# Ch 1 The Living World

How wonderful is the living world ! The wide range of living types is amazing. The extraordinary habitats in which we find living organisms, be it cold mountains, deciduous forests, oceans, fresh water lakes, deserts or hot springs, leave us speechless. The beauty of a galloping horse, of the migrating birds, the valley of flowers or the attacking shark evokes awe and a deep sense of wonder. The ecological conflict and cooperation among members of a population and among populations of a community or even the molecular traffic inside a cell make us deeply reflect on – what indeed is life? This question has two implicit questions within it. The first is a technical one and seeks answer to what living is as opposed to the non-living, and the second is a philosophical one, and seeks answer to what the purpose of life is. As scientists, we shall not attempt answering the second question. We will try to reflect on – what is living? 1.1 DIVERSITY IN THE LIVING WORLD If you look around you will see a large variety of living organisms, be it potted plants, insects, birds, your pets or other animals and plants. There are also several organisms that you cannot see with your naked eye but they are all around you. If you were to increase the area that you make observations in, the range and variety of organisms that you see would increase. Obviously, if you were to visit a dense forest, you would probably see a much greater number and kinds of living organisms in it. Each different kind of plant, animal or organism that you see, represents a species. The number of species that are known and described range between 1.7-1.8 million. This refers to biodiversity or the number and THE LIVING WORLD CHAPTER 1 1.1 Diversity in the Living World 1.2 Taxonomic Categories 2024-25 4 BIOLOGY 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. 2024-25 THE LIVING WORLD 5 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 2024-25 6 BIOLOGY used Systema Naturae as the title of his publication. The scope of systematics was later enlarged to include identification, nomenclature and classification. Systematics takes into account evolutionary relationships between organisms. 1.2 TAXONOMIC CATEGORIES Classification is not a single step process but involves hierarchy of steps in which each step represents a rank or category. Since the category is a part of overall taxonomic arrangement, it is called the taxonomic category and all categories together constitute the taxonomic hierarchy. Each category, referred to as a unit of classification, in fact, represents a rank and is commonly termed as taxon (pl.: taxa). Taxonomic categories and hierarchy can be illustrated by an example. Insects represent a group of organisms sharing common features like three pairs of jointed legs. It means insects are recognisable concrete objects which can be classified, and thus were given a rank or category. Can you name other such groups of organisms? Remember, groups represent category. Category further denotes rank. Each rank or taxon, in fact, represents a unit of classification. These taxonomic groups/ categories are distinct biological entities and not merely morphological aggregates. Taxonomical studies of all known organisms have led to the development of common categories such as kingdom, phylum or division (for plants), class, order, family, genus and species. All organisms, including those in the plant and animal kingdoms have species as the lowest category. Now the question you may ask is, how to place an organism in various categories? The basic requirement is the knowledge of characters of an individual or group of organisms. This helps in identifying similarities and dissimilarities among the individuals of the same kind of organisms as well as of other kinds of organisms. 1.2.1 Species Taxonomic studies consider a group of individual organisms with fundamental similarities as a species. One should be able to distinguish one species from the other closely related species based on the distinct morphological differences. Let us consider Mangifera indica, Solanum tuberosum (potato) and Panthera leo (lion). All the three names, indica, tuberosum and leo, represent the specific epithets, while the first words Mangifera, Solanum and Panthera are genera and represents another higher level of taxon or category. Each genus may have one or more than one specific epithets representing different organisms, but having morphological similarities. For example, Panthera has another specific epithet called tigris and Solanum includes species like nigrum and 2024-25 THE LIVING WORLD 7 melongena. Human beings belong to the species sapiens which is grouped in the genus Homo. The scientific name thus, for human being, is written as Homo sapiens. 1.2.2 Genus Genus comprises a group of related species which has more characters in common in comparison to species of other genera. We can say that genera are aggregates of closely related species. For example, potato and brinjal are two different species but both belong to the genus Solanum. Lion (Panthera leo), leopard (P. pardus) and tiger (P. tigris) with several common features, are all species of the genus Panthera. This genus differs from another genus Felis which includes cats. 1.2.3 Family The next category, Family, has a group of related genera with still less number of similarities as compared to genus and species. Families are characterised on the basis of both vegetative and reproductive features of plant species. Among plants for example, three different genera Solanum, Petunia and Datura are placed in the family Solanaceae. Among animals for example, genus Panthera, comprising lion, tiger, leopard is put along with genus, Felis (cats) in the family Felidae. Similarly, if you observe the features of a cat and a dog, you will find some similarities and some differences as well. They are separated into two different families – Felidae and Canidae, respectively. 1.2.4 Order You have seen earlier that categories like species, genus and families are based on a number of similar characters. Generally, order and other higher taxonomic categories are identified based on the aggregates of characters. Order being a higher category, is the assemblage of families which exhibit a few similar characters. The similar characters are less in number as compared to different genera included in a family. Plant families like Convolvulaceae, Solanaceae are included in the order Polymoniales mainly based on the floral characters. The animal order, Carnivora, includes families like Felidae and Canidae. 1.2.5 Class This category includes related orders. For example, order Primata comprising monkey, gorilla and gibbon is placed in class Mammalia along with order Carnivora that includes animals like tiger, cat and dog. Class Mammalia has other orders also. 1.2.6 Phylum Classes comprising animals like fishes, amphibians, reptiles, birds along with mammals constitute the next higher category called Phylum. All 2024-25 8 BIOLOGY these, based on the common features like presence of notochord and dorsal hollow neural system, are included in phylum Chordata. In case of plants, classes with a few similar characters are assigned to a higher category called Division. 1.2.7 Kingdom All animals belonging to various phyla are assigned to the highest category called Kingdom Animalia in the classification system of animals. The Kingdom Plantae, on the other hand, is distinct, and comprises all plants from various divisions. Henceforth, we will refer to these two groups as animal and plant kingdoms. The taxonomic categories from species to kingdom have been shown in ascending order starting with species in Figure 1.1. These are broad categories. However, taxonomists have also developed sub-categories in this hierarchy to facilitate more sound and scientific placement of various taxa. Look at the hierarchy in Figure 1.1. Can you recall the basis of arrangement? Say, for example, as we go higher from species to kingdom, the number of common characteristics goes on decreasing. Lower the taxa, more are the characteristics that the members within the taxon share. Higher the category, greater is the difficulty of determining the relationship to other taxa at the same level. Hence, the problem of classification becomes more complex. Table 1.1 indicates the taxonomic categories to which some common organisms like housefly, man, mango and wheat belong. Figure 1.1 Taxonomic categories showing hierarchial arrangement in ascending order Common Biological Genus Family Order Class Phylum/ Name Name Division Man Homo sapiens Homo Hominidae Primata Mammalia Chordata Housefly Musca Musca Muscidae Diptera Insecta Arthropoda domestica Mango Mangifera Mangifera Anacardiaceae Sapindales Dicotyledonae Angiospermae indica Wheat Triticum Triticum Poaceae Poales Monocotyledonae Angiospermae

