them also occur in association with fungi (lichen) and animals (e.g., on sloth bear).

The form and size of algae is highly variable, ranging from colonial forms like *Volvox* and the filamentous forms like *Ulothrix* and *Spirogyra* (Figure 3.1). A few of the marine forms such as kelps, form massive plant bodies.

The algae reproduce by vegetative, asexual and sexual methods. Vegetative reproduction is by fragmentation. Each fragment develops into a thallus. Asexual reproduction is by the production of different types of spores, the most common being the **zoospores**. They are flagellated (motile) and on germination gives rise to new plants. Sexual reproduction takes place through fusion of two gametes. These gametes can be flagellated and similar in size (as in *Ulothrix*) or non-flagellated (non-motile) but similar in size (as in *Spirogyra*). Such reproduction is called **isogamous**. Fusion of two gametes dissimilar in size, as in species of *Eudorina* is termed as **anisogamous**. Fusion between one large, non-motile (static) female gamete and a smaller, motile male gamete is termed **oogamous**, e.g., *Volvox*, *Fucus*.

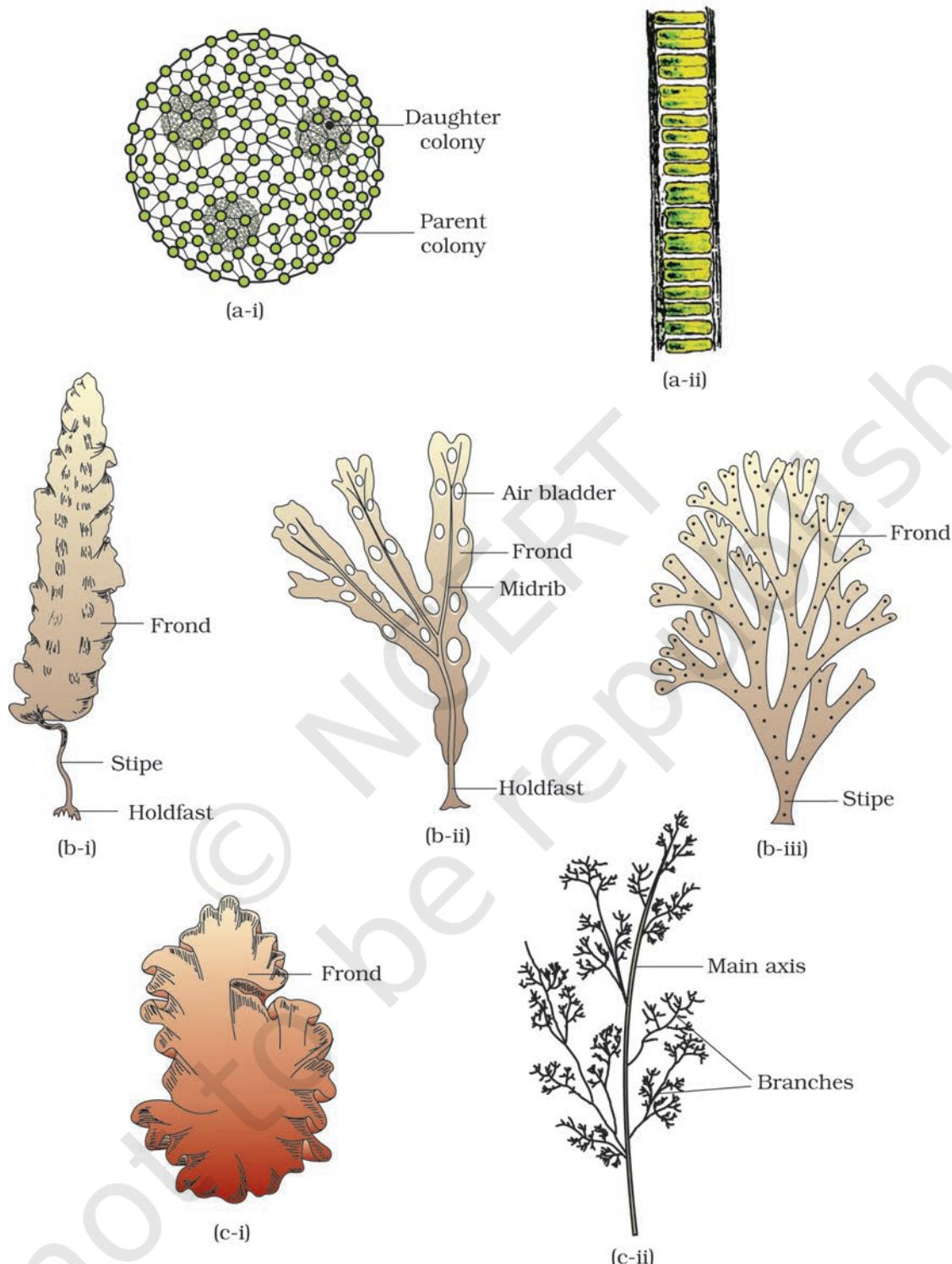


Figure 3.1 Algae : (a) Green algae (i) *Volvox* (ii) *Ulothrix*
 (b) Brown algae (i) *Laminaria* (ii) *Fucus* (iii) *Dictyota*
 (c) Red algae (i) *Porphyra* (ii) *Polysiphonia*

Algae are useful to man in a variety of ways. At least a half of the total carbon dioxide fixation on earth is carried out by algae through photosynthesis. Being photosynthetic they increase the level of dissolved oxygen in their immediate environment. They are of paramount importance as primary producers of energy-rich compounds which form the basis of the food cycles of all aquatic animals. Many species of *Porphyra*, *Laminaria* and *Sargassum* are among the 70 species of marine algae used as food. Certain marine brown and red algae produce large amounts of hydrocolloids (water holding substances), e.g., **algin** (brown algae) and **carrageen** (red algae) which are used commercially. Agar, one of the commercial products obtained from *Gelidium* and *Gracilaria* are used to grow microbes and in preparations of ice-creams and jellies. *Chlorella* a unicellular alga rich in proteins is used as food supplement even by space travellers. The algae are divided into three main classes: **Chlorophyceae**, **Phaeophyceae** and **Rhodophyceae**.

3.1.1 Chlorophyceae

The members of chlorophyceae are commonly called **green algae**. The plant body may be unicellular, colonial or filamentous. They are usually grass green due to the dominance of pigments chlorophyll *a* and *b*. The pigments are localised in definite chloroplasts. The chloroplasts may be discoid, plate-like, reticulate, cup-shaped, spiral or ribbon-shaped in different species. Most of the members have one or more storage bodies called pyrenoids located in the chloroplasts. Pyrenoids contain protein besides starch. Some algae may store food in the form of oil droplets. Green algae usually have a rigid cell wall made of an inner layer of cellulose and an outer layer of pectose.

Vegetative reproduction usually takes place by fragmentation or by formation of different types of spores. Asexual reproduction is by flagellated zoospores produced in zoosporangia. The sexual reproduction shows considerable variation in the type and formation of sex cells and it may be isogamous, anisogamous or oogamous. Some commonly found green algae are: *Chlamydomonas*, *Volvox*, *Ulothrix*, *Spirogyra* and *Chara* (Figure 3.1a).

3.1.2 Phaeophyceae

The members of phaeophyceae or **brown algae** are found primarily in marine habitats. They show great variation in size and form. They range from simple branched, filamentous forms (*Ectocarpus*) to profusely branched forms as represented by kelps, which may reach a height of 100 metres. They possess chlorophyll *a*, *c*, carotenoids and xanthophylls. They vary in colour from olive green to various shades of brown depending upon the amount of the xanthophyll pigment, fucoxanthin present in

them. Food is stored as complex carbohydrates, which may be in the form of laminarin or mannitol. The vegetative cells have a cellulosic wall usually covered on the outside by a gelatinous coating of **algin**. The protoplast contains, in addition to plastids, a centrally located vacuole and nucleus. The plant body is usually attached to the substratum by a **holdfast**, and has a stalk, the **stipe** and leaf like photosynthetic organ – the **frond**. Vegetative reproduction takes place by fragmentation. Asexual reproduction in most brown algae is by biflagellate zoospores that are pear-shaped and have two unequal laterally attached flagella.

Sexual reproduction may be isogamous, anisogamous or oogamous. Union of gametes may take place in water or within the oogonium (oogamous species). The gametes are pyriform (pear-shaped) and bear two laterally attached flagella. The common forms are *Ectocarpus*, *Dictyota*, *Laminaria*, *Sargassum* and *Fucus* (Figure 3.1b).

3.1.3 Rhodophyceae

The members of rhodophyceae are commonly called **red algae** because of the predominance of the red pigment, r-phycoerythrin in their body. Majority of the red algae are marine with greater concentrations found in the warmer areas. They occur in both well-lighted regions close to the surface of water and also at great depths in oceans where relatively little light penetrates.

The red thalli of most of the red algae are multicellular. Some of them have complex body organisation. The food is stored as floridean starch which is very similar to amylopectin and glycogen in structure.

The red algae usually reproduce vegetatively by fragmentation. They reproduce asexually by non-motile spores and sexually by non-motile

TABLE 3.1 Divisions of Algae and their Main Characteristics

Classes	Common Name	Major Pigments	Stored Food	Cell Wall	Flagellar Number and Position of Insertions	Habitat
Chlorophyceae	Green algae	Chlorophyll <i>a, b</i>	Starch	Cellulose	2-8, equal, apical	Fresh water, brackish water, salt water
Phaeophyceae	Brown algae	Chlorophyll <i>a, c</i> , fucoxanthin	Mannitol, laminarin	Cellulose and algin	2, unequal, lateral	Fresh water (rare) brackish water, salt water
Rhodophyceae	Red algae	Chlorophyll <i>a, d</i> , phycoerythrin	Floridean starch	Cellulose, pectin and poly sulphate esters	Absent	Fresh water (some), brackish water, salt water (most)

gametes. Sexual reproduction is oogamous and accompanied by complex post fertilisation developments. The common members are: *Polysiphonia*, *Porphyra* (Figure 3.1c), *Gracilaria* and *Gelidium*.

3.2 BRYOPHYTES

Bryophytes include the various mosses and liverworts that are found commonly growing in moist shaded areas in the hills (Figure 3.2).

