

UNIT 1

DIVERSITY IN THE LIVING WORLD

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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 What is 'Living'?

1.2 Diversity in the Living World

1.3 Taxonomic Categories

1.4 Taxonomical Aids

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 WHAT IS 'LIVING'?

When we try to define 'living', we conventionally look for distinctive characteristics exhibited by living organisms. Growth, reproduction, ability to sense environment and mount a suitable response come to our mind immediately as unique features of living organisms. One can add a few more features like metabolism, ability to self-replicate, self-organise, interact and emergence to this list. Let us try to understand each of these.

All living organisms grow. Increase in mass and increase in number of individuals are twin characteristics of growth. A multicellular organism

grows by cell division. In plants, this growth by cell division occurs continuously throughout their life span. In animals, this growth is seen only up to a certain age. However, cell division occurs in certain tissues to replace lost cells. Unicellular organisms grow by cell division. One can easily observe this in *in vitro* cultures by simply counting the number of cells under the microscope. In majority of higher animals and plants, growth and reproduction are mutually exclusive events. One must remember that increase in body mass is considered as growth. Non-living objects also grow if we take increase in body mass as a criterion for growth. Mountains, boulders and sand mounds do grow. However, this kind of growth exhibited by non-living objects is by accumulation of material on the surface. In living organisms, growth is from inside. Growth, therefore, cannot be taken as a defining property of living organisms. Conditions under which it can be observed in all living organisms have to be explained and then we understand that it is a characteristic of living systems. A dead organism does not grow.

Reproduction, likewise, is a characteristic of living organisms.

In multicellular organisms, reproduction refers to the production of progeny possessing features more or less similar to those of parents. Invariably and implicitly we refer to sexual reproduction. Organisms reproduce by asexual means also. Fungi multiply and spread easily due to the millions of asexual spores they produce. In lower organisms like yeast and hydra, we observe budding. In *Planaria* (flat worms), we observe true regeneration, i.e., a fragmented organism regenerates the lost part of its body and becomes, a new organism. The fungi, the filamentous algae, the protonema of mosses, all easily multiply by fragmentation. When it comes to unicellular organisms like bacteria, unicellular algae or *Amoeba*, reproduction is synonymous with growth, i.e., increase in number of cells. We have already defined growth as equivalent to increase in cell number or mass. Hence, we notice that in single-celled organisms, we are not very clear about the usage of these two terms – growth and reproduction. Further, there are many organisms which do not reproduce (mules, sterile worker bees, infertile human couples, etc). Hence, reproduction also cannot be an all-inclusive defining characteristic of living organisms. Of course, no non-living object is capable of reproducing or replicating by itself.

Another characteristic of life is metabolism. All living organisms are made of chemicals. These chemicals, small and big, belonging to various classes, sizes, functions, etc., are constantly being made and changed into some other biomolecules. These conversions are chemical reactions or metabolic reactions. There are thousands of metabolic reactions occurring simultaneously inside all living organisms, be they

unicellular or multicellular. All plants, animals, fungi and microbes exhibit metabolism. The sum total of all the chemical reactions occurring in our body is metabolism. No non-living object exhibits metabolism. Metabolic reactions can be demonstrated outside the body in cell-free systems. An isolated metabolic reaction(s) outside the body of an organism, performed in a test tube is neither living nor non-living. Hence, while metabolism is a defining feature of all living organisms without exception, isolated metabolic reactions *in vitro* are not living things but surely living reactions.

Hence, cellular organisation of the body is the defining feature of life forms.

Perhaps, the most obvious and technically complicated feature of all living organisms is this ability to sense their surroundings or environment and respond to these environmental stimuli which could be physical, chemical or biological. We sense our environment through our sense organs. Plants respond to external factors like light, water, temperature, other organisms, pollutants, etc. All organisms, from the prokaryotes to the most complex eukaryotes can sense and respond to environmental cues. Photoperiod affects reproduction in seasonal breeders, both plants and animals. All organisms handle chemicals entering their bodies. All organisms therefore, are 'aware' of their surroundings. Human being is the only organism who is aware of himself, i.e., has self-consciousness.

Consciousness therefore, becomes the defining property of living organisms.

When it comes to human beings, it is all the more difficult to define the living state. We observe patients lying in coma in hospitals virtually supported by machines which replace heart and lungs. The patient is otherwise brain-dead. The patient has no self-consciousness. Are such patients who never come back to normal life, living or non-living?

In higher classes, you will come to know that all living phenomena are due to underlying interactions. Properties of tissues are not present in the constituent cells but arise as a result of interactions among the constituent cells. Similarly, properties of cellular organelles are not present in the molecular constituents of the organelle but arise as a result of interactions among the molecular components comprising the organelle. These interactions result in emergent properties at a higher level of organisation. This phenomenon is true in the hierarchy of organisational complexity at all levels. Therefore, we can say that living organisms are self-replicating, evolving and self-regulating interactive systems capable of responding to external stimuli. Biology is the story of life on earth. Biology is the story of evolution of living organisms on earth. All living organisms – present, past and future, are linked to one another by the sharing of the common genetic material, but to varying degrees.

1.2 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.

1.3 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.

1.3.1 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*.

1.3.2 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.

1.3.3 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.

1.3.4 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.

1.3.5 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.