# Ch 2 Biological Classification

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. BIOLOGICAL CLASSIFICATION CHAPTER 2 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 2024-25 BIOLOGICAL CLASSIFICATION 11 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 Five Kingdoms Characters Cell type Cell wall Nuclear membrane Body organisation Mode of nutrition Monera Prokaryotic Noncellulosic (Polysaccharide + amino acid) Absent Cellular Autotrophic (chemosynthetic and photosynthetic) and Heterotrophic (saprophytic/parasitic) Protista Eukaryotic Present in some Present Cellular Autotrophic (Photosynthetic) and Heterotrophic Fungi Eukaryotic Present with chitin Present Multiceullar/ loose tissue Heterotrophic (Saprophytic/ Parasitic) Plantae Eukaryotic Present (cellulose) Present Tissue/ organ Autotrophic (Photosynthetic) Animalia Eukaryotic Absent Present Tissue/organ/ organ system Heterotrophic (Holoz o ic/ Saprophytic etc.) TABLE 2.1 Characteristics of the Five Kingdoms 2024-25 12 BIOLOGY in their walls while the green plants had a cellulosic cell wall. When such characteristics were considered, the fungi were placed in a separate kingdom – Kingdom Fungi. All prokaryotic organisms were grouped together under Kingdom Monera and the unicellular eukaryotic organisms were placed in Kingdom Protista. Kingdom Protista has brought together Chlamydomonas, Chlorella (earlier placed in Algae within Plants and both having cell walls) with Paramoecium and Amoeba (which were earlier placed in the animal kingdom which lack cell wall). It has put together organisms which, in earlier classifications, were placed in different kingdoms. This happened because the criteria for classification changed. This kind of changes will take place in future too depending on the improvement in our understanding of characteristics and evolutionary relationships. Over time, an attempt has been made to evolve a classification system which reflects not only the morphological, physiological and reproductive similarities, but is also phylogenetic, i.e., is based on evolutionary relationships. In this chapter we will study characteristics of Kingdoms Monera, Protista and Fungi of the Whittaker system of classification. The Kingdoms Plantae and Animalia, commonly referred to as plant and animal kingdoms, respectively, will be dealt separately in chapters 3 and 4. Spore Flagellum Cocci Bacilli Spirilla Vibrio Figure 2.1 Bacteria of different shapes 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). 2024-25 BIOLOGICAL CLASSIFICATION 13 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. Figure 2.2 A filamentous blue-green algae – Nostoc 2.1.2 Eubacteria There are thousands of different eubacteria or ‘true bacteria’. They are characterised by the presence of a rigid cell wall, and if motile, a flagellum. The cyanobacteria (also referred to as blue-green algae) have chlorophyll a similar to green plants and are photosynthetic autotrophs (Figure 2.2). The cyanobacteria are unicellular, colonial or filamentous, freshwater/marine or terrestrial algae. The colonies are generally surrounded by gelatinous sheath. They often form blooms in polluted water bodies. Some of these organisms can fix atmospheric nitrogen in specialised cells called heterocysts, e.g., Nostoc and Anabaena. Chemosynthetic autotrophic bacteria oxidise various inorganic substances such as nitrates, nitrites and ammonia and use the released energy for their ATP production. They play a great role in recycling nutrients like nitrogen, phosphorous, iron and sulphur. Heterotrophic bacteria are most abundant in nature. The majority are important decomposers. Many of them have a significant impact on human affairs. They are helpful in making curd from milk, production of antibiotics, fixing nitrogen in legume 2024-25 14 BIOLOGY 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. Figure 2.3 A dividing bacterium 2024-25 BIOLOGICAL CLASSIFICATION 15 2.2.2 Dinoflagellates These organisms are mostly marine and photosynthetic. They appear yellow, green, brown, blue or red depending on the main pigments present in their cells. The cell wall has stiff cellulose plates on the outer surface. Most of them have two flagella; one lies longitudinally and the other transversely in a furrow between the wall plates. Very often, red dinoflagellates (Example: Gonyaulax) undergo such rapid multiplication that they make the sea appear red (red tides). Toxins released by such large numbers may even kill other marine animals such as fishes. 2.2.3 Euglenoids Majority of them are fresh water organisms found in stagnant water. Instead of a cell wall, they have a protein rich layer called pellicle which makes their body flexible. They have two flagella, a short and a long one. Though they are photosynthetic in the presence of sunlight, when deprived of sunlight they behave like heterotrophs by predating on other smaller organisms. Interestingly, the pigments of euglenoids are identical to those present in higher plants. Example: Euglena (Figure 2.4b). 2.2.4 Slime Moulds Slime moulds are saprophytic protists. The body moves along decaying twigs and leaves engulfing organic material. Under suitable conditions, they form an aggregation called plasmodium which may grow and spread over several feet. During unfavourable conditions, the plasmodium differentiates and forms fruiting bodies bearing spores at their tips. The spores possess true walls. They are extremely resistant and survive for many years, even under adverse conditions. The spores are dispersed by air currents. 2.2.5 Protozoans All protozoans are heterotrophs and live as predators or parasites. They are believed to be primitive relatives of animals. There are four major groups of protozoans. Amoeboid protozoans: These organisms live in fresh water, sea water or moist soil. They move and capture Figure 2.4 (a) Dinoflagellates (b) Euglena (c) Slime mould (d) Paramoecium (d) (a) (c) (b) 2024-25 16 BIOLOGY 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 diaseases such as sleeping sickness. Example: Trypanosoma. Ciliated protozoans: These are aquatic, actively moving organisms because of the presence of thousands of cilia. They have a cavity (gullet) that opens to the outside of the cell surface. The coordinated movement of rows of cilia causes the water laden with food to be steered into the gullet. Example: Paramoecium (Figure 2.4d). Sporozoans: This includes diverse organisms that have an infectious spore-like stage in their life cycle. The most notorious is Plasmodium (malarial parasite) which causes malaria, a disease which has a staggering effect on human population. 2.3 KINGDOM FUNGI The fungi constitute a unique kingdom of heterotrophic organisms. They show a great diversity in morphology and habitat. You must have seen fungi on a moist bread and rotten fruits. The common mushroom you eat and toadstools are also fungi. White spots seen on mustard leaves are due to a parasitic fungus. Some unicellular fungi, e.g., yeast are used to make bread and beer. Other fungi cause diseases in plants and animals; wheat rust-causing Puccinia is an important example. Some are the source of antibiotics, e.g., Penicillium. Fungi are cosmopolitan and occur in air, water, soil and on animals and plants. They prefer to grow in warm and humid places. Have you ever wondered why we keep food in the refrigerator ? Yes, it is to prevent food from going bad due to bacterial or fungal infections. With the exception of yeasts which are unicellular, fungi are filamentous. Their bodies consist of long, slender thread-like structures called hyphae. The network of hyphae is known as mycelium. Some hyphae are continuous tubes filled with multinucleated cytoplasm – these are called coenocytic hyphae. Others have septae or cross walls in their hyphae. The cell walls of fungi are composed of chitin and polysaccharides. Most fungi are heterotrophic and absorb soluble organic matter from dead substrates and hence are called saprophytes. Those that depend on living plants and animals are called parasites. They can also live as symbionts – in association with algae as lichens and with roots of higher plants as mycorrhiza. Reproduction in fungi can take place by vegetative means – fragmentation, fission and budding. Asexual reproduction is by spores 2024-25 BIOLOGICAL CLASSIFICATION 17 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 zygospore 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 rarelyunicellular, e.g., yeast (Saccharomyces). They are saprophytic, decomposers, parasitic or coprophilous (growing on dung). Mycelium Figure 2.5 Fungi: (a) Mucor (b) Aspergillus (c) Agaricus (c) (a) (b) 2024-25 18 BIOLOGY 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 asci (singular ascus). These asci 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 dueteromycetes 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. 2024-25 BIOLOGICAL CLASSIFICATION 19 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. 2024-25 20 BIOLOGY Once they infect a cell they take over the machinery of the host cell to replicate themselves, killing the host. Would you call viruses living or non-living? Virus means venom or poisonous fluid. Dmitri Ivanowsky (1892) recognised certain microbes as causal organism of the mosaic disease of tobacco (Figure 2.6a). These were found to be smaller than bacteria because they passed through bacteria-proof filters. M.W. Beijerinek (1898) demonstrated that the extract of the infected plants of tobacco could cause infection in healthy plants and named the new pathogen “virus” and called the fluid as Contagium vivum fluidum (infectious living fluid). W.M. Stanley (1935) showed that viruses could be crystallised and crystals consist largely of proteins. They are inert outside their specific host cell. Viruses are obligate parasites. In addition to proteins, viruses also contain genetic material, that could be either RNA or DNA. No virus contains both RNA and DNA. A virus is a nucleoprotein and the genetic material is infectious. In general, viruses that infect plants have single stranded RNA and viruses that infect animals have either single or double stranded RNA or double stranded DNA. Bacterial viruses or bacteriophages (viruses that infect the bacteria) are usually double stranded DNA viruses (Figure 2.6b). The protein coat called capsid made of small subunits called capsomeres, protects the nucleic acid. These capsomeres are arranged in helical or polyhedral geometric forms. Viruses cause diseases like mumps, small pox, herpes and influenza. AIDS in humans is also caused by a virus. In plants, the symptoms can be mosaic formation, leaf rolling and curling, yellowing and vein clearing, dwarfing and stunted growth. RNA Capsid (a) Sheath Head Tail fibres Collar (b) Figure 2.6 (a) Tobacco Mosaic Virus (TMV) (b) Bacteriophage 2024-25 BIOLOGICAL CLASSIFICATION 21 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. Viroids : In 1971, T.O. Diener discovered a new infectious agent that was smaller than viruses and caused potato spindle tuber disease. It was found to be a free RNA; it lacked the protein coat that is found in viruses, hence the name viroid. The RNA of the viroid was of low molecular weight. Prions : In modern medicine certain infectious neurological diseases were found to be transmitted by an agent consisting of abnormally folded protein. The agent was similar in size to viruses. These agents were called prions. The most notable diseases caused by prions are bovine spongiform encephalopathy (BSE) commonly called mad cow disease in cattle and its analogous variant Cr–Jacob disease (CJD) in humans. Lichens : Lichens are symbiotic associations i.e. mutually useful associations, between algae and fungi. The algal component is known as phycobiont and fungal component as mycobiont, which are autotrophic and heterotrophic, respectively. Algae prepare food for fungi and fungi provide shelter and absorb mineral nutrients and water for its partner. So close is their association that if one saw a lichen in nature one would never imagine that they had two different organisms within them. Lichens are very good pollution indicators – they do not grow in polluted areas.