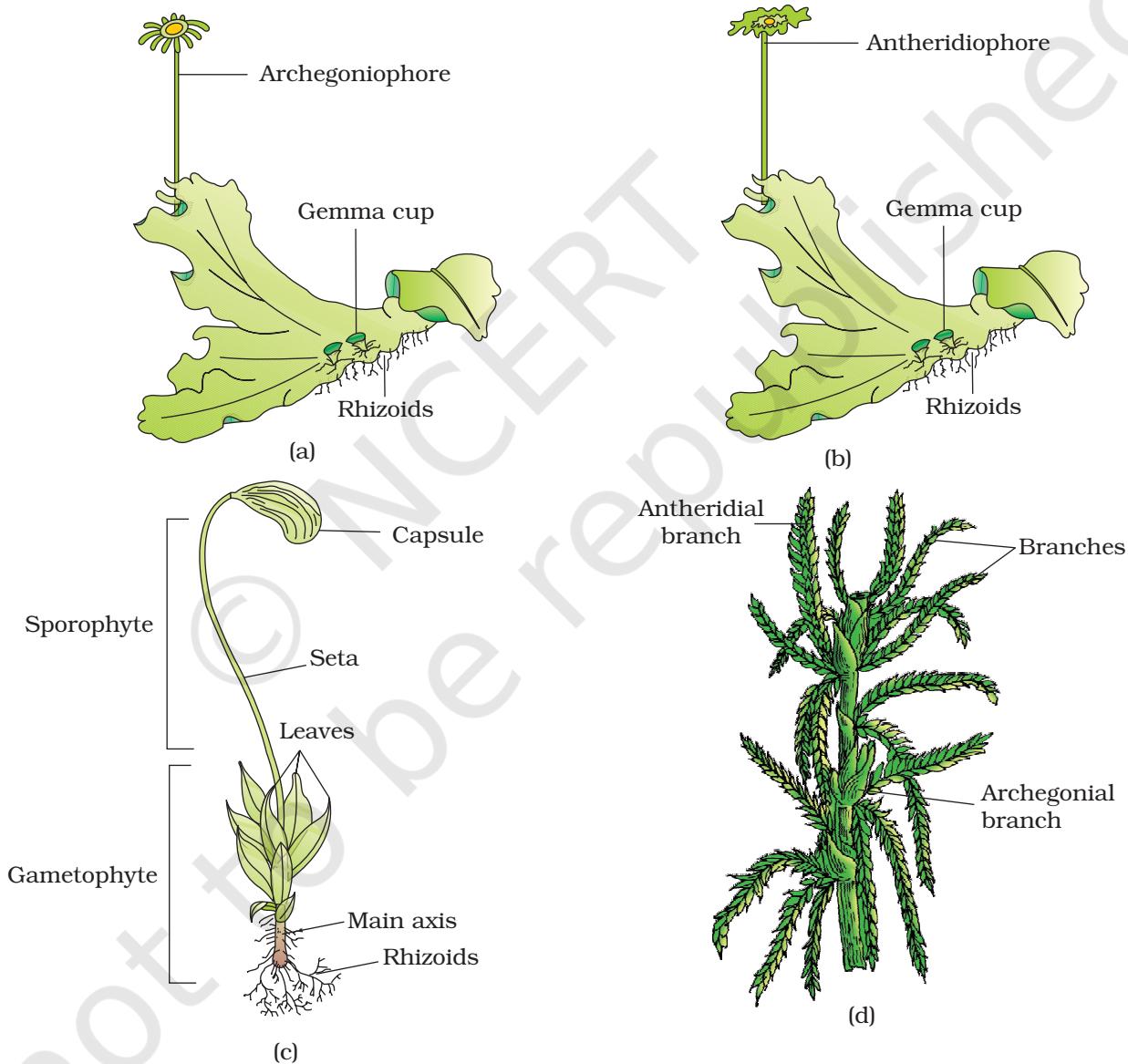


Figure 3.2 Bryophytes: A liverwort – *Marchantia* (a) Female thallus (b) Male thallus Mosses – (c) *Funaria*, gametophyte and sporophyte (d) *Sphagnum* gametophyte

Bryophytes are also called amphibians of the plant kingdom because these plants can live in soil but are dependent on water for sexual reproduction. They usually occur in damp, humid and shaded localities. They play an important role in plant succession on bare rocks/soil.

The plant body of bryophytes is more differentiated than that of algae. It is thallus-like and prostrate or erect, and attached to the substratum by unicellular or multicellular rhizoids. They lack true roots, stem or leaves. They may possess root-like, leaf-like or stem-like structures. The main plant body of the bryophyte is haploid. It produces gametes, hence is called a **gametophyte**. The sex organs in bryophytes are multicellular. The male sex organ is called **antheridium**. They produce biflagellate **antherozoids**. The female sex organ called **archegonium** is flask-shaped and produces a single egg. The antherozoids are released into water where they come in contact with archegonium. An antherozoid fuses with the egg to produce the zygote. Zygotes do not undergo reduction division immediately. They produce a multicellular body called a **sporophyte**. The sporophyte is not free-living but attached to the photosynthetic gametophyte and derives nourishment from it. Some cells of the sporophyte undergo reduction division (meiosis) to produce haploid spores. These spores germinate to produce gametophyte.

Bryophytes in general are of little economic importance but some mosses provide food for herbaceous mammals, birds and other animals. Species of *Sphagnum*, a moss, provide peat that have long been used as fuel, and as packing material for trans-shipment of living material because of their capacity to hold water. Mosses along with lichens are the first organisms to colonise rocks and hence, are of great ecological importance. They decompose rocks making the substrate suitable for the growth of higher plants. Since mosses form dense mats on the soil, they reduce the impact of falling rain and prevent soil erosion. The bryophytes are divided into **liverworts** and **mosses**.

3.2.1 Liverworts

The liverworts grow usually in moist, shady habitats such as banks of streams, marshy ground, damp soil, bark of trees and deep in the woods. The plant body of a liverwort is thalloid, e.g., *Marchantia*. The thallus is dorsiventral and closely appressed to the substrate. The leafy members have tiny leaf-like appendages in two rows on the stem-like structures.

Asexual reproduction in liverworts takes place by fragmentation of thalli, or by the formation of specialised structures called **gemmae** (sing. gemma). Gemmae are green, multicellular, asexual buds, which develop in small receptacles called gemma cups located on the thalli. The gemmae become detached from the parent body and germinate to form new individuals. During sexual reproduction, male and female sex

organs are produced either on the same or on different thalli. The sporophyte is differentiated into a foot, seta and capsule. After meiosis, spores are produced within the capsule. These spores germinate to form free-living gametophytes.

3.2.2 Mosses

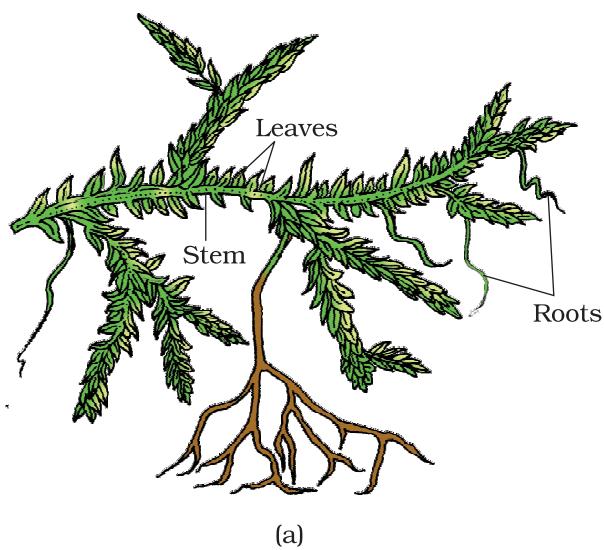
The predominant stage of the life cycle of a moss is the gametophyte which consists of two stages. The first stage is the **protonema** stage, which develops directly from a spore. It is a creeping, green, branched and frequently filamentous stage. The second stage is the **leafy stage**, which develops from the secondary protonema as a lateral bud. They consist of upright, slender axes bearing spirally arranged leaves. They are attached to the soil through multicellular and branched rhizoids. This stage bears the sex organs.

Vegetative reproduction in mosses is by fragmentation and budding in the secondary protonema. In sexual reproduction, the sex organs antheridia and archegonia are produced at the apex of the leafy shoots. After fertilisation, the zygote develops into a sporophyte, consisting of a foot, seta and capsule. The sporophyte in mosses is more elaborate than that in liverworts. The capsule contains spores. Spores are formed after meiosis. The mosses have an elaborate mechanism of spore dispersal. Common examples of mosses are *Funaria*, *Polytrichum* and *Sphagnum* (Figure 3.2).

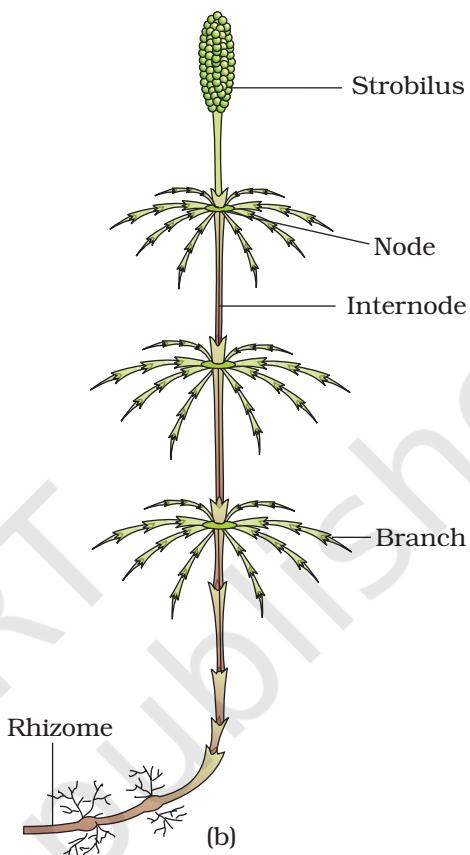
3.3 PTERIDOPHYTES

The Pteridophytes include horsetails and ferns. Pteridophytes are used for medicinal purposes and as soil-binders. They are also frequently grown as ornamentals. Evolutionarily, they are the first terrestrial plants to possess vascular tissues – xylem and phloem. You shall study more about these tissues in Chapter 6. The pteridophytes are found in cool, damp, shady places though some may flourish well in sandy-soil conditions.

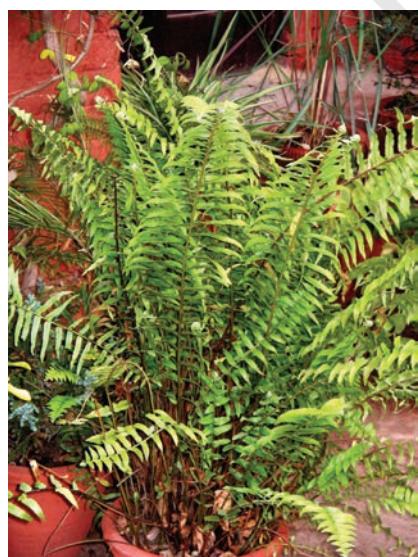
You may recall that in bryophytes the dominant phase in the life cycle is the gametophytic plant body. However, in pteridophytes, the main plant body is a sporophyte which is differentiated into true root, stem and leaves (Figure 3.3). These organs possess well-differentiated vascular tissues. The leaves in pteridophyta are small (microphylls) as in *Selaginella* or large (macrophylls) as in ferns. The sporophytes bear sporangia that are subtended by leaf-like appendages called **sporophylls**. In some cases sporophylls may form distinct compact structures called strobili or cones (*Selaginella*, *Equisetum*). The sporangia produce spores by meiosis in spore mother cells. The spores germinate to give rise to inconspicuous, small but multicellular,



(a)



(b)



(c)



(d)

Figure 3.3 Pteridophytes : (a) *Selaginella* (b) *Equisetum* (c) Fern (d) *Salvinia*

free-living, mostly photosynthetic thalloid gametophytes called **prothallus**. These gametophytes require cool, damp, shady places to grow. Because of this specific restricted requirement and the need for water for fertilisation, the spread of living pteridophytes is limited and restricted to narrow geographical regions. The gametophytes bear male and female sex organs called antheridia and archegonia, respectively. Water is required for transfer of antherozoids – the male gametes released from the antheridia, to the mouth of archegonium. Fusion of male gamete with the egg present in the archegonium result in the formation of zygote. Zygote thereafter produces a multicellular well-differentiated sporophyte which is the dominant phase of the pteridophytes. In majority of the pteridophytes all the spores are of similar kinds; such plants are called **homosporous**. Genera like *Selaginella* and *Salvinia* which produce two kinds of spores, macro (large) and micro (small) spores, are known as **heterosporous**. The megaspores and microspores germinate and give rise to female and male gametophytes, respectively. The female gametophytes in these plants are retained on the parent sporophytes for variable periods. The development of the zygotes into young embryos take place within the female gametophytes. This event is a precursor to the **seed habit** considered an important step in evolution.