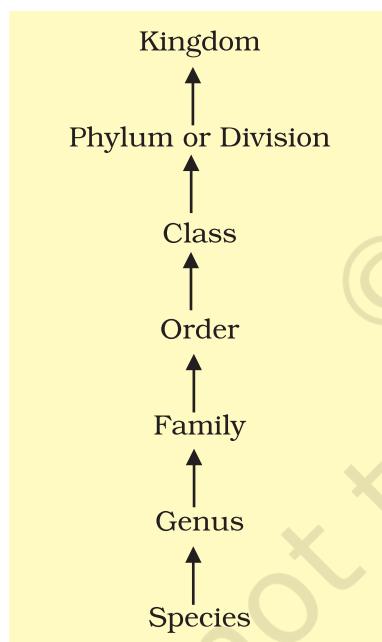


Figure 1.1 Taxonomic categories showing hierachial arrangement in ascending order

1.3.6 Phylum

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

1.3.7 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

1.4 TAXONOMICAL AIDS

Taxonomic studies of various species of plants, animals and other organisms are useful in agriculture, forestry, industry and in general in knowing our bio-resources and their diversity. These studies would require correct classification and identification of organisms. Identification of organisms requires intensive laboratory and field studies. The collection of actual specimens of plant and animal species is essential and is the prime source of taxonomic studies. These are also fundamental to studies and essential for training in systematics. It is used for classification of an organism, and the information gathered is also stored along with the specimens. In some cases the specimen is preserved for future studies.

Biologists have established certain procedures and techniques to store and preserve the information as well as the specimens. Some of these are explained to help you understand the usage of these aids.

1.4.1 Herbarium

Herbarium is a store house of collected plant specimens that are dried, pressed and preserved on sheets. Further, these sheets are arranged

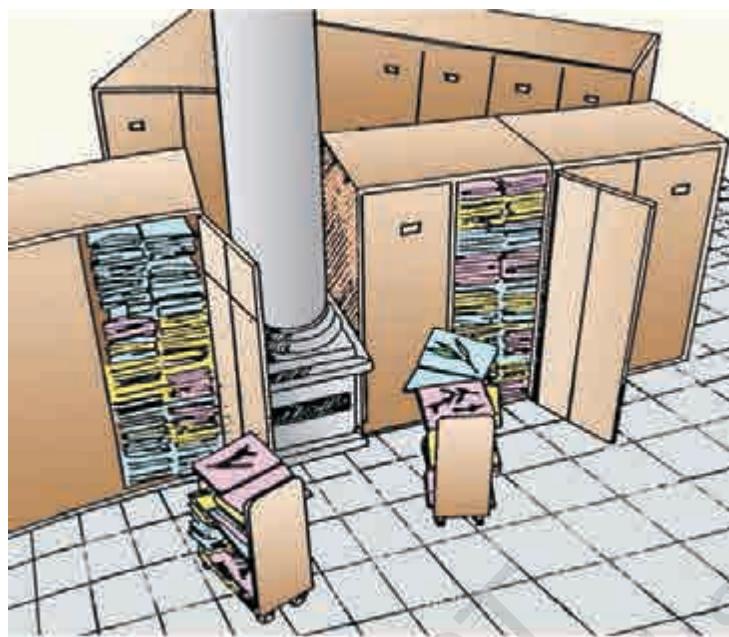


Figure 1.2 Herbarium showing stored specimens

according to a universally accepted system of classification. These specimens, along with their descriptions on herbarium sheets, become a store house or repository for future use (Figure 1.2). The herbarium sheets also carry a label providing information about date and place of collection, English, local and botanical names, family, collector's name, etc. Herbaria also serve as quick referral systems in taxonomical studies.

1.4.2 Botanical Gardens

These specialised gardens have collections of living plants for reference. Plant species in these gardens are grown for identification purposes and each plant is labelled indicating its botanical/scientific name and its family. The famous botanical gardens are at Kew (England), Indian Botanical Garden, Howrah (India) and at National Botanical Research Institute, Lucknow (India).

1.4.3 Museum

Biological museums are generally set up in educational institutes such as schools and colleges. Museums have collections of preserved plant and animal specimens for study and reference. Specimens are preserved in the containers or jars in preservative solutions. Plant and animal specimens may also be preserved as dry specimens. Insects are preserved in insect boxes after collecting, killing and pinning. Larger animals like birds and mammals are usually stuffed and preserved. Museums often have collections of skeletons of animals too.

1.4.4 Zoological Parks

These are the places where wild animals are kept in protected environments under human care and which enable us to learn about their food habits and behaviour. All animals in a zoo are provided, as far as possible, the conditions similar to their natural habitats. Children love visiting these parks, commonly called Zoos (Figure 1.3).



1.4.5 Key

Key is another taxonomical aid used for identification of plants and animals based on the similarities and dissimilarities. The keys are based on the contrasting characters generally in a pair called couplet. It represents the choice made between two opposite options. This results in acceptance of only one and rejection of the other. Each statement in the key is called a lead. Separate taxonomic keys are required for each taxonomic category such as family, genus and species for identification purposes. Keys are generally analytical in nature.

Flora, manuals, monographs and catalogues are some other means of recording descriptions. They also help in correct identification. Flora contains the actual account of habitat and distribution of plants of a given area. These provide the index to the plant species found in a particular area. Manuals are useful in providing information for identification of names of species found in an area. Monographs contain information on any one taxon.

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.

Taxonomists have developed a variety of taxonomic aids to facilitate identification, naming and classification of organisms. These studies are carried out from the actual specimens which are collected from the field and preserved as referrals in the form of herbaria, museums and in botanical gardens and zoological parks. It requires special techniques for collection and preservation of specimens in herbaria and museums. Live specimens, on the other hand, of plants and animals, are found in botanical gardens or in zoological parks. Taxonomists also prepare and disseminate information through manuals and monographs for further taxonomic studies. Taxonomic keys are tools that help in identification based on characteristics.

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. How is a key helpful in the identification and classification of an organism?
11. Illustrate the taxonomical hierarchy with suitable examples of a plant and an animal.

