The biological world is enormously diverse. There has to be an approach that enables us to get an idea of a group of Organisms by studying a particular type. This calls for a systematic arrangement of organisms on the basis of their similarities and dissimilarities. Systematic arrangement of organisms on the basis of their relatedness is called taxonomy. As defined by Ernst Mayr, taxonomy is the theory and practice of classifying organisms. The study of taxonomy gives an idea of the range of diversity of organisms, and also throws light on their relatedness.

How classification helps: The aim of classification is to identify and arrange organisms in such a manner that they fall into natural groups. Organisms are classified on the basis of the most obvious characters. Thus, classification helps establish a hierarchy of groups of organisms on the basis of their common features. This is useful in the following ways:

1. It makes the systematic study of the wide variety of organisms easier.
2. It gives us a clear picture of all organisms and the way they are related to each other.
3. It provides a base for different branches of biology. For instance, it helps map the distribution of flora and fauna in different parts of the world—a subject known as biogeography. It is also useful in the study of ecology, which deals with the interrelation between organisms and their relation with the environment.
4. Taxonomy also provides the foundation for advancement in those branches of science which are directly useful to us, e.g., medicine and agriculture. Being able to identify a disease-causing organism or an agent which spreads it, for example, is always a help in finding ways of fighting against it.

Linnaeus: father of taxonomy: Carolus Linnaeus, a Swedish botanist, is considered the father of taxonomy. He formulated a method of naming organisms called the binomial system of nomenclature. In this system, each type of organism has two Latin names—one for its genus and the other for its species. Thus, all frogs have the genus name Rana and the Indian bullfrog has the species name tigrina, so the bullfrog is called Rana tigrina.

Linnaeus also introduced a sequence of groups of organisms, or a way of classifying them. All organisms were divided into kingdoms. The kingdoms were divided into phyla (singular: phylum), the phyla into classes and the classes into orders. Then came family, followed by genus and species. Individuals of a species bear the closest resemblance to each other. The species within a genus have many common features. The genera (plural of genus) of one family are more closely linked than those of another family, and so on. To sum up:

Organisms → Super kingdoms → Kingdoms → Phyla → Classes → Orders →Families →Genera → Species

Members of a species breed among themselves. The species is the most basic unit of classification. It is also the basic unit of evolution.

Basis of classification: Taxonomy deals with nomenclature, identification and classification of organisms. Nomenclature is naming the organisms. The correct name of an organism is determined following some scientific rules. This implies assigning an organism to a particular taxonomic group. Classification deals with the arrangement of organisms or group of organisms into categories according to a systematic plan. The categories used in classification are kingdom, phylum, class, order, family, genus and species. These living forms vary in shape, size, structure,

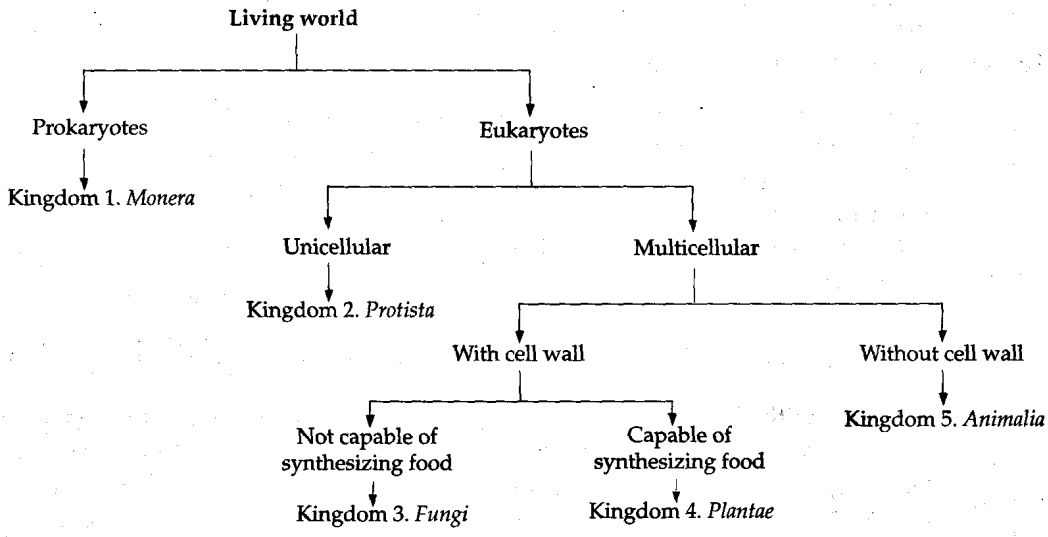
ABHYAS Academy, Behind Pragat Shiv Mandir, Near Govt. College, Nishat Cinema Road, Ambala Cantt.
Ph No. +91-171-2631595, 9416541198, e-Mail: anusethi1968@yahoo.com Website: www. abhyasonline.in

function, etc. The variations in their appearance, body design and behaviour form the basis of classification.