The pteridophytes are further classified into four classes: Psilopsida (*Psilotum*); Lycopsida (*Selaginella*, *Lycopodium*), Sphenopsida (*Equisetum*) and Pteropsida (*Dryopteris*, *Pteris*, *Adiantum*).

3.4 GYMNOSPERMS

The gymnosperms (*gymnos* : naked, *sperma* : seeds) are plants in which the ovules are not enclosed by any ovary wall and remain exposed, both before and after fertilisation. The seeds that develop post-fertilisation, are not covered, i.e., are naked. Gymnosperms include medium-sized trees or tall trees and shrubs (Figure 3.4). One of the gymnosperms, the giant redwood tree *Sequoia* is one of the tallest tree species. The roots are generally tap roots. Roots in some genera have fungal association in the form of **mycorrhiza** (*Pinus*), while in some others (*Cycas*) small specialised roots called coraloid roots are associated with N₂-fixing cyanobacteria. The stems are unbranched (*Cycas*) or branched (*Pinus*, *Cedrus*). The leaves may be simple or compound. In *Cycas* the pinnate leaves persist for a few years. The leaves in gymnosperms are well-adapted to withstand extremes of temperature, humidity and wind. In conifers, the needle-like leaves reduce the surface area. Their thick cuticle and sunken stomata also help to reduce water loss.

The gymnosperms are heterosporous; they produce haploid microspores and megaspores. The two kinds of spores are produced within sporangia that are borne on sporophylls which are arranged spirally along an axis to form lax or compact strobili or **cones**. The strobili bearing **microsporophylls** and **microsporangia** are called microsporangiate or **male strobili**. The microspores develop into a male gametophytic generation which is highly reduced and is confined to only a limited number of cells. This reduced gametophyte is called a **pollen grain**. The development of pollen grains take place within the microsporangia. The cones bearing megasporophylls with ovules or **megasporangia** are called macrosporangiate or **female strobili**. The male or female cones or strobili may be borne on the same tree (*Pinus*). However, in *Cycas* male cones and megasporophylls are borne on different trees. The megaspore mother cell is differentiated from one of the cells of the nucellus. The nucellus is protected by envelopes and the composite structure is called an **ovule**. The ovules are borne on megasporophylls which may be clustered to form the female cones. The megaspore mother cell divides meiotically to form four megaspores. One of the megaspores enclosed within the **megasporangium** develops into a multicellular female gametophyte that bears two or more **archegonia** or female sex organs. The multicellular female gametophyte is also retained within megasporangium.

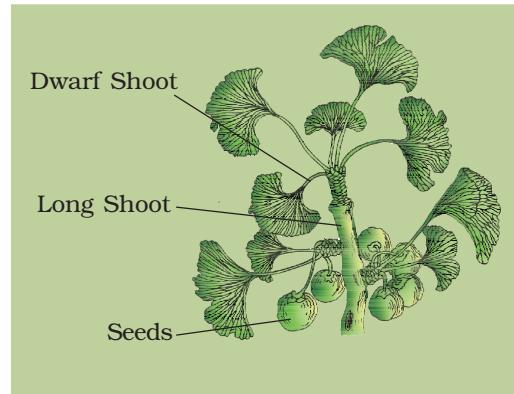
Unlike bryophytes and pteridophytes, in gymnosperms the male and the female gametophytes do not have an independent free-living existence. They remain within the sporangia retained on the sporophytes. The pollen grain is released from the microsporangium. They are carried in air currents and come in contact with the opening of the ovules borne on megasporophylls. The pollen tube carrying the male gametes grows towards archegonia in the ovules and discharge their contents near the mouth of the archegonia. Following fertilisation, zygote develops into an embryo and the ovules into seeds. These seeds are not covered.



(a)



(b)



(c)

Figure 3.4 Gymnosperms: (a) *Cycas*
(b) *Pinus* (c) *Ginkgo*

3.5 ANGIOSPERMS

Unlike the gymnosperms where the ovules are naked, in the angiosperms or flowering plants, the pollen grains and ovules are developed in specialised structures called **flowers**. In angiosperms, the seeds are enclosed in fruits. The angiosperms are an exceptionally large group of plants occurring in wide range of habitats. They range in size from the smallest *Wolffia* to tall trees of *Eucalyptus* (over 100 metres). They provide us with food, fodder, fuel, medicines and several other commercially important products. They are divided into two classes : the **dicotyledons** and the **monocotyledons** (Figure 3.5).



(a)



(b)

Figure 3.5 Angiosperms : (a) A dicotyledon (b) A monocotyledon

SUMMARY

Plant kingdom includes algae, bryophytes, pteridophytes, gymnosperms and angiosperms. Algae are chlorophyll-bearing simple, thalloid, autotrophic and largely aquatic organisms. Depending on the type of pigment possessed and the type of stored food, algae are classified into three classes, namely Chlorophyceae, Phaeophyceae and Rhodophyceae. Algae usually reproduce vegetatively by fragmentation, asexually by formation of different types of spores and sexually by formation of gametes which may show isogamy, anisogamy or oogamy.

Bryophytes are plants which can live in soil but are dependent on water for sexual reproduction. Their plant body is more differentiated than that of algae. It is thallus-like and prostrate or erect and attached to the substratum by rhizoids. They possess root-like, leaf-like and stem-

like structures. The bryophytes are divided into liverworts and mosses. The plant body of liverworts is thalloid and dorsiventral whereas mosses have upright, slender axes bearing spirally arranged leaves. The main plant body of a bryophyte is gamete-producing and is called a gametophyte. It bears the male sex organs called antheridia and female sex organs called archegonia. The male and female gametes produced fuse to form zygote which produces a multicellular body called a sporophyte. It produces haploid spores. The spores germinate to form gametophytes.

In pteridophytes the main plant is a sporophyte which is differentiated into true root, stem and leaves. These organs possess well-differentiated vascular tissues. The sporophytes bear sporangia which produce spores. The spores germinate to form gametophytes which require cool, damp places to grow. The gametophytes bear male and female sex organs called antheridia and archegonia, respectively. Water is required for transfer of male gametes to archegonium where zygote is formed after fertilisation. The zygote produces a sporophyte.

The gymnosperms are the plants in which ovules are not enclosed by any ovary wall. After fertilisation the seeds remain exposed and therefore these plants are called naked-seeded plants. The gymnosperms produce microspores and megaspores which are produced in microsporangia and megasporangia borne on the sporophylls. The sporophylls – microsporophylls and megasporophylls – are arranged spirally on axis to form male and female cones, respectively. The pollen grain germinates and pollen tube releases the male gamete into the ovule, where it fuses with the egg cell in archegonia. Following fertilisation, the zygote develops into embryo and the ovules into seeds.

The angiosperms are divided into two classes – the dicotyledons and the monocotyledons.

EXERCISES

1. What is the basis of classification of algae?
2. When and where does reduction division take place in the life cycle of a liverwort, a moss, a fern, a gymnosperm and an angiosperm?
3. Name three groups of plants that bear archegonia. Briefly describe the life cycle of any one of them.
4. Mention the ploidy of the following: protonemal cell of a moss; primary endosperm nucleus in dicot, leaf cell of a moss; prothallus cell of a fern; gemma cell in *Marchantia*; meristem cell of monocot, ovum of a liverwort, and zygote of a fern.

5. Write a note on economic importance of algae and gymnosperms.
6. Both gymnosperms and angiosperms bear seeds, then why are they classified separately?
7. What is heterospory? Briefly comment on its significance. Give two examples.
8. Explain briefly the following terms with suitable examples:-
 - (i) protonema
 - (ii) antheridium
 - (iii) archegonium
 - (iv) diplontic
 - (v) sporophyll
 - (vi) isogamy
9. Differentiate between the following:-
 - (i) red algae and brown algae
 - (ii) liverworts and moss
 - (iii) homosporous and heterosporous pteridophyte
10. Match the following (column I with column II)

Column I	Column II
(a) <i>Chlamydomonas</i>	(i) Moss
(b) <i>Cycas</i>	(ii) Pteridophyte
(c) <i>Selaginella</i>	(iii) Algae
(d) <i>Sphagnum</i>	(iv) Gymnosperm
11. Describe the important characteristics of gymnosperms.



CHAPTER 4

ANIMAL KINGDOM

4.1 Basis of Classification

4.2 Classification of Animals

When you look around, you will observe different animals with different structures and forms. As over a million species of animals have been described till now, the need for classification becomes all the more important. The classification also helps in assigning a systematic position to newly described species.

4.1 BASIS OF CLASSIFICATION

Inspite of differences in structure and form of different animals, there are fundamental features common to various individuals in relation to the arrangement of cells, body symmetry, nature of coelom, patterns of digestive, circulatory or reproductive systems. These features are used as the basis of animal classification and some of them are discussed here.