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 (without cellulose) 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 *Paramecium* 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).

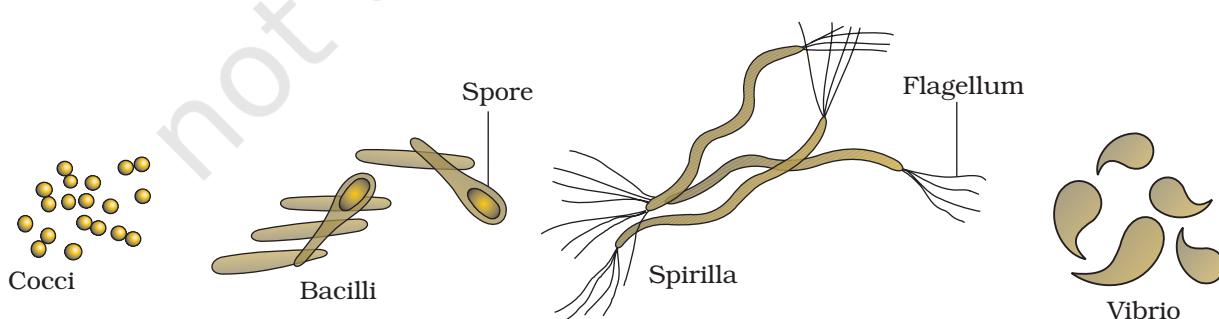


Figure 2.1 Bacteria of different shapes

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 Archaebacteria

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). Archaebacteria 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 α 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

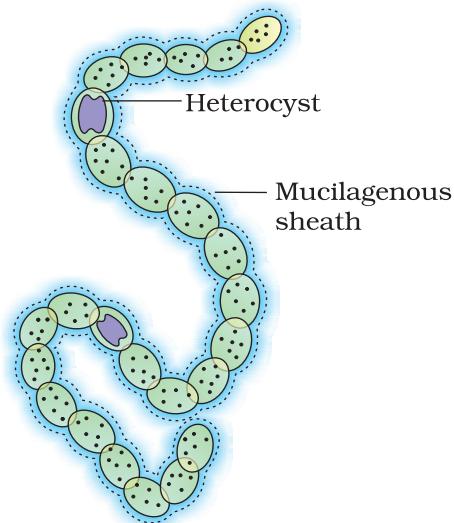


Figure 2.2 A filamentous blue-green algae – *Nostoc*

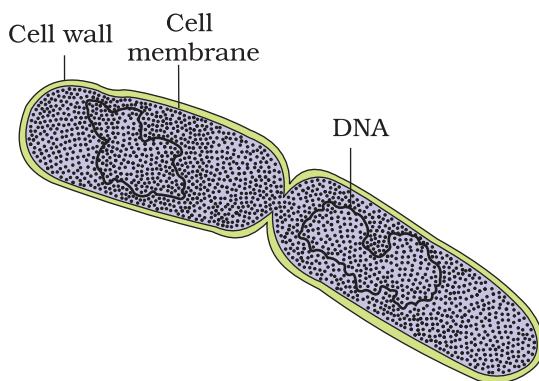


Figure 2.3 A dividing bacterium

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 2.4a).

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

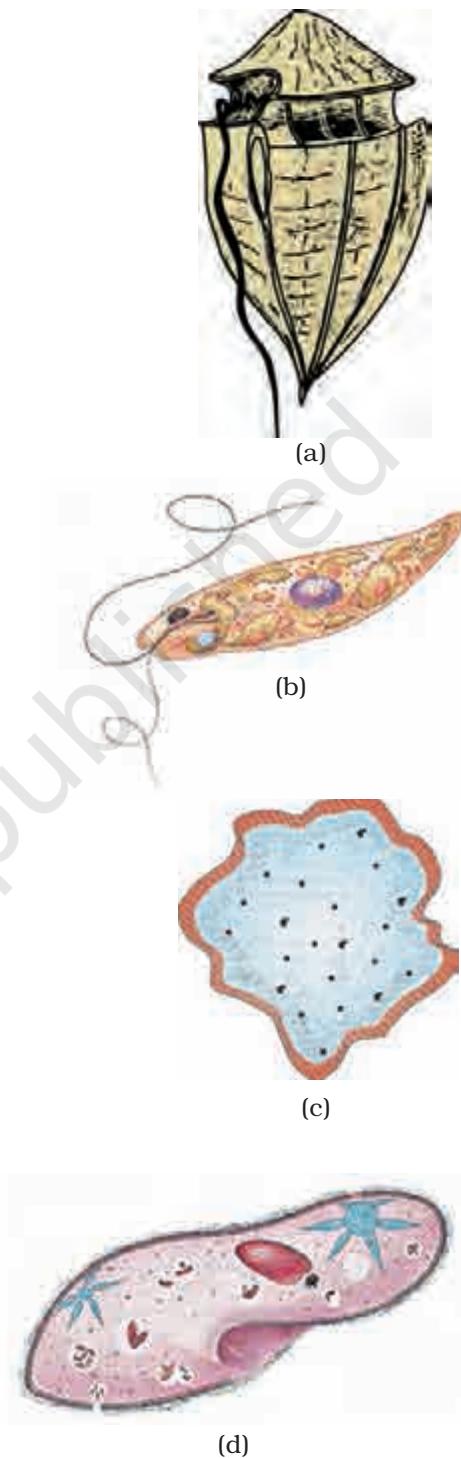


Figure 2.4 (a) *Dinoflagellates*
 (b) *Euglena*
 (c) *Slime mould*
 (d) *Paramoecium*

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 2.4b).

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.