# Ch 3 Plant Kingdom

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, PLANT KINGDOM CHAPTER 3 3.1 Algae 3.2 Bryophytes 3.3 Pteridophytes 3.4 Gymnosperms 3.5 Angiosperms 2024-25 24 BIOLOGY not only the external features, but also internal features, like ultrastructure, anatomy, embryology and phytochemistry. Such a classification for flowering plants was given by George Bentham and Joseph Dalton Hooker. At present phylogenetic classification systems based on evolutionary relationships between the various organisms are acceptable. This assumes that organisms belonging to the same taxa have a common ancestor. We now use information from many other sources too to help resolve difficulties in classification. These become more important when there is no supporting fossil evidence. Numerical Taxonomy which is now easily carried out using computers is based on all observable characteristics. Number and codes are assigned to all the characters and the data are then processed. In this way each character is given equal importance and at the same time hundreds of characters can be considered. Cytotaxonomy that is based on cytological information like chromosome number, structure, behaviour and chemotaxonomy that uses the chemical constituents of the plant to resolve confusions, are also used by taxonomists these days. 3.1 ALGAE Algae are chlorophyll-bearing, simple, thalloid, autotrophic and largely aquatic (both fresh water and marine) organisms. They occur in a variety of other habitats: moist stones, soils and wood. Some of them also occur in association with fungi (lichen) and animals (e.g., on sloth bear). The form and size of algae is highly variable, ranging from colonial forms like Volvox and the filamentous forms like Ulothrix and Spirogyra (Figure 3.1). A few of the marine forms such as kelps, form massive plant bodies. The algae reproduce by vegetative, asexual and sexual methods. Vegetative reproduction is by fragmentation. Each fragment develops into a thallus. Asexual reproduction is by the production of different types of spores, the most common being the zoospores. They are flagellated (motile) and on germination gives rise to new plants. Sexual reproduction takes place through fusion of two gametes. These gametes can be flagellated and similar in size (as in Ulothrix) or non-flagellated (non-motile) but similar in size (as in Spirogyra). Such reproduction is called isogamous. Fusion of two gametes dissimilar in size, as in species of Eudorina is termed as anisogamous. Fusion between one large, nonmotile (static) female gamete and a smaller, motile male gamete is termed oogamous, e.g., Volvox, Fucus. 2024-25 PLANT KINGDOM 25 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 2024-25 26 BIOLOGY 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 2024-25 PLANT KINGDOM 27 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 Major Stored Cell Wall Flagellar Habitat Name Pigments Food Number and Position of Insertions Chlorophyceae Green Chlorophyll Starch Cellulose 2-8, equal, Fresh water, algae a, b apical brackish water, salt water Phaeophyceae Brown Chlorophyll Mannitol, Cellulose 2, unequal, Fresh water algae a, c, laminarin and algin lateral (rare) brackish fucoxanthin water, salt water Rhodophyceae Red Chlorophyll Floridean Cellulose, Absent Fresh water algae a, d, starch pectin and (some), phycoerythrin poly brackish sulphate water, salt esters water (most) 2024-25 28 BIOLOGY 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). Archegoniophore (a) (b) (c) (d) Antheridiophore Capsule Antheridial branch Branches Archegonial branch Seta Sporophyte Gametophyte Leaves Main axis Rhizoids Gemma cup Rhizoids Gemma cup Rhizoids Figure 3.2 Bryophytes: A liverwort – Marchantia (a) Female thallus (b) Male thallus Mosses – (c) Funaria, gametophyte and sporophyte (d) Sphagnum gametophyte 2024-25 PLANT KINGDOM 29 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 2024-25 30 BIOLOGY 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, 2024-25 PLANT KINGDOM 31 Figure 3.3 Pteridophytes : (a) Selaginella (b) Equisetum (c) Fern (d) Salvinia Strobilus Node Internode Branch Rhizome (b) (c) (d) 2024-25 32 BIOLOGY 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 coralloid 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. 2024-25 PLANT KINGDOM 33 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. (c) Figure 3.4 Gymnosperms: (a) Cycas (b) Pinus (c) Ginkgo Dwarf Shoot Long Shoot Seeds (b) (a) 2024-25 34 BIOLOGY 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). 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 possesed and the type of stored food, algae are classfied 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- (a) (b) Figure 3.5 Angiosperms : (a) A dicotyledon (b) A monocotyledon

# Ch 4 Animal Kingdom

1. What are the difficulties that you would face in classification of animals, if common fundamental features are not taken into account?

2. If you are given a specimen, what are the steps that you would follow to classify it?

3. How useful is the study of the nature of body cavity and coelom in the classification of animals?

4. Distinguish between intracellular and extracellular digestion?

5. What is the difference between direct and indirect development?

6. What are the peculiar features that you find in parasitic platyhelminthes?

7. What are the reasons that you can think of for the arthropods to constitute the largest group of the animal kingdom?

8. Water vascular system is the characteristic of which group of the following: (a) Porifera (b) Ctenophora (c) Echinodermata (d) Chordata

9. “All vertebrates are chordates but all chordates are not vertebrates”. Justify the statement.

10. How important is the presence of air bladder in Pisces?

11. What are the modifications that are observed in birds that help them fly?

12. Could the number of eggs or young ones produced by an oviparous and viviparous mother be equal? Why?

13. Segmentation in the body is first observed in which of the following: (a) Platyhelminthes (b) Aschelminthes (c) Annelida (d) Arthropoda