4.1.1 Levels of Organisation

Though all members of Animalia are multicellular, all of them do not exhibit the same pattern of organisation of cells. For example, in sponges, the cells are arranged as loose cell aggregates, i.e., they exhibit **cellular level** of organisation. Some division of labour (activities) occur among the cells. In coelenterates, the arrangement of cells is more complex. Here the cells performing the same function are arranged into tissues, hence is called **tissue level** of organisation. A still higher level of organisation, i.e., **organ level** is exhibited by members of Platyhelminthes and other higher phyla where tissues are grouped together to form organs, each specialised for a particular function. In animals like Annelids, Arthropods, Molluscs,

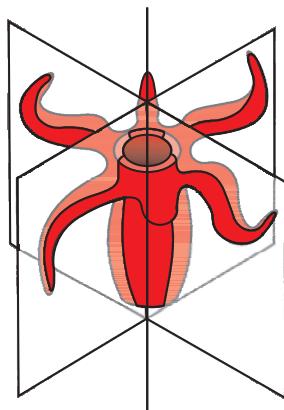


Figure 4.1 (a) Radial symmetry

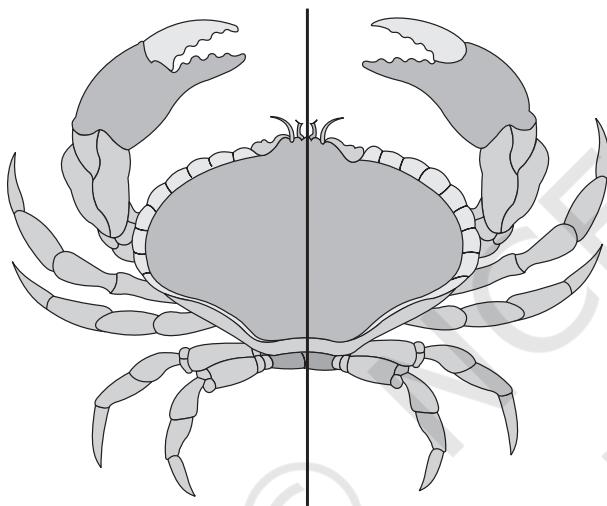


Figure 4.1 (b) Bilateral symmetry

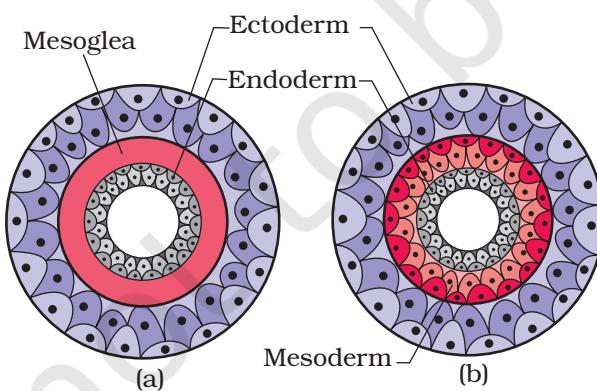


Figure 4.2 Showing germinal layers :
(a) Diploblastic (b) Triploblastic

Echinoderms and Chordates, organs have associated to form functional systems, each system concerned with a specific physiological function. This pattern is called **organ system** level of organisation. Organ systems in different groups of animals exhibit various patterns of complexities. For example, the digestive system in Platyhelminthes has only a single opening to the outside of the body that serves as both mouth and anus, and is hence called incomplete. A complete digestive system has two openings, mouth and anus. Similarly, the circulatory system may be of two types:

- (i) **open type** in which the blood is pumped out of the heart and the cells and tissues are directly bathed in it and
- (ii) **closed type** in which the blood is circulated through a series of vessels of varying diameters (arteries, veins and capillaries).

4.1.2 Symmetry

Animals can be categorised on the basis of their symmetry. Sponges are mostly **asymmetrical**, i.e., any plane that passes through the centre does not divide them into equal halves. When any plane passing through the central axis of the body divides the organism into two identical halves, it is called **radial symmetry**. Coelenterates, ctenophores and echinoderms have this kind of body plan (Figure 4.1a). Animals like annelids, arthropods, etc., where the body can be divided into identical left and right halves in only one plane, exhibit **bilateral symmetry** (Figure 4.1b).

4.1.3 Diploblastic and Triploblastic Organisation

Animals in which the cells are arranged in two embryonic layers, an external **ectoderm** and an internal **endoderm**, are called **diploblastic** animals, e.g., coelenterates. An undifferentiated layer, mesoglea, is present in between the ectoderm and the endoderm (Figure 4.2a).

Those animals in which the developing embryo has a third germinal layer, **mesoderm**, in between the ectoderm and endoderm, are called **triploblastic** animals (platyhelminthes to chordates, Figure 4.2b).

4.1.4 Coelom

Presence or absence of a cavity between the body wall and the gut wall is very important in classification. The body cavity, which is lined by mesoderm is called **coelom**. Animals possessing coelom are called **coelomates**, e.g., annelids, molluscs, arthropods, echinoderms, hemichordates and chordates (Figure 4.3a). In some animals, the body cavity is not lined by mesoderm, instead, the mesoderm is present as scattered pouches in between the ectoderm and endoderm. Such a body cavity is called pseudocoelom and the animals possessing them are called **pseudocoelomates**, e.g., aschelminthes (Figure 4.3b). The animals in which the body cavity is absent are called **acoelomates**, e.g., platyhelminthes (Figure 4.3c).

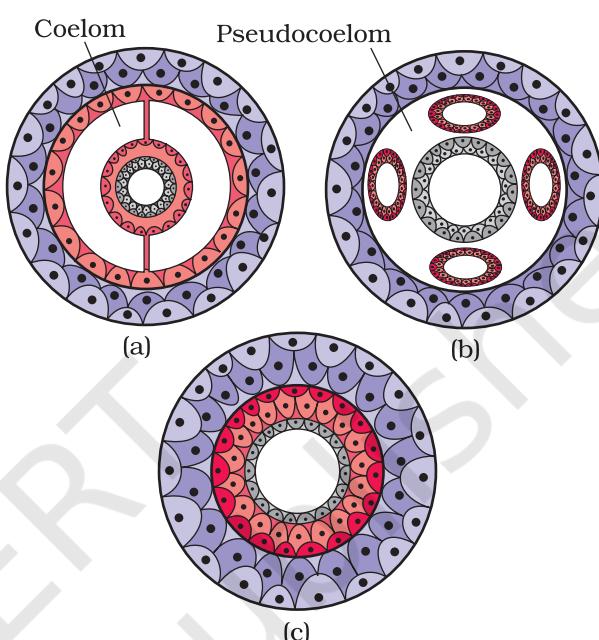


Figure 4.3 Diagrammatic sectional view of :
 (a) Coelomate (b) Pseudocoelomate
 (c) Acoelomate

4.1.5 Segmentation

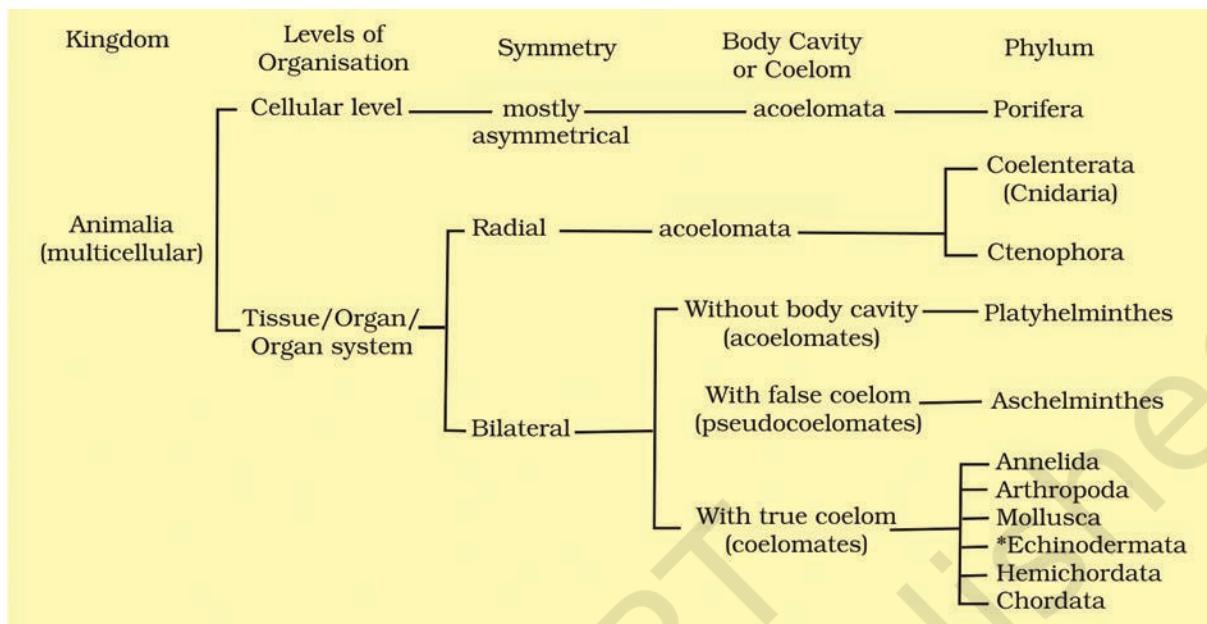
In some animals, the body is externally and internally divided into segments with a serial repetition of at least some organs. For example, in earthworm, the body shows this pattern called metameric segmentation and the phenomenon is known as **metamerism**.

4.1.6 Notochord

Notochord is a mesodermally derived rod-like structure formed on the dorsal side during embryonic development in some animals. Animals with notochord are called chordates and those animals which do not form this structure are called non-chordates, e.g., porifera to echinoderms.

4.2 CLASSIFICATION OF ANIMALS

The broad classification of Animalia based on common fundamental features as mentioned in the preceding sections is given in Figure 4.4.



*Echinodermata exhibits radial or bilateral symmetry depending on the stage.

Figure 4.4 Broad classification of Kingdom Animalia based on common fundamental features

The important characteristic features of the different phyla are described.

4.2.1 Phylum – Porifera

Members of this phylum are commonly known as sponges. They are generally marine and mostly asymmetrical animals (Figure 4.5). These are primitive multicellular animals and have cellular level of organisation. Sponges have a water transport or canal system. Water enters through minute pores (**ostia**) in the body wall into a central cavity, **spongocoel**, from where it goes out through the **osculum**. This pathway of water transport is helpful in food gathering, respiratory exchange and removal of waste. **Choanocytes** or collar cells line the spongocoel and the canals. Digestion is intracellular. The body is supported by a skeleton made up of **spicules** or **spongin fibres**. Sexes are not separate (**hermaphrodite**), i.e., eggs and sperms are produced by the same individual. Sponges reproduce asexually by fragmentation and sexually by formation of gametes. Fertilisation is internal and development is indirect having a larval stage which is morphologically distinct from the adult.

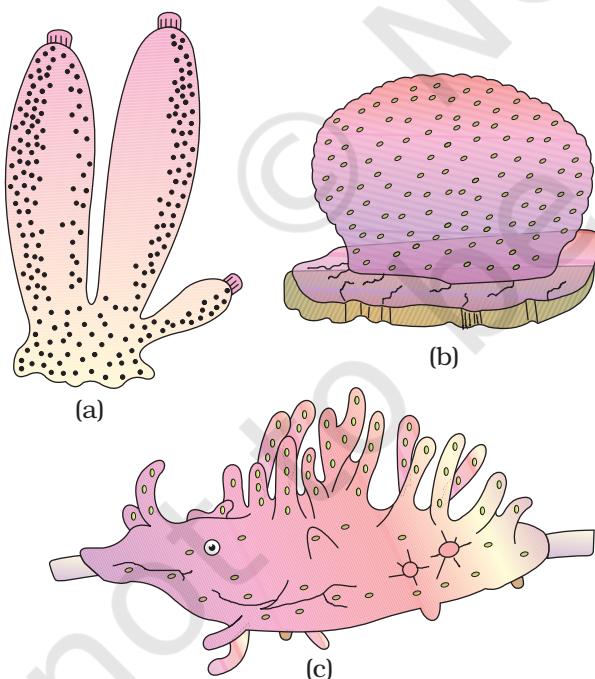


Figure 4.5 Examples of Porifera : (a) *Sycon* (b) *Euspongia* (c) *Spongilla*

Examples: *Sycon* (Scypha), *Spongilla* (Fresh water sponge) and *Euspongia* (Bath sponge).