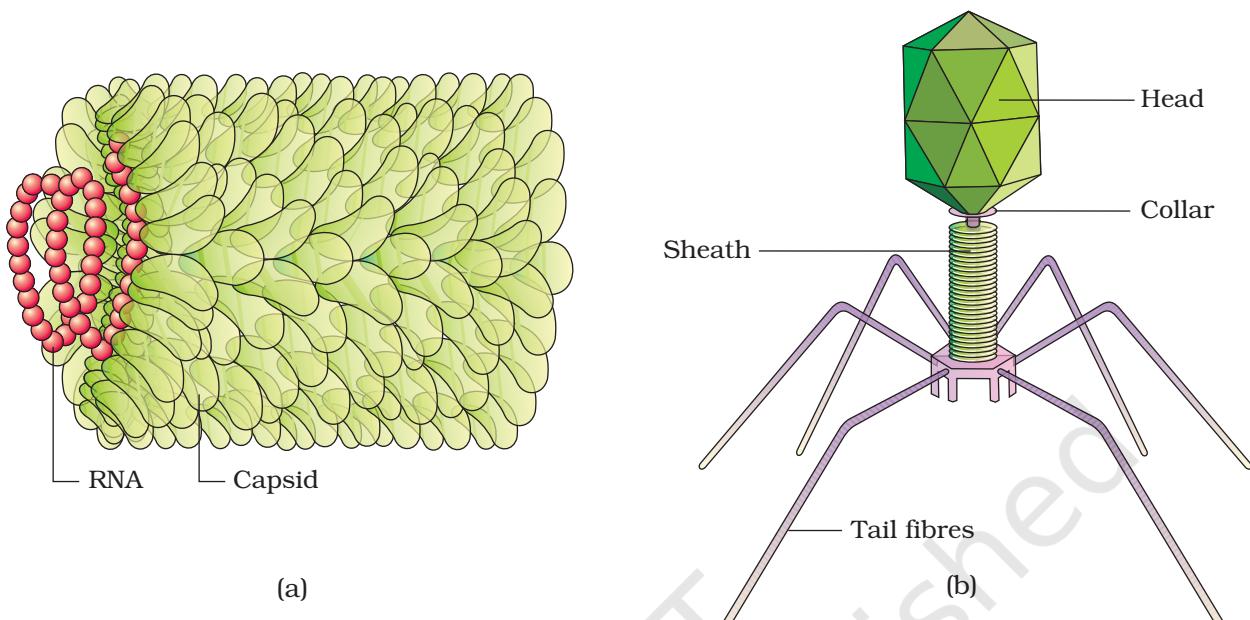


Figure 2.6 (a) Tobacco Mosaic Virus (TMV) (b) Bacteriophage

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?

The name virus that means venom or poisonous fluid was given by Pasteur. D.J. 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 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 consisted 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](#)
- [3.6 Plant Life Cycles and Alternation of Generations](#)

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 *Udorina* 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*.