Taxonomic hierarchy: In taxonomic study an organism is given an appropriate place in a systematic framework of classification. The framework, by which taxonomic groups are arranged in a definite order from higher to lower categories, is called taxonomic hierarchy. In the animal and plant kingdom, the lowest category is species and the highest is kingdom. The grouping of organisms into these categories, i.e., species, genus, family, order, class and phylum is determined by their similar characters and their relationships.

Systems of classification and evolution: To begin with, Linnaeus (1758) divided all organisms into two kingdoms—plants (Plantae) and animals (Animalia). Plants and animals seemed so obviously different that this appeared to be a very logical way of classifying organisms. Plants can prepare their own food with the help of chlorophyll. Animals do not have chlorophyll, so they cannot manufacture food. Plant cells have a cell wall, while animal cells do not. A third kingdom called Protista was created by Ernst Haeckel (1866), a German zoologist. All unicellular animals were placed in this kingdom. Then two superkingdoms were created. One for prokaryotes, or unicellular organisms lacking a true nucleus. And the other for eukaryotes, or all organisms (unicellular and multicellular) with a true nucleus. The prefixes 'super' and 'sub' are often used to divide or join the groups (kingdom, phylum, etc.) under the system of classification we have already discussed. The superkingdoms Prokaryota include bacteria and cyanobacteria. It has only one kingdom under it. This kingdom of bacteria and cyanobacteria is called Monera. Cyanobacteria are prokaryotic like bacteria, but can photosynthesize like plants.

The creation of the kingdom "Monera" did not solve all the problems with classifying organisms. Fungi created the next problem. Like bacteria, they cannot photosynthesize, but they are eukaryotic. They could neither be placed in Monera, nor in Protista, which now includes photosynthesizing algae. A new kingdom was then created for fungi. Robert Whittaker (1969) is credited with the creation of the kingdoms Monera and Fungi.



In the chart above, the important characteristics of the five kingdoms are given in brief.

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Ph No. +91-171-2631595, 9416541198, e-Mail: anusethi1968@yahoo.com Website: www. abhyasonline.in

The five kingdoms of Monera, Protista, Fungi, Plantae and Animalia include all organisms except viruses. Viruses cannot really be called living organisms because they are noncellular. A virus is just a bit of DNA or RNA inside a covering of protein. The kingdom Monera falls under the superkingdom Prokaryota. The other four kingdoms fall under the superkingdom Eukaryota.

Classification depends on evolution: The classification of organisms is closely related to their evolution. Evolution refers to the process by which the early organisms on the earth diversified into various forms through a slow and continuous process. The older forms have given rise to the newer forms. But the newer forms are sufficiently different to be recognized as new types (species) which breed amongst their own members and not with the ancestral types. The newly formed species in turn may give rise to still newer forms. This results in the complexity of structure, i.e., the older organisms are simpler and the younger organisms are more complex. **Charles Darwin**, an English naturalist, first described the idea of evolution in his book 'The Origin of Species', published in 1859. According to him, most life forms that we see today have developed by an accumulation of changes in body design over a period of time through natural selection. These new forms are more complex than their ancestral forms.

Monera: This kingdom comprises of single-celled prokaryotic bacteria, filamentous actinomycetes and photosynthetic blue-green algae (cyanobacteria). Carl Woese (1977) divided Monera into Archaebacteria (primitive bacteria) and Eubacteria (true bacteria).

Bacteria: Bacteria are unicellular and generally occur singly. Some of them are found in groups. They are named according to their shapes. Rod-shaped bacteria are called bacilli (singular: bacillus), e.g., Bacillus anthracis, which causes the disease anthrax. Spherical bacteria are called cocci (singular: coccus), e.g., Streptococcus pneumoniae, which causes the disease pneumonia. Other types are spiral bacteria called spirilla and comma-shaped called vibrio.