4.2.2 Phylum – Coelenterata (Cnidaria)

They are aquatic, mostly marine, sessile or free-swimming, radially symmetrical animals (Figure 4.6). The name cnidaria is derived from the

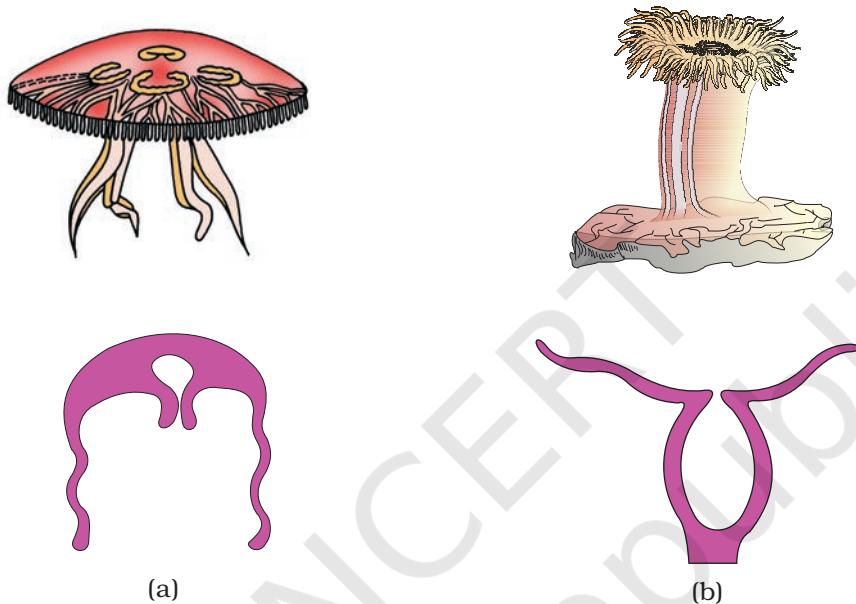


Figure 4.6 Examples of Coelenterata indicating outline of their body form :
(a) *Aurelia* (Medusa) (b) *Adamsia* (Polyp)

cnidoblasts or cnidocytes (which contain the stinging capsules or nematocysts) present on the tentacles and the body. Cnidoblasts are used for anchorage, defense and for the capture of prey (Figure 4.7). Cnidarians exhibit tissue level of organisation and are diploblastic. They have a central gastro-vascular cavity with a single opening, mouth on **hypostome**. Digestion is extracellular and intracellular. Some of the cnidarians, e.g., **corals** have a skeleton composed of calcium carbonate. Cnidarians exhibit two basic body forms called **polyp** and **medusa** (Figure 4.6). The former is a sessile and cylindrical form like *Hydra*, *Adamsia*, etc. whereas, the latter is umbrella-shaped and free-swimming like *Aurelia* or jelly fish. Those cnidarians which exist in both forms exhibit alternation of generation (Metagenesis), i.e., polyps produce medusae asexually and medusae form the polyps sexually (e.g., *Obelia*).

Examples: *Physalia* (Portuguese man-of-war), *Adamsia* (Sea anemone), *Pennatula* (Sea-pen), *Gorgonia* (Sea-fan) and *Meandrina* (Brain coral).



Figure 4.7 Diagrammatic view of Cnidoblast

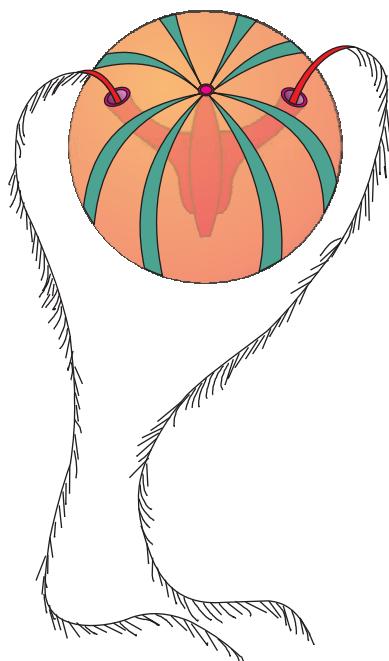


Figure 4.8 Example of Ctenophora (*Pleurobrachia*)

4.2.3 Phylum – Ctenophora

Ctenophores, commonly known as **sea walnuts** or **comb jellies** are exclusively marine, radially symmetrical, diploblastic organisms with tissue level of organisation. The body bears eight external rows of ciliated **comb plates**, which help in locomotion (Figure 4.8). Digestion is both extracellular and intracellular. **Bioluminescence** (the property of a living organism to emit light) is well-marked in ctenophores. Sexes are not separate. Reproduction takes place only by sexual means. Fertilisation is external with indirect development.

Examples: *Pleurobrachia* and *Ctenoplana*.

4.2.4 Phylum – Platyhelminthes

They have dorso-ventrally flattened body, hence are called **flatworms** (Figure 4.9). These are mostly endoparasites found in animals including human beings. Flatworms are bilaterally symmetrical, triploblastic and acoelomate animals with organ level of organisation. Hooks and suckers are present in the parasitic forms. Some of them absorb nutrients from the host directly through their body surface. Specialised cells called flame cells help in osmoregulation and excretion. Sexes are not separate. Fertilisation is internal and development is through many larval stages. Some members like *Planaria* possess high regeneration capacity.

Examples: *Taenia* (Tapeworm), *Fasciola* (Liver fluke).

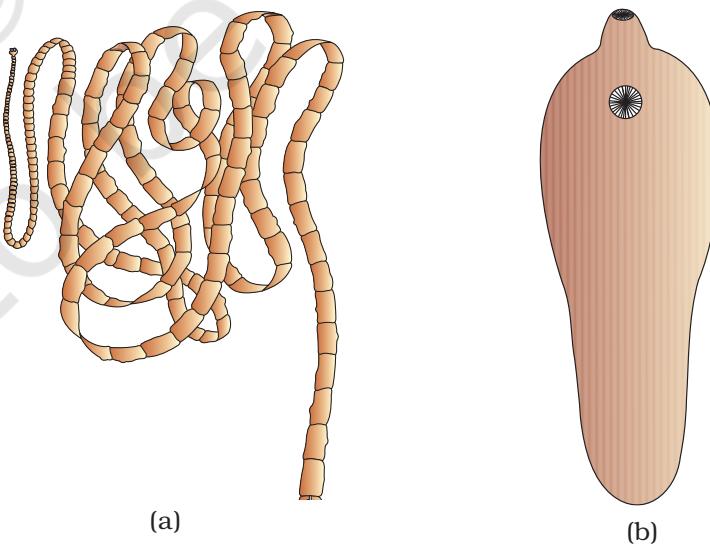


Figure 4.9 Examples of Platyhelminthes : (a) Tape worm (b) Liver fluke

4.2.5 Phylum – Aschelminthes

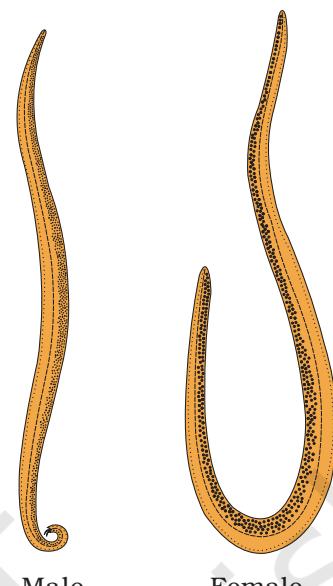
The body of the aschelminthes is circular in cross-section, hence, the name **roundworms** (Figure 4.10). They may be freeliving, aquatic and terrestrial or parasitic in plants and animals. Roundworms have organ-system level of body organisation. They are bilaterally symmetrical, triploblastic and pseudocoelomate animals. Alimentary canal is complete with a well-developed **muscular pharynx**. An excretory tube removes body wastes from the body cavity through the excretory pore. Sexes are separate (**dioecious**), i.e., males and females are distinct. Often females are longer than males. Fertilisation is internal and development may be direct (the young ones resemble the adult) or indirect.

Examples : *Ascaris* (Roundworm), *Wuchereria* (Filaria worm), *Ancylostoma* (Hookworm).

4.2.6 Phylum – Annelida

They may be aquatic (marine and fresh water) or terrestrial; free-living, and sometimes parasitic. They exhibit organ-system level of body organisation and bilateral symmetry. They are triploblastic, metamerically segmented and coelomate animals. Their body surface is distinctly marked out into **segments** or **metameres** and, hence, the phylum name Annelida (Latin, *annulus* : little ring) (Figure 4.11). They possess longitudinal and circular muscles which help in locomotion. Aquatic annelids like *Nereis* possess lateral appendages, **parapodia**, which help in swimming. A closed circulatory system is present. **Nephridia** (sing. nephridium) help in osmoregulation and excretion. Neural system consists of paired ganglia (sing. ganglion) connected by lateral nerves to a double ventral nerve cord. *Nereis*, an aquatic form, is dioecious, but earthworms and leeches are monoecious. Reproduction is sexual.

Examples : *Nereis*, *Pheretima* (Earthworm) and *Hirudinaria* (Blood sucking leech).