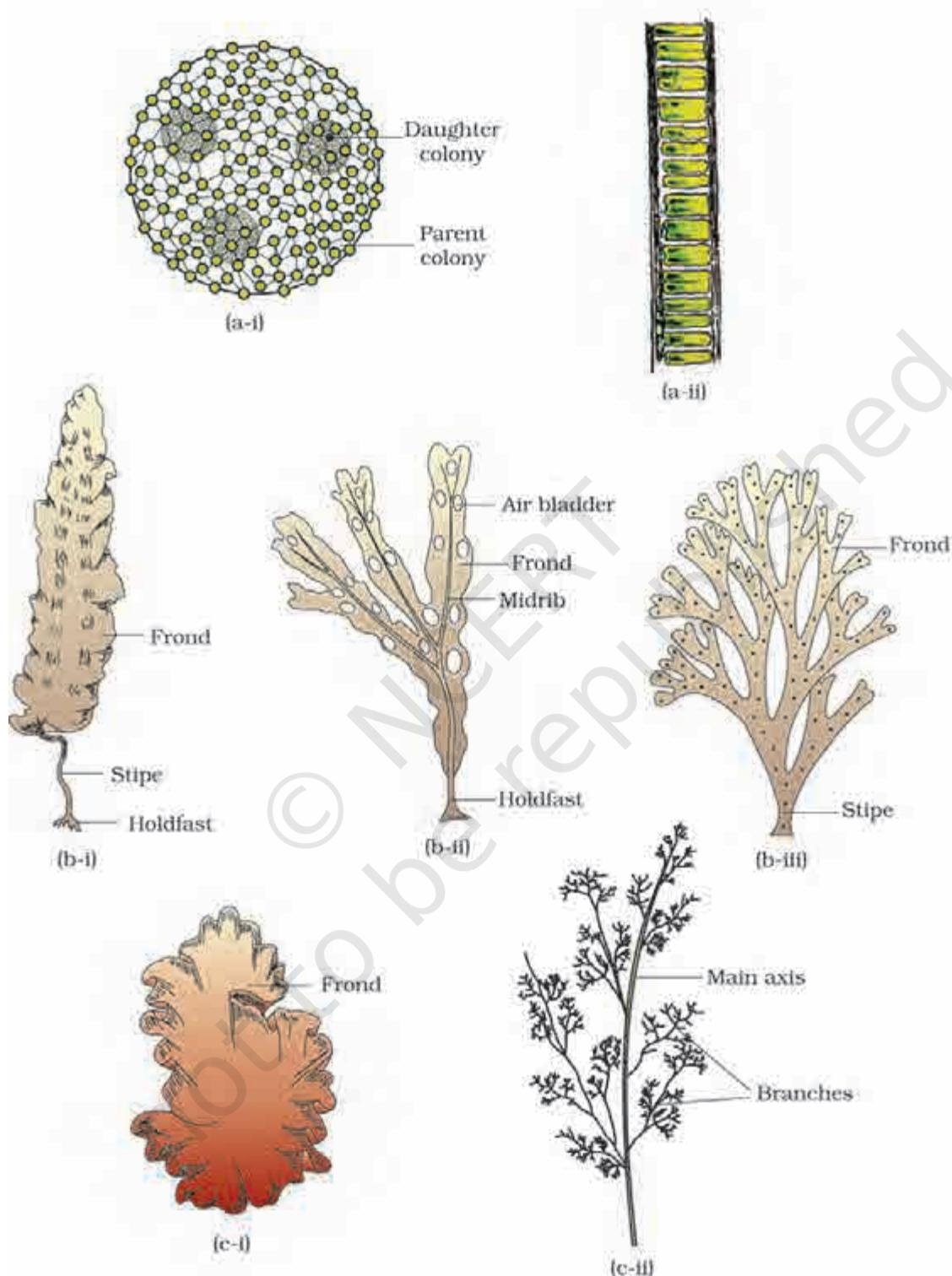


Figure 3.1 Algae : (a) Green algae (i) *Volvox* (ii) *Ulothrix*
 (b) Brown algae (i) *Laminaria* (ii) *Fucus* (iii) *Dictyota*
 (c) Red algae (i) *Porphyra* (ii) *Polysiphonia*

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).

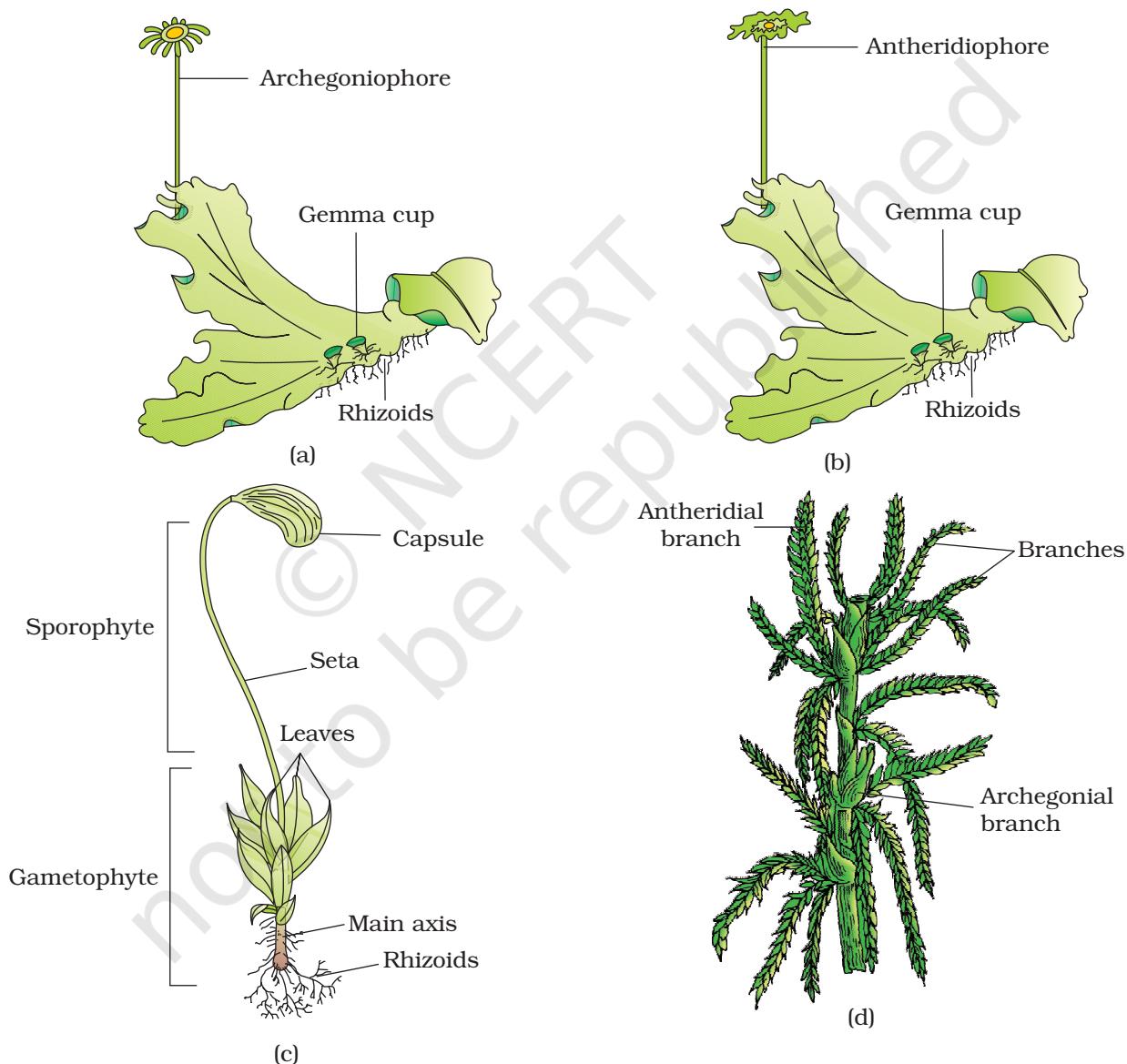


Figure 3.2 Bryophytes: A liverwort – *Marchantia* (a) Female thallus (b) Male thallus Mosses – (c) *Funaria*, gametophyte and sporophyte (d) *Sphagnum* gametophyte