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

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

# Ch 4 Animal Kingdom

When you look around, you will observe different animals with different structures and forms. As over a million species of animals have been described till now, the need for classification becomes all the more important. The classification also helps in assigning a systematic position to newly described species. 4.1 BASIS OF CLASSIFICATION Inspite of differences in structure and form of different animals, there are fundamental features common to various individuals in relation to the arrangement of cells, body symmetry, nature of coelom, patterns of digestive, circulatory or reproductive systems. These features are used as the basis of animal classification and some of them are discussed here. 4.1.1 Levels of Organisation Though all members of Animalia are multicellular, all of them do not exhibit the same pattern of organisation of cells. For example, in sponges, the cells are arranged as loose cell aggregates, i.e., they exhibit cellular level of organisation. Some division of labour (activities) occur among the cells. In coelenterates, the arrangement of cells is more complex. Here the cells performing the same function are arranged into tissues, hence is called tissue level of organisation. A still higher level of organisation, i.e., organ level is exhibited by members of Platyhelminthes and other higher phyla where tissues are grouped together to form organs, each specialised for a particular function. In animals like Annelids, Arthropods, Molluscs, ANIMAL KINGDOM CHAPTER 4 4.1 Basis of Classification 4.2 Classification of Animals 2024-25 38 BIOLOGY Echinoderms and Chordates, organs have associated to form functional systems, each system concerned with a specific physiological function. This pattern is called organ system level of organisation. Organ systems in different groups of animals exhibit various patterns of complexities. For example, the digestive system in Platyhelminthes has only a single opening to the outside of the body that serves as both mouth and anus, and is hence called incomplete. A complete digestive system has two openings, mouth and anus. Similarly, the circulatory system may be of two types: (i) open type in which the blood is pumped out of the heart and the cells and tissues are directly bathed in it and (ii) closed type in which the blood is circulated through a series of vessels of varying diameters (arteries, veins and capillaries). 4.1.2 Symmetry Animals can be categorised on the basis of their symmetry. Sponges are mostly asymmetrical, i.e., any plane that passes through the centre does not divide them into equal halves. When any plane passing through the central axis of the body divides the organism into two identical halves, it is called radial symmetry. Coelenterates, ctenophores and echinoderms have this kind of body plan (Figure 4.1a). Animals like annelids, arthropods, etc., where the body can be divided into identical left and right halves in only one plane, exhibit bilateral symmetry (Figure 4.1b). 4.1.3 Diploblastic and Triploblastic Organisation Animals in which the cells are arranged in two embryonic layers, an external ectoderm and an internal endoderm, are called diploblastic animals, e.g., coelenterates. An undifferentiated layer, mesoglea, is present in between the ectoderm and the endoderm (Figure 4.2a). Figure 4.2 Showing germinal layers : (a) Diploblastic (b) Triploblastic (a) (b) Ectoderm Mesoglea Endoderm Mesoderm Figure 4.1 (b) Bilateral symmetry Figure 4.1 (a) Radial symmetry 2024-25 ANIMAL KINGDOM 39 39 4.1.4 Coelom Presence or absence of a cavity between the body wall and the gut wall is very important in classification. The body cavity, which is lined by mesoderm is called coelom. Animals possessing coelom are called coelomates, e.g., annelids, molluscs, arthropods, echinoderms, hemichordates and chordates (Figure 4.3a). In some animals, the body cavity is not lined by mesoderm, instead, the mesoderm is present as scattered pouches in between the ectoderm and endoderm. Such a body cavity is called pseudocoelom and the animals possessing them are called pseudocoelomates, e.g., aschelminthes (Figure 4.3b). The animals in which the body cavity is absent are called acoelomates, e.g., platyhelminthes (Figure 4.3c). Figure 4.3 Diagrammatic sectional view of : (a) Coelomate (b) Pseudocoelomate (c) Acoelomate Those animals in which the developing embryo has a third germinal layer, mesoderm, in between the ectoderm and endoderm, are called triploblastic animals (platyhelminthes to chordates, Figure 4.2b). 4.1.5 Segmentation In some animals, the body is externally and internally divided into segments with a serial repetition of at least some organs. For example, in earthworm, the body shows this pattern called metameric segmentation and the phenomenon is known as metamerism. 4.1.6 Notochord Notochord is a mesodermally derived rod-like structure formed on the dorsal side during embryonic development in some animals. Animals with notochord are called chordates and those animals which do not form this structure are called non-chordates, e.g., porifera to echinoderms. 4.2 CLASSIFICATION OF ANIMALS The broad classification of Animalia based on common fundamental features as mentioned in the preceding sections is given in Figure 4.4. 2024-25 40 BIOLOGY The important characteristic features of the different phyla are described. 4.2.1 Phylum – Porifera Members of this phylum are commonly known as sponges. They are generally marine and mostly asymmetrical animals (Figure 4.5). These are primitive multicellular animals and have cellular level of organisation. Sponges have a water transport or canal system. Water enters through minute pores (ostia) in the body wall into a central cavity, spongocoel, from where it goes out through the osculum. This pathway of water transport is helpful in food gathering, respiratory exchange and removal of waste. Choanocytes or collar cells line the spongocoel and the canals. Digestion is intracellular. The body is supported by a skeleton made up of spicules or spongin fibres. Sexes are not separate (hermaphrodite), i.e., eggs and sperms are produced by the same individual. Sponges reproduce asexually by fragmentation and sexually by formation of gametes. Fertilisation is internal and development is indirect having a larval stage which is morphologically distinct from the adult. \*Echinodermata exhibits radial or bilateral symmetry depending on the stage. Figure 4.4 Broad classification of Kingdom Animalia based on common fundamental features (a) (b) (c) Figure 4.5 Examples of Porifera : (a) Sycon (b) Euspongia (c) Spongilla 2024-25 ANIMAL KINGDOM 41 41 cnidoblasts or cnidocytes (which contain the stinging capsules or nematocysts) present on the tentacles and the body. Cnidoblasts are used for anchorage, defense and for the capture of prey (Figure 4.7). Cnidarians exhibit tissue level of organisation and are diploblastic. They have a central gastro-vascular cavity with a single opening, mouth on hypostome. Digestion is extracellular and intracellular. Some of the cnidarians, e.g., corals have a skeleton composed of calcium carbonate. Cnidarians exhibit two basic body forms called polyp and medusa (Figure 4.6). The former is a sessile and cylindrical form like Hydra, Adamsia, etc. whereas, the latter is umbrella-shaped and free-swimming like Aurelia or jelly fish. Those cnidarians which exist in both forms exhibit alternation of generation (Metagenesis), i.e., polyps produce medusae asexually and medusae form the polyps sexually (e.g., Obelia). Examples: Physalia (Portuguese man-of-war), Adamsia (Sea anemone), Pennatula (Sea-pen), Gorgonia (Sea-fan) and Meandrina (Brain coral). Figure 4.7 Diagrammatic view of Cnidoblast Figure 4.6 Examples of Coelenterata indicating outline of their body form : (a) Aurelia (Medusa) (b) Adamsia (Polyp) (a) (b) Examples: Sycon (Scypha), Spongilla (Fresh water sponge) and Euspongia (Bath sponge). 