Male

Female

Figure 4.10 Example of Aschelminthes: Roundworm

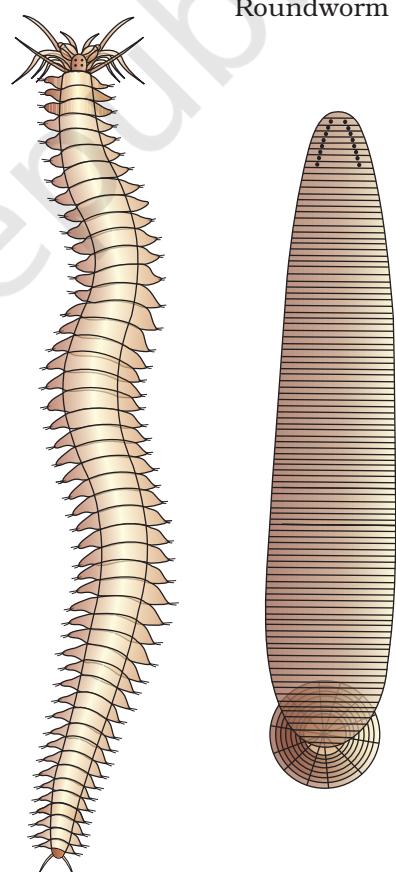


Figure 4.11 Examples of Annelida : (a) *Nereis*
(b) *Hirudinaria*

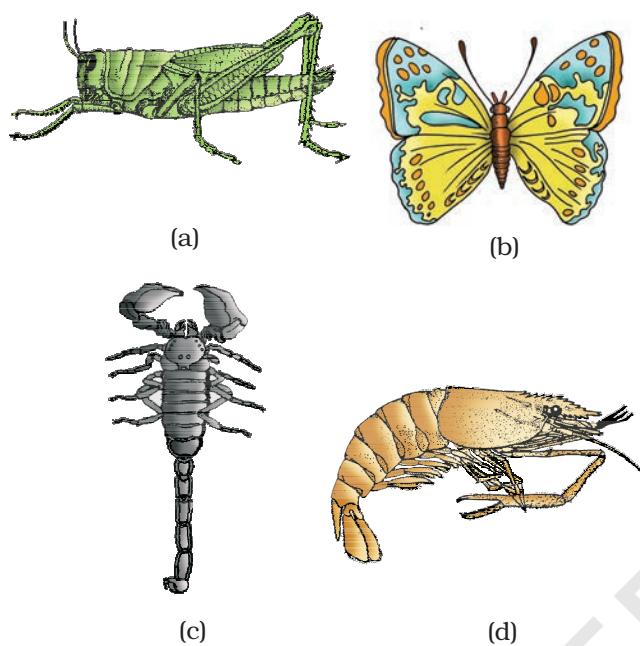


Figure 4.12 Examples of Arthropoda:
 (a) Locust (b) Butterfly
 (c) Scorpion (d) Prawn

4.2.7 Phylum – Arthropoda

This is the **largest phylum** of Animalia which includes insects. Over two-thirds of all named species on earth are arthropods (Figure 4.12). They have organ-system level of organisation. They are bilaterally symmetrical, triploblastic, segmented and coelomate animals. The body of arthropods is covered by chitinous exoskeleton. The body consists of **head, thorax** and **abdomen**. They have **jointed appendages** (arthros-joint, poda-appendages). Respiratory organs are gills, book gills, book lungs or tracheal system. Circulatory system is of open type. Sensory organs like antennae, eyes (compound and simple), statocysts or balancing organs are present. Excretion takes place through **malpighian tubules**. They are mostly dioecious. Fertilisation is usually internal. They are mostly oviparous. Development may be direct or indirect.

Examples: Economically important insects – *Apis* (Honey bee), *Bombyx* (Silkworm), *Laccifer* (Lac insect)

Vectors – *Anopheles*, *Culex* and *Aedes* (Mosquitoes)

Gregarious pest – *Locusta* (Locust)

Living fossil – *Limulus* (King crab).

4.2.8 Phylum – Mollusca

This is the **second largest** animal phylum (Figure 4.13). Molluscs are terrestrial or aquatic (marine or fresh water) having an organ-system level of organisation. They are bilaterally symmetrical, triploblastic and coelomate animals. Body is covered by a calcareous shell and is unsegmented with a distinct **head**, **muscular foot** and **visceral hump**. A soft and spongy layer of skin forms a mantle over the visceral hump. The space between the hump and the mantle is called the mantle cavity in which feather like gills are present. They have respiratory and excretory functions. The anterior head region has sensory tentacles. The mouth contains a file-like rasping organ for feeding, called **radula**.

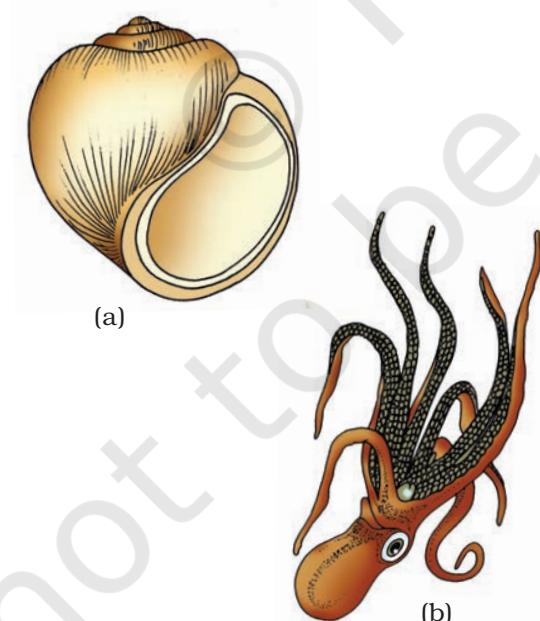


Figure 4.13 Examples of Mollusca :
 (a) *Pila* (b) *Octopus*

They are usually dioecious and oviparous with indirect development.

Examples: *Pila* (Apple snail), *Pinctada* (Pearl oyster), *Sepia* (Cuttlefish), *Loligo* (Squid), *Octopus* (Devil fish), *Aplysia* (Seashore), *Dentalium* (Tusk shell) and *Chaetopleura* (Chiton).

4.2.9 Phylum – Echinodermata

These animals have an endoskeleton of calcareous ossicles and, hence, the name Echinodermata (Spiny bodied, Figure 4.14). All are marine with organ-system level of organisation. The adult echinoderms are radially symmetrical but larvae are bilaterally symmetrical. They are triploblastic and coelomate animals. Digestive system is complete with mouth on the lower (ventral) side and anus on the upper (dorsal) side. The most distinctive feature of echinoderms is the presence of **water vascular system** which helps in locomotion, capture and transport of food and respiration. An excretory system is absent. Sexes are separate. Reproduction is sexual. Fertilisation is usually external. Development is indirect with free-swimming larva.

Examples: *Asterias* (Star fish), *Echinus* (Sea urchin), *Antedon* (Sea lily), *Cucumaria* (Sea cucumber) and *Ophiura* (Brittle star).

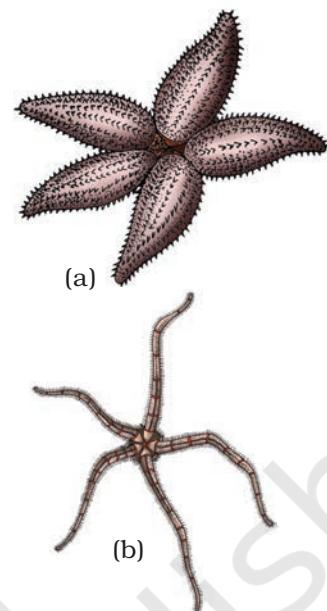


Figure 4.14 Examples of Echinodermata :
 (a) *Asterias*
 (b) *Ophiura*

4.2.10 Phylum – Hemichordata

Hemichordata was earlier considered as a sub-phylum under phylum Chordata. But now it is placed as a separate phylum under non-chordata. Hemichordates have a rudimentary structure in the collar region called stomochord, a structure similar to notochord.

This phylum consists of a small group of **worm-like** marine animals with organ-system level of organisation. They are bilaterally symmetrical, triploblastic and coelomate animals. The body is cylindrical and is composed of an anterior **proboscis**, a **collar** and a long **trunk** (Figure 4.15). Circulatory system is of open type. Respiration takes place through gills. Excretory organ is proboscis gland. Sexes are separate. Fertilisation is external. Development is indirect.

Examples: *Balanoglossus* and *Saccoglossus*.

4.2.11 Phylum – Chordata

Animals belonging to phylum Chordata are fundamentally characterised by the presence of a **notochord**, a **dorsal**

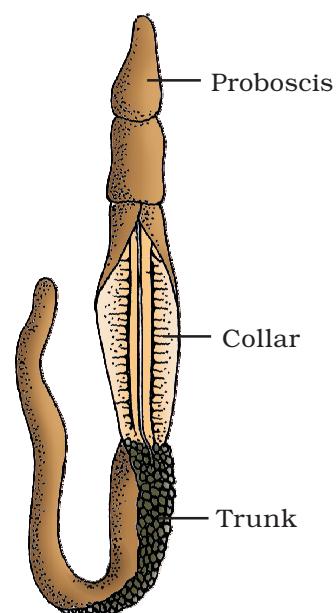


Figure 4.15 *Balanoglossus*

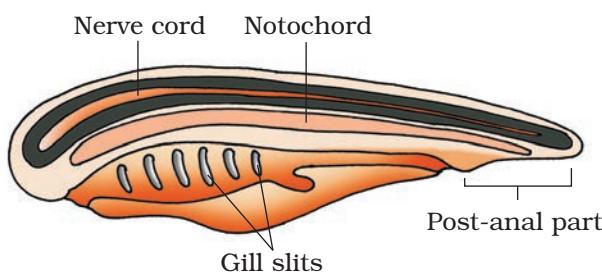


Figure 4.16 Chordata characteristics

TABLE 4.1 Comparison of Chordates and Non-chordates

S.No.	Chordates	Non-chordates
1.	Notochord present.	Notochord absent.
2.	Central nervous system is dorsal, hollow and single.	Central nervous system is ventral, solid and double.
3.	Pharynx perforated by gill slits.	Gill slits are absent.
4.	Heart is ventral.	Heart is dorsal (if present).
5.	A post-anal part (tail) is present.	Post-anal tail is absent.

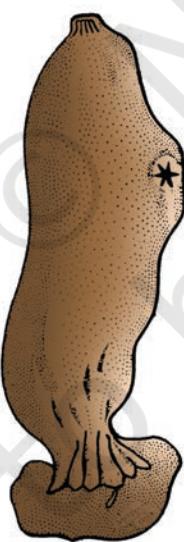


Figure 4.17 Ascidia

hollow nerve cord and **paired pharyngeal gill slits** (Figure 4.16). These are bilaterally symmetrical, triploblastic, coelomate with organ-system level of organisation. They possess a post anal tail and a closed circulatory system.

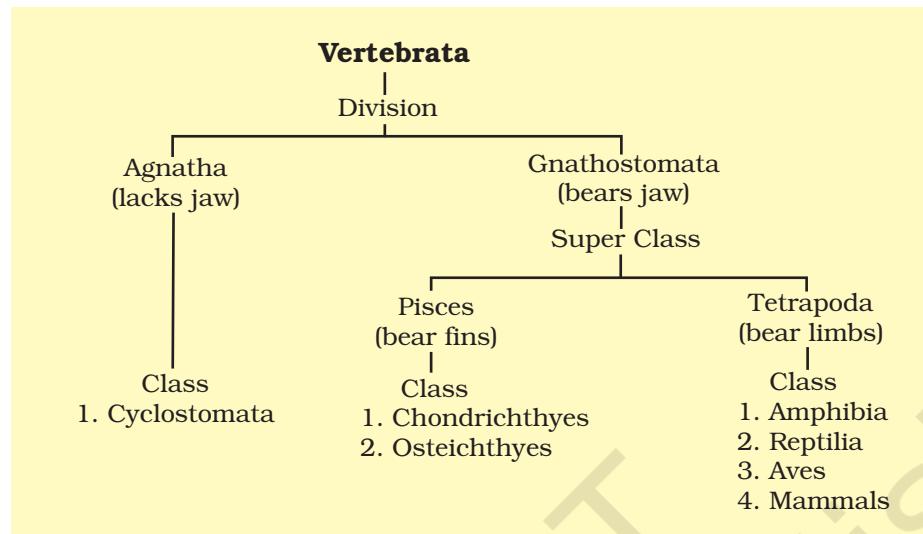
Table 4.1 presents a comparison of salient features of chordates and non-chordates.