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

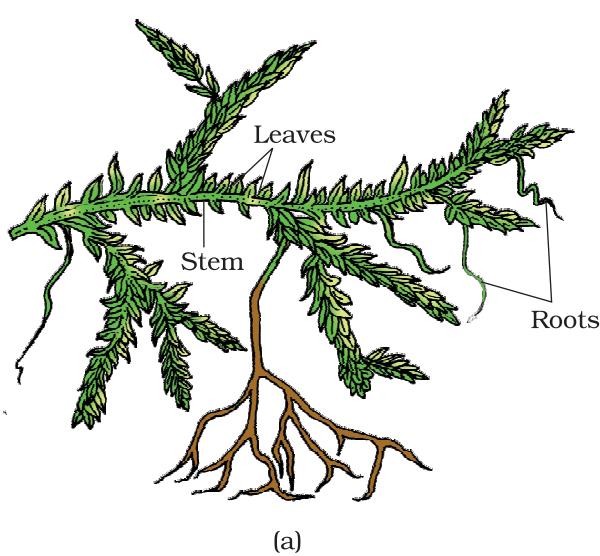
The predominant stage of the life cycle of a moss is the gametophyte which consists of two stages. The first stage is the **protonema** stage, which develops directly from a spore. It is a creeping, green, branched and frequently filamentous stage. The second stage is the **leafy stage**, which develops 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).

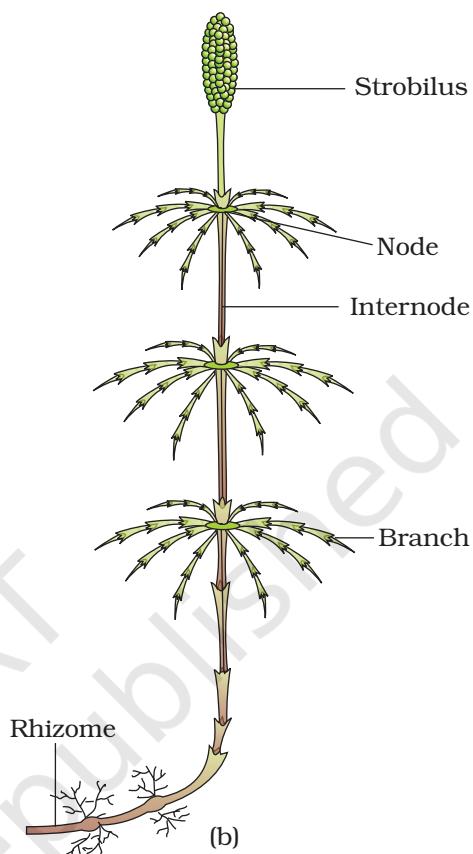
3.3 PTERIDOPHYTES

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.

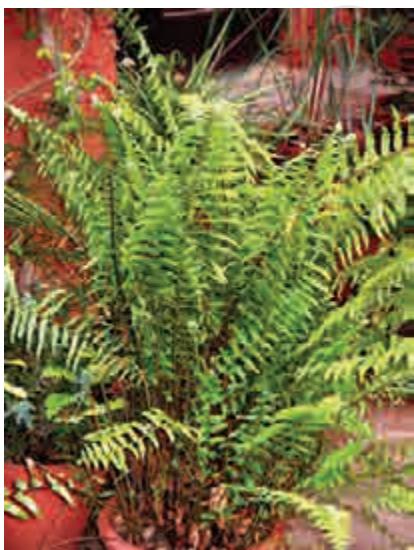
You may recall that in bryophytes the dominant phase in the life cycle is the gametophytic plant body. However, in pteridophytes, the main plant body is a sporophyte which is differentiated into true root, stem and leaves (Figure 3.3). These organs possess well-differentiated vascular tissues. The leaves 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.

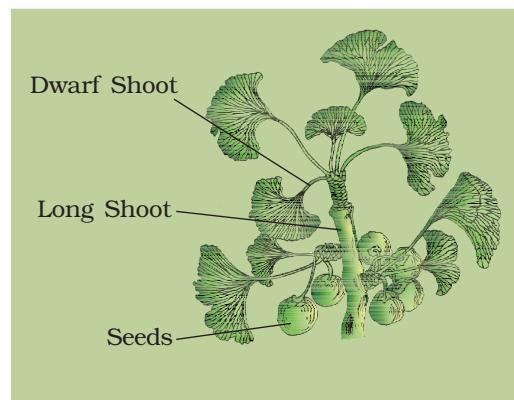
Unlike bryophytes and pteridophytes, in gymnosperms the male and the female gametophytes do not have an independent free-living existence. They remain within the sporangia retained on the sporophytes. The pollen grain is released from the microsporangium. They are carried in air currents and come in 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). The dicotyledons are characterised by seeds having two cotyledons, reticulate venations in leaves, and tetramerous or pentamerous flowers, i.e., having four or five members in each floral whorls. The monocotyledons on the other hand are characterised by single cotyledonous seeds, parallel venation in leaves, and trimerous flowers having three members in each floral whorls. The male sex organ in a flower is the stamen. Each stamen consists of a slender filament with an anther at the tip. Within the anthers, the pollen mother cell divide by meioses to produce microspores which matures into pollen grains. The female sex organ in a flower is the pistil. Pistil consists of an ovary at its base, a long slender style and stigma. Inside the ovary, ovules are present. Generally each ovule has a megasporangium that undergoes meiosis to form four haploid megasporangium. Three of them degenerate and one divide to form the embryo sac. Each embryo-sac has a three-celled **egg apparatus** – one **egg cell** and two **synergids**, three **antipodal** cells and two **polar nuclei**. The polar



(a)



(b)