4.2.2 Phylum – Coelenterata (Cnidaria) They are aquatic, mostly marine, sessile or free-swimming, radially symmetrical animals (Figure 4.6). The name cnidaria is derived from the 2024-25 42 BIOLOGY 4.2.3 Phylum – Ctenophora Ctenophores, commonly known as sea walnuts or comb jellies are exclusively marine, radially symmetrical, diploblastic organisms with tissue level of organisation. The body bears eight external rows of ciliated comb plates, which help in locomotion (Figure 4.8). Digestion is both extracellular and intracellular. Bioluminescence (the property of a living organism to emit light) is well-marked in ctenophores. Sexes are not separate. Reproduction takes place only by sexual means. Fertilisation is external with indirect development. Examples: Pleurobrachia and Ctenoplana. 4.2.4 Phylum – Platyhelminthes They have dorso-ventrally flattened body, hence are called flatworms (Figure 4.9). These are mostly endoparasites found in animals including human beings. Flatworms are bilaterally symmetrical, triploblastic and acoelomate animals with organ level of organisation. Hooks and suckers are present in the parasitic forms. Some of them absorb nutrients from the host directly through their body surface. Specialised cells called flame cells help in osmoregulation and excretion. Sexes are not separate. Fertilisation is internal and development is through many larval stages. Some members like Planaria possess high regeneration capacity. Examples: Taenia (Tapeworm), Fasciola (Liver fluke). Figure 4.8 Example of Ctenophora (Pleurobrachia) (a) (b) Figure 4.9 Examples of Platyhelminthes : (a) Tape worm (b) Liver fluke 2024-25 ANIMAL KINGDOM 43 43 4.2.5 Phylum – Aschelminthes The body of the aschelminthes is circular in cross-section, hence, the name roundworms (Figure 4.10). They may be freeliving, aquatic and terrestrial or parasitic in plants and animals. Roundworms have organ-system level of body organisation. They are bilaterally symmetrical, triploblastic and pseudocoelomate animals. Alimentary canal is complete with a welldeveloped muscular pharynx. An excretory tube removes body wastes from the body cavity through the excretory pore. Sexes are separate (dioecious), i.e., males and females are distinct. Often females are longer than males. Fertilisation is internal and development may be direct (the young ones resemble the adult) or indirect. Examples : Ascaris (Roundworm), Wuchereria (Filaria worm), Ancylostoma (Hookworm). 4.2.6 Phylum – Annelida They may be aquatic (marine and fresh water) or terrestrial; free-living, and sometimes parasitic. They exhibit organ-system level of body organisation and bilateral symmetry. They are triploblastic, metamerically segmented and coelomate animals. Their body surface is distinctly marked out into segments or metameres and, hence, the phylum name Annelida (Latin, annulus : little ring) (Figure 4.11). They possess longitudinal and circular muscles which help in locomotion. Aquatic annelids like Nereis possess lateral appendages, parapodia, which help in swimming. A closed circulatory system is present. Nephridia (sing. nephridium) help in osmoregulation and excretion. Neural system consists of paired ganglia (sing. ganglion) connected by lateral nerves to a double ventral nerve cord. Nereis, an aquatic form, is dioecious, but earthworms and leeches are monoecious. Reproduction is sexual. Examples : Nereis, Pheretima (Earthworm) and Hirudinaria (Blood sucking leech). Figure 4.11 Examples of Annelida : (a) Nereis (b) Hirudinaria Male Female Figure 4.10 Example of Aschelminthes: Roundworm 2024-25 44 BIOLOGY 4.2.7 Phylum – Arthropoda This is the largest phylum of Animalia which includes insects. Over two-thirds of all named species on earth are arthropods (Figure 4.12). They have organ-system level of organisation. They are bilaterally symmetrical, triploblastic, segmented and coelomate animals. The body of arthropods is covered by chitinous exoskeleton. The body consists of head, thorax and abdomen. They have jointed appendages (arthros-joint, poda-appendages). Respiratory organs are gills, book gills, book lungs or tracheal system. Circulatory system is of open type. Sensory organs like antennae, eyes (compound and simple), statocysts or balancing organs are present. Excretion takes place through malpighian tubules. They are mostly dioecious. Fertilisation is usually internal. They are mostly oviparous. Development may be direct or indirect. Examples: Economically important insects – Apis (Honey bee), Bombyx (Silkworm), Laccifer (Lac insect) Vectors – Anopheles, Culex and Aedes (Mosquitoes) Gregarious pest – Locusta (Locust) Living fossil – Limulus (King crab). 4.2.8 Phylum – Mollusca This is the second largest animal phylum (Figure 4.13). Molluscs are terrestrial or aquatic (marine or fresh water) having an organ-system level of organisation. They are bilaterally symmetrical, triploblastic and coelomate animals. Body is covered by a calcareous shell and is unsegmented with a distinct head, muscular foot and visceral hump. A soft and spongy layer of skin forms a mantle over the visceral hump. The space between the hump and the mantle is called the mantle cavity in which feather like gills are present. They have respiratory and excretory functions. The anterior head region has sensory tentacles. The mouth contains a file-like rasping organ for feeding, called radula. Figure 4.12 Examples of Arthropoda : (a) Locust (b) Butterfly (c) Scorpion (d) Prawn (a) (c) (b) (d) Figure 4.13 Examples of Mollusca : (a) Pila (b) Octopus (b) (a) 2024-25 ANIMAL KINGDOM 45 45 They are usually dioecious and oviparous with indirect development. Examples: Pila (Apple snail), Pinctada (Pearl oyster), Sepia (Cuttlefish), Loligo (Squid), Octopus (Devil fish), Aplysia (Seahare), Dentalium (Tusk shell) and Chaetopleura (Chiton). 4.2.9 Phylum – Echinodermata These animals have an endoskeleton of calcareous ossicles and, hence, the name Echinodermata (Spiny bodied, Figure 4.14). All are marine with organ-system level of organisation. The adult echinoderms are radially symmetrical but larvae are bilaterally symmetrical. They are triploblastic and coelomate animals. Digestive system is complete with mouth on the lower (ventral) side and anus on the upper (dorsal) side. The most distinctive feature of echinoderms is the presence of water vascular system which helps in locomotion, capture and transport of food and respiration. An excretory system is absent. Sexes are separate. Reproduction is sexual. Fertilisation is usually external. Development is indirect with free-swimming larva. Examples: Asterias (Star fish), Echinus (Sea urchin), Antedon (Sea lily), Cucumaria (Sea cucumber) and Ophiura (Brittle star). 4.2.10 Phylum – Hemichordata Hemichordata was earlier considered as a sub-phylum under phylum Chordata. But now it is placed as a separate phylum under non-chordata. Hemichordates have a rudimentary structure in the collar region called stomochord, a structure similar to notochord. This phylum consists of a small group of worm-like marine animals with organ-system level of organisation. They are bilaterally symmetrical, triploblastic and coelomate animals. The body is cylindrical and is composed of an anterior proboscis, a collar and a long trunk (Figure 4.15). Circulatory system is of open type. Respiration takes place through gills. Excretory organ is proboscis gland. Sexes are separate. Fertilisation is external. Development is indirect. Examples: Balanoglossus and Saccoglossus. 4.2.11 Phylum – Chordata Animals belonging to phylum Chordata are fundamentally characterised by the presence of a notochord, a dorsal Figure 4.14 Examples of Echinodermata : (a) Asterias (b) Ophiura (a) (b) Figure 4.15 Balanoglossus Proboscis Collar Trunk 2024-25 46 BIOLOGY hollow nerve cord and paired pharyngeal gill slits (Figure 4.16). These are bilaterally symmetrical, triploblastic, coelomate with organ-system level of organisation. They possess a post anal tail and a closed circulatory system. Table 4.1 presents a comparison of salient features of chordates and non-chordates. Phylum Chordata is divided into three subphyla: Urochordata or Tunicata, Cephalochordata and Vertebrata. Subphyla Urochordata and Cephalochordata are often referred to as protochordates (Figure 4.17) and are exclusively marine. In Urochordata, notochord is present only in larval tail, while in Cephalochordata, it extends from head to tail region and is persistent throughout their life. Examples: Urochordata – Ascidia, Salpa, Doliolum; Cephalochordata – Branchiostoma (Amphioxus or Lancelet). The members of subphylum Vertebrata possess notochord during the embryonic period. The notochord is replaced by a cartilaginous or bony vertebral column in the adult. Thus all vertebrates are chordates but all chordates are not vertebrates. Besides the basic chordate characters, vertebrates have a ventral muscular heart with two, three or four chambers, kidneys for excretion and osmoregulation and paired appendages which may be fins or limbs. Nerve cord Notochord Post-anal part Gill slits Figure 4.16 Chordata characteristics Figure 4.17 Ascidia TABLE 4.1 Comparison of Chordates and Non-chordates S.No. Chordates Non-chordates 1. Notochord present. Notochord absent. 