Phylum Chordata is divided into three subphyla: **Urochordata** or **Tunicata**, **Cephalochordata** and **Vertebrata**.

Subphyla Urochordata and Cephalochordata are often referred to as **protochordates** (Figure 4.17) and are exclusively marine. In Urochordata, notochord is present only in larval tail, while in Cephalochordata, it extends from head to tail region and is persistent throughout their life. Examples: Urochordata – *Ascidia*, *Salpa*, *Doliolum*; Cephalochordata – *Branchiostoma* (*Amphioxus* or Lancelet).

The members of subphylum Vertebrata possess notochord during the embryonic period. The notochord is replaced by a cartilaginous or bony **vertebral column** in the adult. Thus all vertebrates are chordates but all chordates are not vertebrates. Besides the basic chordate characters, vertebrates have a ventral muscular heart with two, three or four chambers, kidneys for excretion and osmoregulation and paired appendages which may be fins or limbs.

The subphylum Vertebrata is further divided as follows:



4.2.11.1 Class – Cyclostomata

All living members of the class Cyclostomata are ectoparasites on some fishes. They have an elongated body bearing 6-15 pairs of **gill slits** for respiration. Cyclostomes have a sucking and circular mouth without jaws (Fig. 4.18). Their body is devoid of scales and paired fins. Cranium and vertebral column are cartilaginous. Circulation is of closed type. Cyclostomes are marine but migrate for spawning to fresh water. After spawning, within a few days, they die. Their larvae, after metamorphosis, return to the ocean.

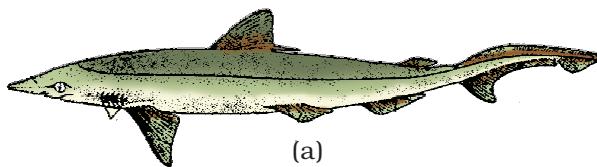
Examples: *Petromyzon* (Lamprey) and *Myxine* (Hagfish).

4.2.11.2 Class – Chondrichthyes

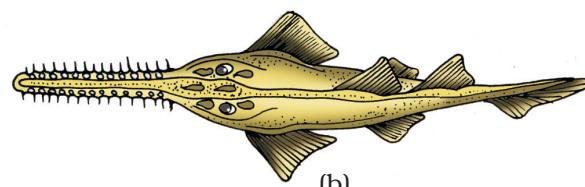
They are marine animals with streamlined body and have cartilaginous endoskeleton (Figure 4.19). Mouth is located ventrally. **Notochord** is **persistent** throughout life. Gill slits are separate and without **operculum** (gill cover). The skin is tough, containing minute **placoid scales**. Teeth are modified placoid scales which are backwardly directed. Their jaws are very powerful. These animals are predaceous. Due to the absence of air bladder, they have to swim constantly to avoid sinking.



Figure 4.18 A jawless vertebrate - *Petromyzon*



(a)



(b)

Figure 4.19 Example of Cartilaginous fishes :
(a) *Scoliodon* (b) *Pristis*

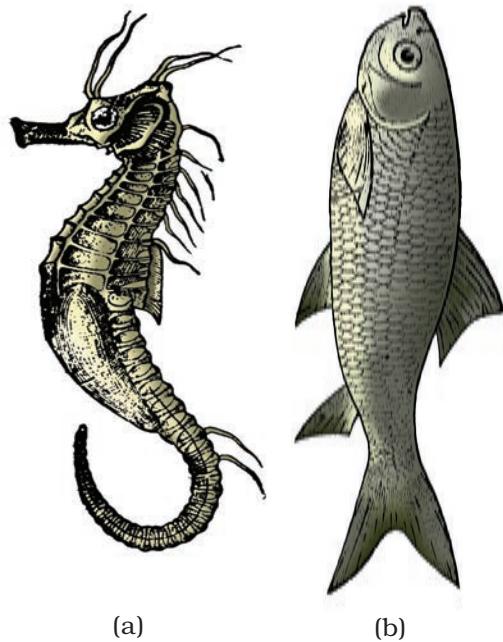


Figure 4.20 Examples of Bony fishes :
(a) *Hippocampus* (b) *Catla*

Heart is two-chambered (one auricle and one ventricle). Some of them have **electric organs** (e.g., *Torpedo*) and some possess **poison sting** (e.g., *Trygon*). They are cold-blooded (**poikilothermous**) animals, i.e., they lack the capacity to regulate their body temperature. Sexes are separate. In males pelvic fins bear claspers. They have internal fertilisation and many of them are viviparous.

Examples: *Scoliodon* (Dog fish), *Pristis* (Saw fish), *Carcharodon* (Great white shark), *Trygon* (Sting ray).

4.2.11.3 Class – Osteichthyes

It includes both marine and fresh water fishes with bony endoskeleton. Their body is streamlined. Mouth is mostly terminal (Figure 4.20). They have four pairs of gills which are covered by an **operculum** on each side. Skin is covered with cycloid/ctenoid scales. **Air bladder** is present which regulates buoyancy. Heart is two-chambered (one auricle and one ventricle). They are cold-blooded animals. Sexes are separate. Fertilisation is usually external. They are mostly oviparous and development is direct.

Examples: Marine – *Exocoetus* (Flying fish), *Hippocampus* (Sea horse); Freshwater – *Labeo* (Rohu), *Catla* (Katla), *Clarias* (Magur); Aquarium – *Betta* (Fighting fish), *Pterophyllum* (Angel fish).

4.2.11.4 Class – Amphibia

As the name indicates (Gr., *Amphi* : dual, *bios*, life), amphibians can live in aquatic as well as terrestrial habitats (Figure 4.21). Most of them have two pairs of limbs. Body is divisible into **head** and **trunk**. Tail may be present in some. The amphibian skin is moist (without scales). The eyes have eyelids. A **tympanum** represents the ear. Alimentary canal, urinary and reproductive tracts open into a common chamber called **cloaca** which opens to the exterior. Respiration is by gills, lungs and through skin. The heart is three-chambered (two auricles and one ventricle). These are cold-blooded animals. Sexes are separate. Fertilisation is external. They are oviparous and development is indirect.

Examples: *Bufo* (Toad), *Rana* (Frog), *Hyla* (Tree frog), *Salamandra* (Salamander), *Ichthyophis* (Limbless amphibia).

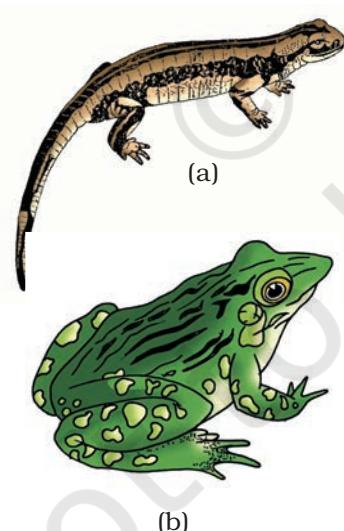


Figure 4.21 Examples of Amphibia :
(a) *Salamandra*
(b) *Rana*

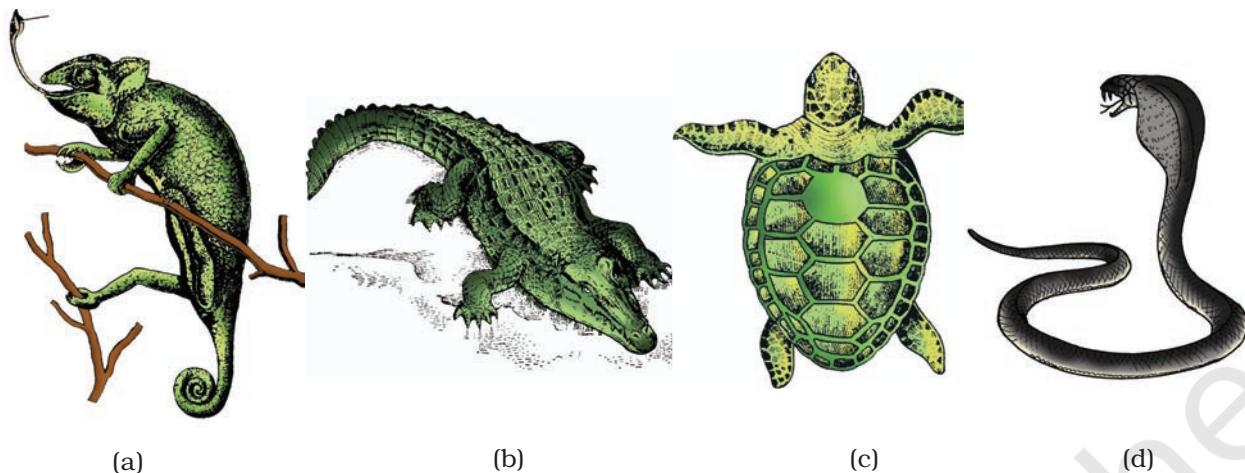


Figure 4.22 Reptiles: (a) *Chameleoon* (b) *Crocodilus* (c) *Chelone* (d) *Naja*

4.2.11.5 Class – *Reptilia*

The class name refers to their creeping or crawling mode of locomotion (*Latin, repere or reptum*, to creep or crawl). They are mostly terrestrial animals and their body is covered by dry and cornified skin, epidermal **scales** or **scutes** (Fig. 4.22). They do not have external ear openings. Tympanum represents ear. Limbs, when present, are two pairs. Heart is usually three-chambered, but four-chambered in crocodiles. Reptiles are poikilotherms. Snakes and lizards shed their scales as skin cast. Sexes are separate. Fertilisation is internal. They are oviparous and development is direct.

Examples: *Chelone* (Turtle), *Testudo* (Tortoise), *Chameleoon* (Tree lizard), *Calotes* (Garden lizard), *Crocodilus* (Crocodile), *Alligator* (Alligator), *Hemidactylus* (Wall lizard), Poisonous snakes – *Naja* (Cobra), *Bangarus* (Krait), *Vipera* (Viper).