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

nuclei eventually fuse to produce a diploid secondary nucleus. Pollen grain, after dispersal from the anthers, are carried by wind or various other agencies to the stigma of a pistil. This is termed as pollination. The pollen grains germinate on the stigma and the resulting pollen tubes grow through the tissues of stigma and style and reach the ovule. The pollen tubes enter the embryo-sac where two male gametes are discharged. One of the male gametes fuses with the egg cell (syngamy) to form a zygote. The other male gamete fuses with the diploid secondary nucleus to produce the triploid primary endosperm nucleus (PEN). Because of the occurrence of two fusions i.e., syngamy and triple fusion, this event is termed as **double fertilisation**, an event unique to angiosperms. The zygote develops into an embryo (with one or two cotyledons) and the PEN develops into endosperm which provides nourishment to the developing embryo. The synergids and antipodal cells degenerate after fertilisation. During these events the ovules develop into seeds and the ovaries develop into fruit. The life cycle of an angiosperm is shown in Figure 3.6.

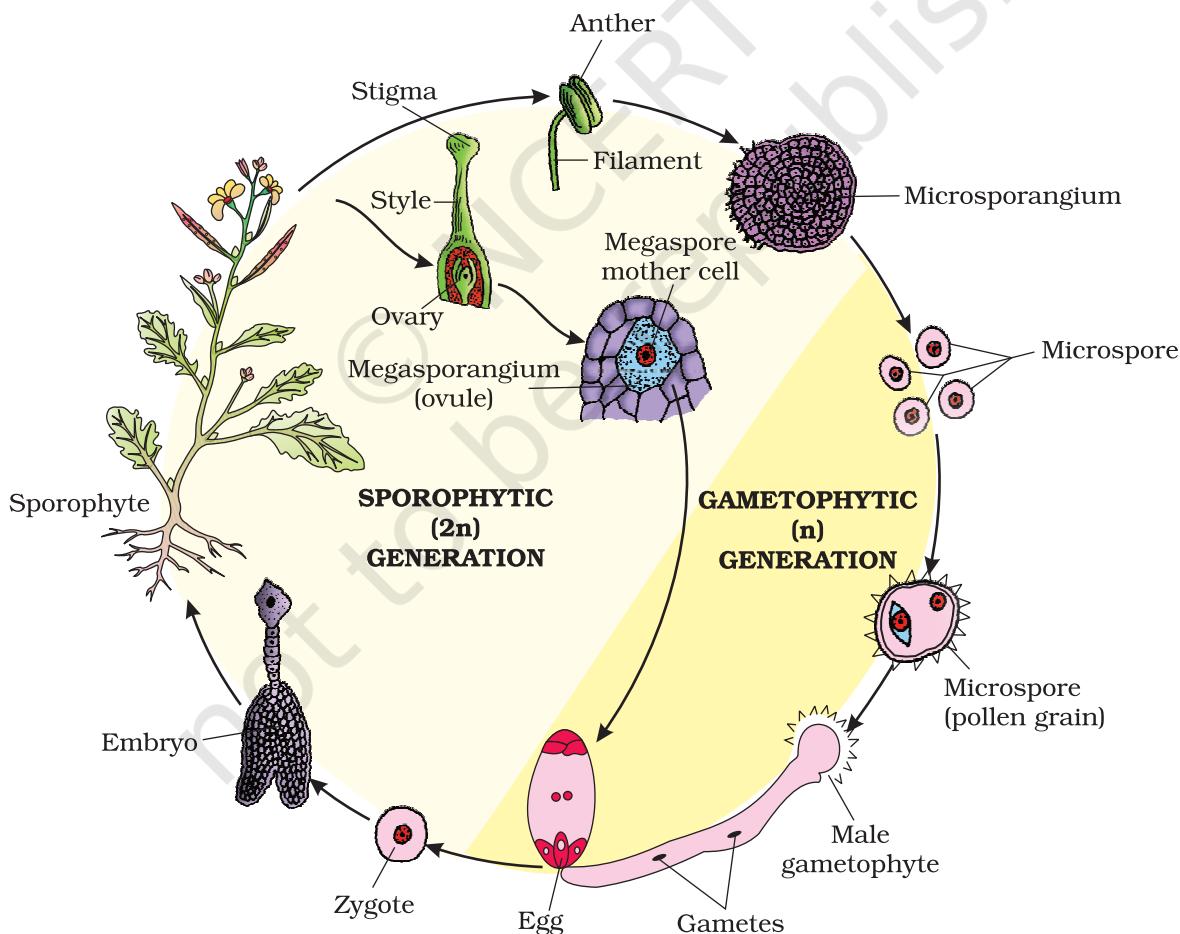


Figure 3.6 Life cycle of an angiosperm

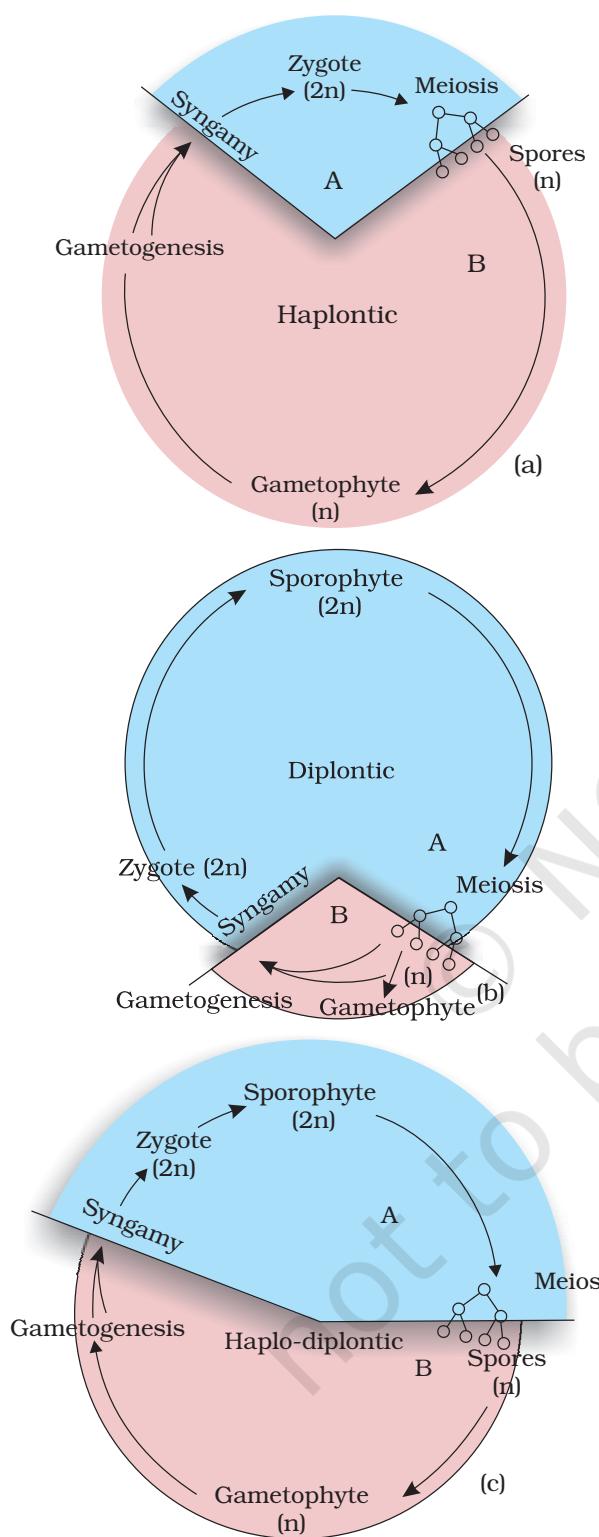


Figure 3.7 Life cycle patterns : (a) Haplontic (b) Diplontic (c) Haplo-diplontic

3.6 PLANT LIFE CYCLES AND ALTERNATION OF GENERATIONS

In plants, both haploid and diploid cells can divide by mitosis. This ability leads to the formation of different plant bodies - haploid and diploid. The haploid plant body produces gametes by mitosis. This plant body represents a gametophyte. Following fertilisation the zygote also divides by mitosis to produce a diploid sporophytic plant body. Haploid spores are produced by this plant body by meiosis. These in turn, divide by mitosis to form a haploid plant body once again. Thus, during the life cycle of any sexually reproducing plant, there is an alternation of generations between gamete producing haploid gametophyte and spore producing diploid sporophyte.

However, different plant groups, as well as individuals representing them, differ in the following patterns:

1. Sporophytic generation is represented only by the one-celled zygote. There are no free-living sporophytes. Meiosis in the zygote results in the formation of haploid spores. The haploid spores divide mitotically and form the gametophyte. The dominant, photosynthetic phase in such plants is the free-living gametophyte. This kind of life cycle is termed as **haplontic**. Many algae such as *Volvox*, *Spirogyra* and some species of *Chlamydomonas* represent this pattern (Figure 3.7 a).