2. Central nervous system is dorsal, Central nervous system is ventral, solid hollow and single. and double. 3. Pharynx perforated by gill slits. Gill slits are absent. 4. Heart is ventral. Heart is dorsal (if present). 5. A post-anal part (tail) is present. Post-anal tail is absent. 2024-25 ANIMAL KINGDOM 47 47 4.2.11.1 4.2.11.14.2.11.1 Class – Cyclostomata All living members of the class Cyclostomata are ectoparasites on some fishes. They have an elongated body bearing 6-15 pairs of gill slits for respiration. Cyclostomes have a sucking and circular mouth without jaws (Fig. 4.18). Their body is devoid of scales and paired fins. Cranium and vertebral column are cartilaginous. Circulation is of closed type. Cyclostomes are marine but migrate for spawning to fresh water. After spawning, within a few days, they die. Their larvae, after metamorphosis, return to the ocean. Examples: Petromyzon (Lamprey) and Myxine (Hagfish). 4.2.11.2 4.2.11.24.2.11.2 Class – Chondrichthyes They are marine animals with streamlined body and have cartilaginous endoskeleton (Figure 4.19). Mouth is located ventrally. Notochord is persistent throughout life. Gill slits are separate and without operculum (gill cover). The skin is tough, containing minute placoid scales. Teeth are modified placoid scales which are backwardly directed. Their jaws are very powerful. These animals are predaceous. Due to the absence of air bladder, they have to swim constantly to avoid sinking. Vertebrata Division Agnatha (lacks jaw) Class 1. Cyclostomata Gnathostomata (bears jaw) Super Class Pisces (bear fins) Tetrapoda (bear limbs) Class 1. Amphibia 2. Reptilia 3. Aves 4. Mammals Class 1. Chondrichthyes 2. Osteichthyes The subphylum Vertebrata is further divided as follows: Figure 4.18 A jawless vertebrate - Petromyzon Figure 4.19 Example of Cartilaginous fishes : (a) Scoliodon (b) Pristis (a) (b) 2024-25 48 BIOLOGY Heart is two-chambered (one auricle and one ventricle). Some of them have electric organs (e.g., Torpedo) and some possess poison sting (e.g., Trygon). They are cold-blooded (poikilothermous) animals, i.e., they lack the capacity to regulate their body temperature. Sexes are separate. In males pelvic fins bear claspers. They have internal fertilisation and many of them are viviparous. Examples: Scoliodon (Dog fish), Pristis (Saw fish), Carcharodon (Great white shark), Trygon (Sting ray). 4.2.11.3 4.2.11.34.2.11.3 Class – Osteichthyes It includes both marine and fresh water fishes with bony endoskeleton. Their body is streamlined. Mouth is mostly terminal (Figure 4.20). They have four pairs of gills which are covered by an operculum on each side. Skin is covered with cycloid/ctenoid scales. Air bladder is present which regulates buoyancy. Heart is twochambered (one auricle and one ventricle). They are cold-blooded animals. Sexes are separate. Fertilisation is usually external. They are mostly oviparous and development is direct. Examples: Marine – Exocoetus (Flying fish), Hippocampus (Sea horse); Freshwater – Labeo (Rohu), Catla (Katla), Clarias (Magur); Aquarium – Betta (Fighting fish), Pterophyllum (Angel fish). 4.2.11.4 4.2.11.44.2.11.4 Class – Amphibia As the name indicates (Gr., Amphi : dual, bios, life), amphibians can live in aquatic as well as terrestrial habitats (Figure 4.21). Most of them have two pairs of limbs. Body is divisible into head and trunk. Tail may be present in some. The amphibian skin is moist (without scales). The eyes have eyelids. A tympanum represents the ear. Alimentary canal, urinary and reproductive tracts open into a common chamber called cloaca which opens to the exterior. Respiration is by gills, lungs and through skin. The heart is threechambered (two auricles and one ventricle). These are cold-blooded animals. Sexes are separate. Fertilisation is external. They are oviparous and development is indirect. Examples: Bufo (Toad), Rana (Frog), Hyla (Tree frog), Salamandra (Salamander), Ichthyophis (Limbless amphibia). Figure 4.21 Examples of Amphibia : (a) Salamandra (b) Rana (a) (b) Figure 4.20 Examples of Bony fishes : (a) Hippocampus (b) Catla (a) (b) 2024-25 ANIMAL KINGDOM 49 49 4.2.11.5 4.2.11.54.2.11.5 Class – Reptilia The class name refers to their creeping or crawling mode of locomotion (Latin, repere or reptum, to creep or crawl). They are mostly terrestrial animals and their body is covered by dry and cornified skin, epidermal scales or scutes (Fig. 4.22). They do not have external ear openings. Tympanum represents ear. Limbs, when present, are two pairs. Heart is usually three-chambered, but four-chambered in crocodiles. Reptiles are poikilotherms. Snakes and lizards shed their scales as skin cast. Sexes are separate. Fertilisation is internal. They are oviparous and development is direct. Examples: Chelone (Turtle), Testudo (Tortoise), Chameleon (Tree lizard), Calotes (Garden lizard), Crocodilus (Crocodile), Alligator (Alligator). Hemidactylus (Wall lizard), Poisonous snakes – Naja (Cobra), Bangarus (Krait), Vipera (Viper). 4.2.11.6 4.2.11.64.2.11.6 Class – Aves The characteristic features of Aves (birds) are the presence of feathers and most of them can fly except flightless birds (e.g., Ostrich). They possess beak (Figure 4.23). The forelimbs are modified into wings. The hind limbs generally have scales and are modified for walking, swimming or clasping the tree branches. Skin is dry without glands except the oil gland at the base of the tail. Endoskeleton is fully ossified (bony) and the long bones are hollow with air cavities (pneumatic). The digestive tract of birds has additional chambers, the crop and gizzard. Heart is completely fourchambered. They are warm-blooded (homoiothermous) animals, i.e., they are able to maintain a constant body temperature. Respiration is by Figure 4.22 Reptiles: (a) Chameleon (b) Crocodilus (c) Chelone (d) Naja (a) (b) (c) (d) 2024-25 50 BIOLOGY lungs. Air sacs connected to lungs supplement respiration. Sexes are separate. Fertilisation is internal. They are oviparous and development is direct. Examples : Corvus (Crow), Columba (Pigeon), Psittacula (Parrot), Struthio (Ostrich), Pavo (Peacock), Aptenodytes (Penguin), Neophron (Vulture). 4.2.11.7 4.2.11.74.2.11.7 Class – Mammalia They are found in a variety of habitats – polar ice caps, deserts, mountains, forests, grasslands and dark caves. Some of them have adapted to fly or live in water. The most unique mammalian characteristic is the presence of milk producing glands (mammary glands) by which the young ones are nourished. They have two pairs of limbs, adapted for walking, running, climbing, burrowing, swimming or flying (Figure 4.24). The skin of (a) Figure 4.23 Some birds : (a) Neophron (b) Struthio (c) Psittacula (d) Pavo (b) (c) (d) Figure 4.24 Some mammals : (a) Ornithorhynchus (b) Macropus (c) Pteropus (d) Balaenoptera (a) (b) (c) (d) 2024-25 ANIMAL KINGDOM 51 51 mammals is unique in possessing hair. External ears or pinnae are present. Different types of teeth are present in the jaw. Heart is fourchambered. They are homoiothermous. Respiration is by lungs. Sexes are separate and fertilisation is internal. They are viviparous with few exceptions and development is direct. Examples: Oviparous-Ornithorhynchus (Platypus); Viviparous - Macropus (Kangaroo), Pteropus (Flying fox), Camelus (Camel), Macaca (Monkey), Rattus (Rat), Canis (Dog), Felis (Cat), Elephas (Elephant), Equus (Horse), Delphinus (Common dolphin), Balaenoptera (Blue whale), Panthera tigris (Tiger), Panthera leo (Lion). The salient distinguishing features of all phyla under animal kingdom is comprehensively given in the Table 4.2.