4.2.11.6 Class – *Aves*

The characteristic features of Aves (birds) are the presence of **feathers** and most of them can fly except flightless birds (e.g., Ostrich). They possess **beak** (Figure 4.23). The forelimbs are modified into **wings**. The hind limbs generally have scales and are modified for walking, swimming or clasping the tree branches. Skin is dry without glands except the oil gland at the base of the tail. Endoskeleton is fully ossified (bony) and the long bones are hollow with **air cavities** (pneumatic). The digestive tract of birds has additional chambers, the crop and gizzard. Heart is completely four-chambered. They are warm-blooded (**homioiothermous**) animals, i.e., they are able to maintain a constant body temperature. Respiration is by

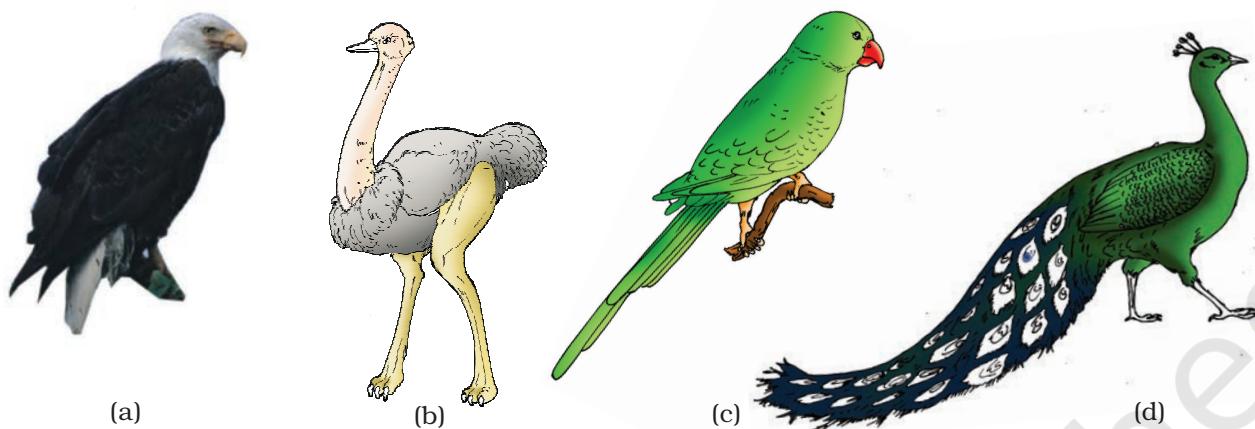


Figure 4.23 Some birds : (a) *Neophron* (b) *Struthio* (c) *Psittacula* (d) *Pavo*

lungs. Air sacs connected to lungs supplement respiration. Sexes are separate. Fertilisation is internal. They are oviparous and development is direct.

Examples : *Corvus* (Crow), *Columba* (Pigeon), *Psittacula* (Parrot), *Struthio* (Ostrich), *Pavo* (Peacock), *Aptenodytes* (Penguin), *Neophron* (Vulture).

4.2.11.7 Class – Mammalia

They are found in a variety of habitats – polar ice caps, deserts, mountains, forests, grasslands and dark caves. Some of them have adapted to fly or live in water. The most unique mammalian characteristic is the presence of milk producing glands (**mammary glands**) by which the young ones are nourished. They have two pairs of limbs, adapted for walking, running, climbing, burrowing, swimming or flying (Figure 4.24). The skin of

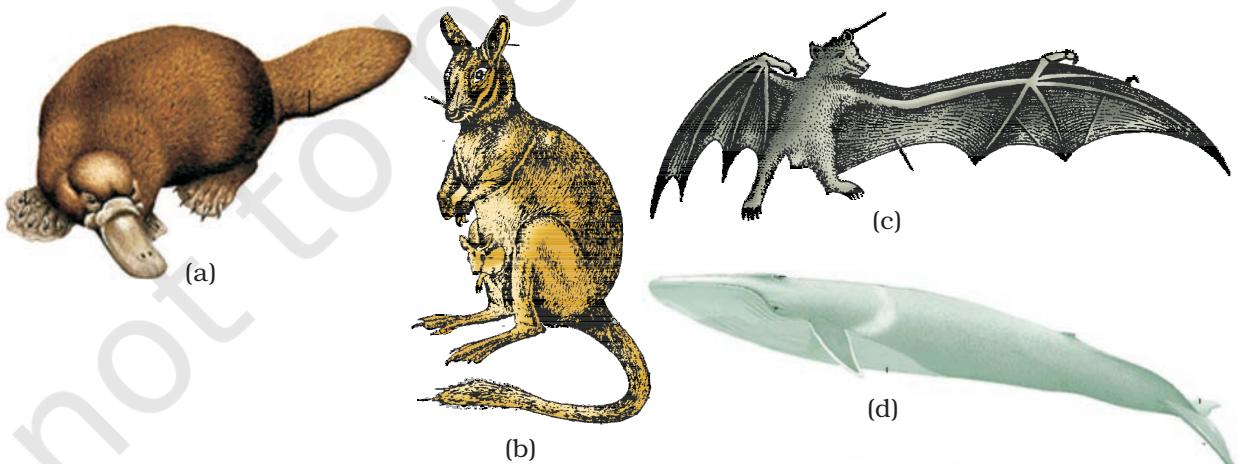


Figure 4.24 Some mammals : (a) *Ornithorhynchus* (b) *Macropus* (c) *Pteropus* (d) *Balaenoptera*

mammals is unique in possessing **hair**. External ears or **pinnae** are present. Different types of teeth are present in the jaw. Heart is four-chambered. They are homoiothermous. Respiration is by lungs. Sexes are separate and fertilisation is internal. They are viviparous with few exceptions and development is direct.

Examples: Oviparous-*Ornithorhynchus* (Platypus); Viviparous - *Macropus* (Kangaroo), *Pteropus* (Flying fox), *Camelus* (Camel), *Macaca* (Monkey), *Rattus* (Rat), *Canis* (Dog), *Felis* (Cat), *Elephas* (Elephant), *Equus* (Horse), *Delphinus* (Common dolphin), *Balaenoptera* (Blue whale), *Panthera tigris* (Tiger), *Panthera leo* (Lion).

The salient distinguishing features of all phyla under animal kingdom is comprehensively given in the Table 4.2.

TABLE 4.2 Salient Features of Different Phyla in the Animal Kingdom

Phylum	Level of Organisation	Symmetry	Coelom	Segmentation	Digestive System	Circulatory System	Respiratory System	Distinctive Features
Porifera	Cellular	Various	Absent	Absent	Absent	Absent	Absent	Body with pores and canals in walls.
Coelenterata (Cnidaria)	Tissue	Radial	Absent	Absent	Incomplete	Absent	Absent	Cnidoblasts present.
Ctenophora	Tissue	Radial	Absent	Absent	Incomplete	Absent	Absent	Comb plates for locomotion.
Platyhelminthes	Organ & Organ-system	Bilateral	Absent	Absent	Incomplete	Absent	Absent	Flat body, suckers.
Aschelminthes	Organ-system	Bilateral	Pseudo coelomate	Absent	Complete	Absent	Absent	Often worm-shaped, elongated.
Annelida	Organ-system	Bilateral	Coelomate	Present	Complete	Present	Absent	Body segmentation like rings.
Arthropoda	Organ-system	Bilateral	Coelomate	Present	Complete	Present	Present	Exoskeleton of cuticle, jointed appendages.
Mollusca	Organ-system	Bilateral	Coelomate	Absent	Complete	Present	Present	External skeleton of shell usually present.
Echinodermata	Organ-system	Radial	Coelomate	Absent	Complete	Present	Present	Water vascular system, radial symmetry.
Hemichordata	Organ-system	Bilateral	Coelomate	Absent	Complete	Present	Present	Worm-like with proboscis, collar and trunk.
Chordata	Organ-system	Bilateral	Coelomate	Present	Complete	Present	Present	Notochord, dorsal hollow nerve cord, gill slits with limbs or fins.

SUMMARY

The basic fundamental features such as level of organisation, symmetry, cell organisation, coelom, segmentation, notochord, etc., have enabled us to broadly classify the animal kingdom. Besides the fundamental features, there are many other distinctive characters which are specific for each phyla or class.

Porifera includes multicellular animals which exhibit cellular level of organisation and have characteristic flagellated choanocytes. The coelenterates have tentacles and bear cnidoblasts. They are mostly aquatic, sessile or free-floating. The ctenophores are marine animals with comb plates. The platyhelminths have flat body and exhibit bilateral symmetry. The parasitic forms show distinct suckers and hooks. Aschelminthes are pseudocoelomates and include parasitic as well as non-parasitic roundworms.

Annelids are metamerically segmented animals with a true coelom. The arthropods are the most abundant group of animals characterised by the presence of jointed appendages. The molluscs have a soft body surrounded by an external calcareous shell. The body is covered with external skeleton made of chitin. The echinoderms possess a spiny skin. Their most distinctive feature is the presence of water vascular system. The hemichordates are a small group of worm-like marine animals. They have a cylindrical body with proboscis, collar and trunk.

Phylum Chordata includes animals which possess a notochord either throughout or during early embryonic life. Other common features observed in the chordates are the dorsal, hollow nerve cord and paired pharyngeal gill slits. Some of the vertebrates do not possess jaws (Agnatha) whereas most of them possess jaws (Gnathostomata). Agnatha is represented by the class, Cyclostomata. They are the most primitive chordates and are ectoparasites on fishes. Gnathostomata has two super classes, Pisces and Tetrapoda. Classes Chondrichthyes and Osteichthyes bear fins for locomotion and are grouped under Pisces. The Chondrichthyes are fishes with cartilaginous endoskeleton and are marine. Classes, Amphibia, Reptilia, Aves and Mammalia have two pairs of limbs and are thus grouped under Tetrapoda. The amphibians have adapted to live both on land and water. Reptiles are characterised by the presence

of dry and cornified skin. Limbs are absent in snakes. Fishes, amphibians and reptiles are poikilothermous (cold-blooded). Aves are warm-blooded animals with feathers on their bodies and forelimbs modified into wings for flying. Hind limbs are adapted for walking, swimming, perching or clasping. The unique features of mammals are the presence of mammary glands and hairs on the skin. They commonly exhibit viviparity.

EXERCISES

1. What are the difficulties that you would face in classification of animals, if common fundamental features are not taken into account?
2. If you are given a specimen, what are the steps that you would follow to classify it?
3. How useful is the study of the nature of body cavity and coelom in the classification of animals?
4. Distinguish between intracellular and extracellular digestion?
5. What is the difference between direct and indirect development?
6. What are the peculiar features that you find in parasitic platyhelminthes?
7. What are the reasons that you can think of for the arthropods to constitute the largest group of the animal kingdom?
8. Water vascular system is the characteristic of which group of the following:
(a) Porifera (b) Ctenophora (c) Echinodermata (d) Chordata
9. "All vertebrates are chordates but all chordates are not vertebrates". Justify the statement.
10. How important is the presence of air bladder in Pisces?
11. What are the modifications that are observed in birds that help them fly?
12. Could the number of eggs or young ones produced by an oviparous and viviparous mother be equal? Why?
13. Segmentation in the body is first observed in which of the following:
(a) Platyhelminthes (b) Aschelminthes (c) Annelida (d) Arthropoda

14. Match the following:

- | | |
|-----------------|--------------------------------------|
| (a) Operculum | (i) Ctenophora |
| (b) Parapodia | (ii) Mollusca |
| (c) Scales | (iii) Porifera |
| (d) Comb plates | (iv) Reptilia |
| (e) Radula | (v) Annelida |
| (f) Hairs | (vi) Cyclostomata and Chondrichthyes |
| (g) Choanocytes | (vii) Mammalia |
| (h) Gill slits | (viii) Osteichthyes |

15. Prepare a list of some animals that are found parasitic on human beings.