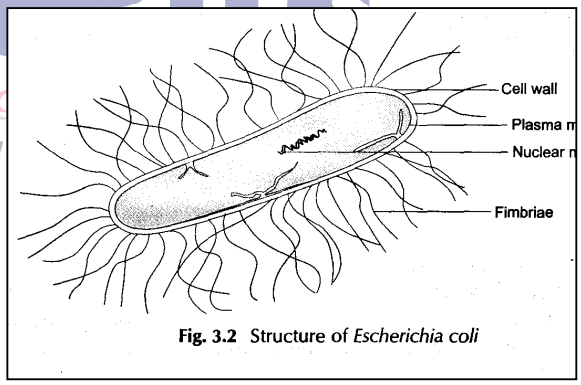
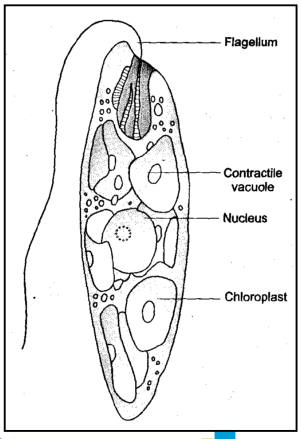


Fig. 3.2 Structure of *Escherichia coli*

Bacteria lack nuclear membrane. Therefore, a distinct nucleus and nucleolus are absent. Bacteria also lack membrane-bound organelles like endoplasmic reticulum, Golgi complex, mitochondria and plastids. Most bacteria lack chlorophyll, hence they are heterotrophic (saprophytic or parasitic). However, a few bacteria possess chlorophyll and are autotrophic. Remember that all parasitic bacteria do not cause diseases. There are many that live harmlessly in our intestine.



Protista: The members of this kingdom are mostly unicellular and eukaryotic. They are usually found in aquatic habitats. Some protists have hairlike cilia or whiplike flagella for their movements. They have

ABHYAS Academy, Behind Pragat Shiv Mandir, Near Govt. College, Nishat Cinema Road, Ambala Cantt.
Ph No. +91-171-2631595, 9416541198, e-Mail: anusethi1968@yahoo.com Website: www. abhyasonline.in

different modes of nutrition. Some members are autotrophic (can synthesize their own food), e.g., unicellular algae like Euglena, while others are heterotrophic (dependent on others for food). Heterotrophic members may be saprophytic (living on dead matter) or parasitic (living on other organisms). On the basis of their modes of nutrition, the protists are grouped as photosynthetic algae (e.g., diatoms), decomposers (e.g., slime moulds), and predators (e.g., protozoans). Protozoans of the genus Amoeba use pseudopodia, or cytoplasmic extensions, for locomotion and ingestion of food.

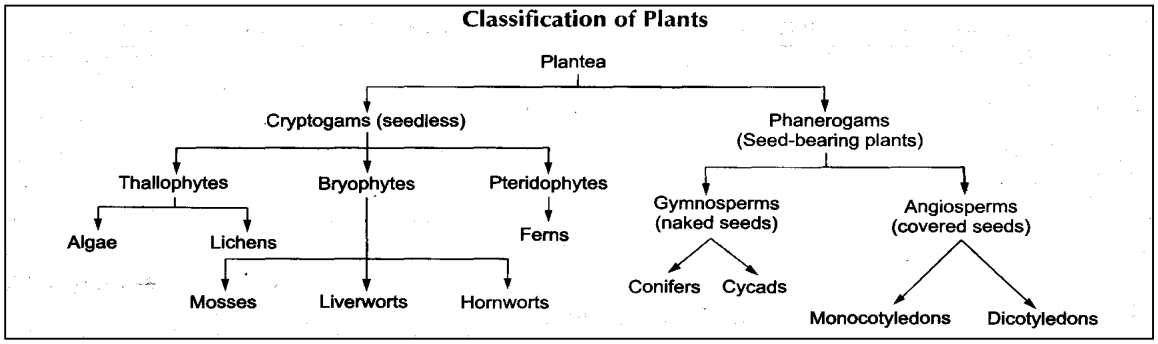
Fungi: Fungi are multicellular organisms whose mode of nutrition is saprotrophic. In other words, they absorb nutrients from dead plant and animal matter, excreta, etc. They release digestive enzymes into dead and decaying organic matter, and then absorb the nutrients present in them in the form of a digested solution. Some fungi are parasitic and some even cause diseases. Ringworm is a skin infection caused by a fungus, while smut is a fungal crop disease. Some fungi, are mutualistic or symbiotic. They absorb nutrients from their partners and help them too, e.g., certain fungi associated with algae.