# Ch 5 Morphology of Flowering Plants

The wide range in the structure of higher plants will never fail to fascinate us. Even though the angiosperms show such a large diversity in external structure or morphology, they are all characterised by presence of roots, stems, leaves, flowers and fruits. In chapters 2 and 3, we talked about classification of plants based on morphological and other characteristics. For any successful attempt at classification and at understanding any higher plant (or for that matter any living organism) we need to know standard technical terms and standard definitions. We also need to know about the possible variations in different parts, found as adaptations of the plants to their environment, e.g., adaptions to various habitats, for protection, climbing, storage, etc. If you pull out any weed you will see that all of them have roots, stems and leaves. They may be bearing flowers and fruits. The underground part of the flowering plant is the root system while the portion above the ground forms the shoot system (Figure 5.1). 5.1 THE ROOT In majority of the dicotyledonous plants, the direct elongation of the radicle leads to the formation of primary root which grows inside the soil. It bears lateral roots of several orders that are referred to as secondary, tertiary, etc. roots. The primary roots and its branches constitute the MORPHOLOGY OF FLOWERING PLANTS CHAPTER 5 5.1 The Root 5.2 The Stem 5.3 The Leaf 5.4 The Inflorescence 5.5 The Flower 5.6 The Fruit 5.7 The Seed 5.8 Semi-technical Description of a Typical Flowering Plant 5.9 Description of Some Important Families 2024-25 58 BIOLOGY Flower Shoot system Root system Fruit Bud Stem Leaf Node Internode Primary root Secondary root { Figure 5.2 Different types of roots : (a) Tap (b) Fibrous (c) Adventitious (b) (c) Figure 5.1 Parts of a flowering plant Fibrous roots Adventitious roots Laterals (a) Main root tap root system, as seen in the mustard plant (Figure 5.2a). In monocotyledonous plants, the primary root is short lived and is replaced by a large number of roots. These roots originate from the base of the stem and constitute the fibrous root system, as seen in the wheat plant (Figure 5.2b). In some plants, like grass, Monstera and the banyan tree, roots arise from parts of the plant other than the radicle and are called adventitious roots (Figure 5.2c). The main functions of the root system are absorption of water and minerals from the soil, providing a proper anchorage to the plant parts, storing reserve food material and synthesis of plant growth regulators. 2024-25 MORPHOLOGY OF FLOWERING PLANTS 59 5.1.1 Regions of the Root The root is covered at the apex by a thimble-like structure called the root cap (Figure 5.3). It protects the tender apex of the root as it makes its way through the soil. A few millimetres above the root cap is the region of meristematic activity. The cells of this region are very small, thin-walled and with dense protoplasm. They divide repeatedly. The cells proximal to this region undergo rapid elongation and enlargement and are responsible for the growth of the root in length. This region is called the region of elongation. The cells of the elongation zone gradually differentiate and mature. Hence, this zone, proximal to region of elongation, is called the region of maturation. From this region some of the epidermal cells form very fine and delicate, thread-like structures called root hairs. These root hairs absorb water and minerals from the soil. Figure 5.3 The regions of the root-tip 5.2 THE STEM What are the features that distinguish a stem from a root? The stem is the ascending part of the axis bearing branches, leaves, flowers and fruits. It develops from the plumule of the embryo of a germinating seed. The stem bears nodes and internodes. The region of the stem where leaves are born are called nodes while internodes are the portions between two nodes. The stem bears buds, which may be terminal or axillary. Stem is generally green when young and later often become woody and dark brown. The main function of the stem is spreading out branches bearing leaves, flowers and fruits. It conducts water, minerals and photosynthates. Some stems perform the function of storage of food, support, protection and of vegetative propagation. 5.3 THE LEAF The leaf is a lateral, generally flattened structure borne on the stem. It develops at the node and bears a bud in its axil. The axillary bud later develops into a branch. Leaves originate from shoot apical meristems and are arranged in an acropetal order. They are the most important vegetative organs for photosynthesis. 2024-25 60 BIOLOGY A typical leaf consists of three main parts: leaf base, petiole and lamina (Figure 5.4 a). The leaf is attached to the stem by the leaf base and may bear two lateral small leaf like structures called stipules. In monocotyledons, the leaf base expands into a sheath covering the stem partially or wholly. In some leguminous plants the leafbase may become swollen, which is called the pulvinus. The petiole help hold the blade to light. Long thin flexible petioles allow leaf blades to flutter in wind, thereby cooling the leaf and bringing fresh air to leaf surface. The lamina or the leaf blade is the green expanded part of the leaf with veins and veinlets. There is, usually, a middle prominent vein, which is known as the midrib. Veins provide rigidity to the leaf blade and act as channels of transport for water, minerals and food materials. The shape, margin, apex, surface and extent of incision of lamina varies in different leaves. 5.3.1 Venation The arrangement of veins and the veinlets in the lamina of leaf is termed as venation. When the veinlets form a network, the venation is termed as reticulate (Figure 5.4 b). When the veins run parallel to each other within a lamina, the venation is termed as parallel (Figure 5.4 c). Leaves of dicotyledonous plants generally possess reticulate venation, while parallel venation is the characteristic of most monocotyledons. 5.3.2 Types of Leaves A leaf is said to be simple, when its lamina is entire or when incised, the incisions do not touch the midrib. When the incisions of the lamina reach up to the midrib breaking it into a number of leaflets, the leaf is called compound. A bud is present in the axil of petiole in both simple and compound leaves, but not in the axil of leaflets of the compound leaf. The compound leaves may be of two types (Figure 5.5). In a pinnately compound leaf a Figure 5.4 Structure of a leaf : (a) Parts of a leaf (b) Reticulate venation (c) Parallel venation (b) (c) (b) Silk Cotton (a) Lamina Petiole Stipule Leaf base Axillary bud (a) Neem Figure 5.5 Compound leaves : (a) pinnately compound leaf (b) palmately compound leaf Rachis 2024-25 MORPHOLOGY OF FLOWERING PLANTS 61 number of leaflets are present on a common axis, the rachis, which represents the midrib of the leaf as in neem. In palmately compound leaves, the leaflets are attached at a common point, i.e., at the tip of petiole, as in silk cotton. 5.3.3 Phyllotaxy Phyllotaxy is the pattern of arrangement of leaves on the stem or branch. This is usually of three types – alternate, opposite and whorled (Figure 5.6). In alternate type of phyllotaxy, a single leaf arises at each node in alternate manner, as in china rose, mustard and sun flower plants. In opposite type, a pair of leaves arise at each node and lie opposite to each other as in Calotropis and guava plants. If more than two leaves arise at a node and form a whorl, it is called whorled, as in Alstonia. 5.4 THE INFLORESCENCE A flower is a modified shoot wherein the shoot apical meristem changes to floral meristem. Internodes do not elongate and the axis gets condensed. The apex produces different kinds of floral appendages laterally at successive nodes instead of leaves. When a shoot tip transforms into a flower, it is always solitary. The arrangement of flowers on the floral axis is termed as inflorescence. Depending on whether the apex gets developed into a flower or continues to grow, two major types of inflorescences are defined – racemose and cymose. In racemose type of inflorescences the main axis continues to grow, the flowers are borne laterally in an acropetal succession (Figure 5.7). In cymose type of inflorescence the main axis terminates in a flower, hence is limited in growth.The flowers are borne in a basipetal order (Figure 5.7). Figure 5.6 Different types of phyllotaxy : (a) Alternate (b) Opposite (c) Whorled (c) Alstonia (a) China rose (b) Guava Figure 5.7 Racemose inflorescence 2024-25 62 BIOLOGY 5.5 THE FLOWER The flower is the reproductive unit in the angiosperms. It is meant for sexual reproduction. A typical flower has four different kinds of whorls arranged successively on the swollen end of the stalk or pedicel, called thalamus or receptacle. These are calyx, corolla, androecium and gynoecium. Calyx and corolla are accessory organs, while androecium and gynoecium are reproductive organs. In some flowers like lily, the calyx and corolla are not distinct and are termed as perianth. When a flower has both androecium and gynoecium, it is bisexual. A flower having either only stamens or only carpels is unisexual. In symmetry, the flower may be actinomorphic (radial symmetry) or zygomorphic (bilateral symmetry). When a flower can be divided into two equal radial halves in any radial plane passing through the centre, it is said to be actinomorphic, e.g., mustard, datura, chilli. When it can be divided into two similar halves only in one particular vertical plane, it is zygomorphic, e.g., pea, gulmohur, bean, Cassia. A flower is asymmetric (irregular) if it cannot be divided into two similar halves by any vertical plane passing through the centre, as in canna. A flower may be trimerous, tetramerous or pentamerous when the floral appendages are in multiple of 3, 4 or 5, respectively. Flowers with bracts-reduced leaf found at the base of the pedicel - are called bracteate and those without bracts, ebracteate. Figure 5.8 Cymose inflorescence Figure 5.9 Position of floral parts on thalamus : (a) Hypogynous (b) and (c) Perigynous (d) Epigynous (a) (b) (c) (d) 2024-25 MORPHOLOGY OF FLOWERING PLANTS 63 Based on the position of calyx, corolla and androecium in respect of the ovary on thalamus, the flowers are described as hypogynous, perigynous and epigynous (Figure 5.9). In the hypogynous flower the gynoecium occupies the highest position while the other parts are situated below it. The ovary in such flowers is said to be superior, e.g., mustard, china rose and brinjal. If gynoecium is situated in the centre and other parts of the flower are located on the rim of the thalamus almost at the same level, it is called perigynous. The ovary here is said to be half inferior, e.g., plum, rose, peach. In epigynous flowers, the margin of thalamus grows upward enclosing the ovary completely and getting fused with it, the other parts of flower arise above the ovary. Hence, the ovary is said to be inferior as in flowers of guava and cucumber, and the ray florets of sunflower. 