2. On the other extreme, is the type wherein the diploid sporophyte is the dominant, photosynthetic, independent phase of the plant. The gametophytic phase is represented by the single to few-celled haploid gametophyte. This kind of life cycle is termed as **diplontic**. An alga, *Fucus sp.*, represents this pattern (Fig. 3.7b). In addition, all seed bearing plants i.e., gymnosperms and angiosperms, follow this pattern with some variations, wherein, the gametophytic phase is few to multi-celled.
3. Bryophytes and pteridophytes, interestingly, exhibit an intermediate condition (**Haplo-diplontic**); both phases are multicellular. However, they differ in their dominant phases.

A dominant, independent, photosynthetic, thalloid or erect phase is represented by a haploid gametophyte and it alternates with the short-lived multicellular sporophyte totally or partially dependent on the gametophyte for its anchorage and nutrition. All bryophytes represent this pattern.

The diploid sporophyte is represented by a dominant, independent, photosynthetic, vascular plant body. It alternates with multicellular, saprophytic/autotrophic, independent but short-lived haploid gametophyte. Such a pattern is known as haplo-diplontic life cycle. All pteridophytes exhibit this pattern (Figure 3.7 c).

Interestingly, while most algal genera are haplontic, some of them such as *Ectocarpus*, *Polysiphonia*, kelps are haplo-diplontic. *Fucus*, an alga is diplontic.

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 megasporangia 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.

In angiosperms, the male sex organs (stamen) and female sex organs (pistil) are borne in a flower. Each stamen consists of a filament and an anther. The anther produces pollen grains (male gametophyte) after meiosis. The pistil consists of an ovary enclosing one to many ovules. Within the ovule is the female gametophyte or embryo sac which contains the egg cell. The pollen tube enters the embryo-sac where two male gametes are discharged. One male gamete fuses with egg cell (syngamy) and other fuses with diploid secondary nucleus (triple fusion). This phenomenon of two fusions is called double fertilisation and is unique to angiosperms. The angiosperms are divided into two classes – the dicotyledons and the monocotyledons.

During the life cycle of any sexually reproducing plant, there is alternation of generations between gamete producing haploid gametophyte and spore producing diploid sporophyte. However, different plant groups as well as individuals may show different patterns of life cycles – haplontic, diplontic or intermediate.

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
- (iv) syngamy and triple fusion

10. How would you distinguish monocots from dicots?

11. 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

12. Describe the important characteristics of gymnosperms.