There are many types of fungi. Moulds, which grow on bread, fruit, etc., and mildews which cause plant diseases, are fungi. Yeast and Penicillium (from which we get penicillin) are useful fungi. Mushrooms too are fungi. Many fungi form a network of tubes which are called hyphae. The network is called mycelium. Fungi reproduce sexually and asexually. Moulds reproduce by both these modes. Yeasts mostly reproduce asexually, though some reproduce sexually too. In mushrooms, sexual reproduction occurs by the formation of spores on club-shaped structures called basidia.

Plantae: This kingdom includes all plants except some algae like diatoms and members of Monera, Protista and Fungi. These multicellular eukaryotes are autotrophic and have chlorophyll pigments to synthesize food. They include red, brown and green algae, mosses, ferns, gymnosperms and flowering plants. Unlike the members of other kingdoms they have rigid cellulose cell wall. We will discuss this kingdom in detail later in this chapter.

Animalia: This kingdom includes all animals except the protozoans, which have been transferred to the kingdom Protista. The members of this kingdom are multicellular, eukaryotic and without cell wall. They show heterotrophic mode of nutrition. This kingdom will also be dealt in detail later in this chapter.

Plantae or plant kingdom: The kingdom of plants (kingdom Plantae) is divided into two subkingdoms—Cryptogamae and Phanerogamae. Cryptogams are plants



which do not have seeds (seedless plants). The lower cryptogams do not have true

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stems, roots or leaves. They do not have vascular systems either. Higher cryptogams, however, do have vascular systems. Phanerogams are higher plants which have seeds. They are also called seed plants. They have true stems, roots, leaves and vascular systems. The subkingdom Cryptogamae has the three divisions Thallophyta, Bryophyta and Pteridophyta. And the subkingdom Phanerogamae is divided into Gymnospermae and Angiospermae. Gymnosperms and angiosperms are grouped together under Spermatophyta which includes all seed-bearing plants.

Thallophyta: Thallophytes have a body which is not differentiated into stem, root and leaves. This kind of undifferentiated body is called thallus, hence the name thallophytes. They do not have a vascular system either. Algae and lichens are included in thallophytes.

Algae: Algae are simple aquatic organisms which are capable of photosynthesis. Some algae, like Chlamydomonas, are unicellular. Some form colonies, while others, like Spirogyra, form filaments. All algae are not green, though they all

Algae	Fungi
All algae have chlorophyll pigments.	Fungi do not have the chlorophyll pigment.
Algae are autotrophic, i.e., they synthesize food through photosynthesis.	Fungi are heterotrophic, i.e., they cannot synthesize food.
Thallus, or the plant body, is unicellular, colonial and filamentous.	Thallus is multicellular and composed of microscopic threads or hyphae.
Food is stored in the form of starch.	Food is stored in the form of glycogen.
Cell wall is mainly made up of cellulose.	Cell wall is mainly composed of chitin.

photosynthesize. Chlamydomonas and Spirogyra are green algae and they live in freshwater. There are marine green algae too. Brown algae are marine and the most complex. Gel-forming substances like agar are extracted from red algae. Red algae are mostly marine. Golden algae live in freshwater.

Lichens: Lichens are a symbiotic association of fungi and algae. Remember that particular lichen is an association of a specific fungus and a specific alga. Both benefit from each other. They grow on rocks, stems of trees, old walls and so on, and may be grey-green or brightly coloured. The fungus forms most of the plant body, absorbs water and nutrients from the surroundings, and provides these to its partner. The alga manufactures food from the raw materials and supplies it to the fungus.

Bryophyta: Bryophytes are simple terrestrial (land) plants. In fact, they were pioneers in establishing the plants on land. They are called amphibians of the plant kingdom. They do not have proper roots and leaves. However, they are green, with stems and leaflike structures which are capable of photosynthesis. They are nonvascular plants, i.e., they do not have xylem and phloem. They are covered by a waxy cuticle which helps them retain water. Mosses, liverworts and hornworts are the three groups of bryophytes.

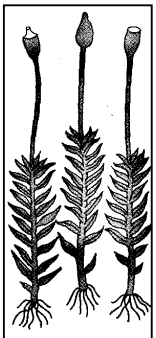
Fig. 3.8 Mosses

Mosses: Mosses grow very close together, forming a velvety, matlike

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cover over soil or wherever (substratum) they grow. They play a great role in soil conservation by holding soil particles together and preventing erosion by rain.

Liverworts: These are very small plants in which the plant body, known as the thallus, is not differentiated into stems and leaves. It has a lobed appearance.

Hornworts: Hornworts are like liverworts in almost all respects. However, they have longer, hornlike reproductive bodies.

Pteridophyta: These are the oldest vascular plants, or plants which have vascular tissue. Their bodies are differentiated into an aerial shoot system and an underground root system.

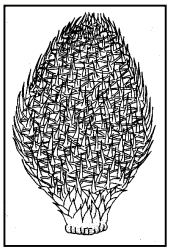
Bryophyta	Pteridophyta
Bryophytes do not have proper roots and leaves.	Pteridophytes have an underground root system and an aerial shoot system.
They do not have vascular tissues (xylem and phloem).	They possess vascular tissues.
They are photosynthetic due to green leaflike structures.	They have large photosynthetic leaves that are divided into leaflets.

The reproductive organs are multicellular. The pollen produced by these plants is carried by the wind and an embryo develops after fertilization. These plants do not produce seeds, or are seedless plants.

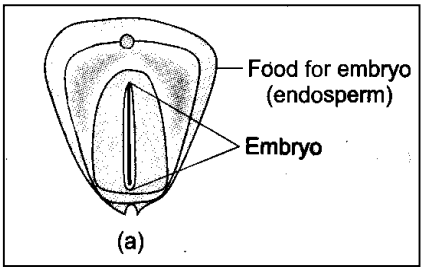
All ferns fall under this group. They are the most developed seedless plants. They have large leaves which are divided into leaflets. The young frond (leaf) is coiled at the tip. As it grows, the tip uncoils.

The reproductive organs in the members of cryptogams (thallophyta, bryophyta and pteridophyta) are inconspicuous or hidden. They produce naked embryos after fertilization (union of male gamete with female gamete) that is called spores.

In the case of phanerogams (gymnosperms and angiosperms), seeds are produced after fertilization. They contain embryo along with stored food. The stored food provides nourishment to the developing embryo.



Gymnosperms: As you have already learnt, phanerogams or seed-bearing plants are of two types— gymnosperms and angiosperms. Gymnosperms bear naked seeds, or seeds which are not enclosed in a fruit. The pollen produced by these plants is dispersed by wind, insect, etc. The zygote, or fertilized egg, develops into an embryo. The embryo and the food it uses to grow are covered by a protective seed coat. In the course of evolution, the gymnosperms appeared before the angiosperms. All conifers (evergreen plants) like pines, firs, cedars and redwoods are gymnosperms. Conifers are among the largest trees and constitute the major source of pulp and paper. Cycads (Cycas) are palmlike gymnosperms, but unlike palms, they bear naked seeds on the scales of cones (Figure 3.10). Gymnosperms do not have flowers.



Angiosperms: Angiosperms, or flowering plants, bear seeds enclosed in a fruit (or the ovules are inside the ovary). They are the most diverse of all plant groups. Their diversity and evolution have been influenced by animals. Angiosperms are divided into monocotyledons and dicotyledons, on the basis of the kind of seeds they bear.

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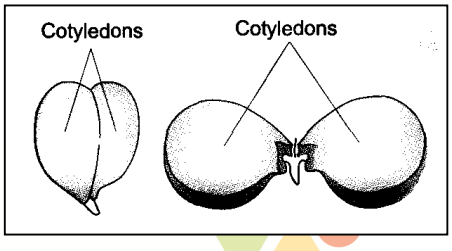
Comparison between Gymnosperm and Angiosperm	
[illegible]	[illegible]
Gymnosperms bear naked seeds, i.e., not enclosed in a fruit.	Angiosperms bear seeds enclosed in a fruit.
They do not have flowers.	They produce flowers.
Vessels are absent in xylem tissue.	All the elements of xylem, i.e., vessels, tracheids, fibres and parenchyma are present.
Companion cells are absent in the phloem tissue.	Companion cells are present.

Monocotyledons: Monocotyledons bear seeds which have a single cotyledon or seed leaf. The veins on their leaves are parallel to each other. Their vascular bundles (xylem and phloem) are arranged in a complex manner. Their root system, called fibrous root system, consists of a network of roots, with no distinct main root. Palms, bamboos, grasses, sugar cane, rice, wheat and corn are some monocotyledons.

Dicotyledons: The seeds of dicotyledons like grams, peas, beans, sunflower and rose have two cotyledons. The veins on their leaves are reticulate, or like a network. Their vascular bundles are arranged in a ring. Their root system, called tap root system, consists of a main tap root with smaller branching root.



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