5.5.1 Parts of a Flower Each flower normally has four floral whorls, viz., calyx, corolla, androecium and gynoecium (Figure 5.10). 5.5.1.1 5.5.1.1 Calyx The calyx is the outermost whorl of the flower and the members are called sepals. Generally, sepals are green, leaf like and protect the flower in the bud stage. The calyx may be gamosepalous (sepals united) or polysepalous (sepals free). 5.5.1.2 5.5.1.2 Corolla Corolla Corolla is composed of petals. Petals are usually brightly coloured to attract insects for pollination. Like calyx, corolla may also be gamopetalous (petals united) or polypetalous (petals free). The shape and colour of corolla vary greatly in plants. Corolla may be tubular, bellshaped, funnel-shaped or wheel-shaped. Aestivation: The mode of arrangement of sepals or petals in floral bud with respect to the other members of the same whorl is known as aestivation. The main types of aestivation are valvate, twisted, imbricate Pedicel Calyx Corolla Androecium Gynoecium Figure 5.10 Parts of a flower 2024-25 64 BIOLOGY and vexillary (Figure 5.11). When sepals or petals in a whorl just touch one another at the margin, without overlapping, as in Calotropis, it is said to be valvate. If one margin of the appendage overlaps that of the next one and so on as in china rose, lady’s finger and cotton, it is called twisted. If the margins of sepals or petals overlap one another but not in any particular direction as in Cassia and gulmohur, the aestivation is called imbricate. In pea and bean flowers, there are five petals, the largest (standard) overlaps the two lateral petals (wings) which in turn overlap the two smallest anterior petals (keel); this type of aestivation is known as vexillary or papilionaceous. 5.5.1.3 5.5.1.3 Androecium Androecium is composed of stamens. Each stamen which represents the male reproductive organ consists of a stalk or a filament and an anther. Each anther is usually bilobed and each lobe has two chambers, the pollen-sacs. The pollen grains are produced in pollen-sacs. A sterile stamen is called staminode. Stamens of flower may be united with other members such as petals or among themselves. When stamens are attached to the petals, they are epipetalous as in brinjal, or epiphyllous when attached to the perianth as in the flowers of lily. The stamens in a flower may either remain free (polyandrous) or may be united in varying degrees. The stamens may be united into one bunch or one bundle (monoadelphous) as in china rose, or two bundles (diadelphous) as in pea, or into more than two bundles (polyadelphous) as in citrus. There may be a variation in the length of filaments within a flower, as in Salvia and mustard. Figure 5.11 Types of aestivation in corolla : (a) Valvate (b) Twisted (c) Imbricate (d) Vexillary (a) (b) (c) (d) 2024-25 MORPHOLOGY OF FLOWERING PLANTS 65 5.5.1.4 5.5.1.4 Gynoecium Gynoecium is the female reproductive part of the flower and is made up of one or more carpels. A carpel consists of three parts namely stigma, style and ovary. Ovary is the enlarged basal part, on which lies the elongated tube, the style. The style connects the ovary to the stigma. The stigma is usually at the tip of the style and is the receptive surface for pollen grains. Each ovary bears one or more ovules attached to a flattened, cushion-like placenta. When more than one carpel is present, they may be free (as in lotus and rose) and are called apocarpous. They are termed syncarpous when carpels are fused, as in mustard and tomato. After fertilisation, the ovules develop into seeds and the ovary matures into a fruit. Placentation: The arrangement of ovules within the ovary is known as placentation. The placentation are of different types namely, marginal, axile, parietal, basal, central and free central (Figure 5.12). In marginal placentation the placenta forms a ridge along the ventral suture of the ovary and the ovules are borne on this ridge forming two rows, as in pea. When the placenta is axial and the ovules are attached to it in a multilocular ovary, the placentaion is said to be axile, as in china rose, tomato and lemon. In parietal placentation, the ovules develop on the inner wall of the ovary or on peripheral part. Ovary is one-chambered but it becomes twochambered due to the formation of the false septum, e.g., mustard and Argemone. When the ovules are borne on central axis and septa are absent, as in Dianthus and Primrose the placentation is called free central. In basal placentation, the placenta develops at the base of ovary and a single ovule is attached to it, as in sunflower, marigold. 5.6 THE FRUIT The fruit is a characteristic feature of the flowering plants. It is a mature or ripened ovary, developed after fertilisation. If a fruit is formed without fertilisation of the ovary, it is called a parthenocarpic fruit. Generally, the fruit consists of a wall or pericarp and seeds. The pericarp may be dry or fleshy. When pericarp is thick and fleshy, it is differentiated into the outer epicarp, the middle mesocarp and the inner endocarp. In mango and coconut, the fruit is known as a drupe (Figure 5.13). They develop from monocarpellary superior ovaries and are one seeded. In mango the pericarp is well differentiated into an Figure 5.12 Types of placentation : (a) Marginal (b) Axile (c) Parietal (d) Free central (e) Basal (a) (e) (b) (d) (c) (a) 2024-25 66 BIOLOGY Seed coat Hilum Micropyle Cotyledon Plumule Radicle Figure 5.14 Structure of dicotyledonous seed outer thin epicarp, a middle fleshy edible mesocarp and an inner stony hard endocarp. In coconut which is also a drupe, the mesocarp is fibrous. 5.7 THE SEED The ovules after fertilisation, develop into seeds. A seed is made up of a seed coat and an embryo. The embryo is made up of a radicle, an embryonal axis and one (as in wheat, maize) or two cotyledons (as in gram and pea). 5.7.1 Structure of a Dicotyledonous Seed The outermost covering of a seed is the seed coat. The seed coat has two layers, the outer testa and the inner tegmen. The hilum is a scar on the seed coat through which the developing seeds were attached to the fruit. Above the hilum is a small pore called the micropyle. Within the seed coat is the embryo, consisting of an embryonal axis and two cotyledons. The cotyledons are often fleshy and full of reserve food materials. At the two ends of the embryonal axis are present the radicle and the plumule (Figure 5.14). In some seeds such as castor the endosperm formed as a result of double fertilisation, is a food storing tissue and called endospermic seeds. In plants such as bean, gram and pea, the endosperm is not present in mature seeds and such seeds are called non-endospermous. 5.7.2 Structure of Monocotyledonous Seed Generally, monocotyledonous seeds are endospermic but some as in orchids are non-endospermic. In the seeds of cereals such as maize the Figure 5.13 Parts of a fruit : (a) Mango (b) Coconut (a) (b) 2024-25 MORPHOLOGY OF FLOWERING PLANTS 67 Figure 5.15 Structure of a monocotyledonous seed Seed coat & fruit-wall Aleurone layer Endosperm Scutellum Coleoptile Plumule Radicle Coleorhiza Endosperm Embryo seed coat is membranous and generally fused with the fruit wall. The endosperm is bulky and stores food. The outer covering of endosperm separates the embryo by a proteinous layer called aleurone layer. The embryo is small and situated in a groove at one end of the endosperm. It consists of one large and shield shaped cotyledon known as scutellum and a short axis with a plumule and a radicle. The plumule and radicle are enclosed in sheaths which are called coleoptile and coleorhiza respectively (Figure 5.15). 5.8 SEMI-TECHNICAL DESCRIPTION OF A TYPICAL FLOWERING PLANT Various morphological features are used to describe a flowering plant. The description has to be brief, in a simple and scientific language and presented in a proper sequence. The plant is described beginning with its habit, vegetative characters – roots, stem and leaves and then floral characters inflorescence and flower parts. After describing various parts of plant, a floral diagram and a floral formula are presented. The floral formula is represented by some symbols. In the floral formula, Br stands for bracteate K stands for calyx , C for corolla, P for perianth, A for androecium and G for Gynoecium, G for superior ovary and G for inferior ovary, for male, for female, for bisexual plants, ⊕ for actinomorphic Figure 5.16 Floral diagram with floral formula ⊕ K2+2 C4 A2+4 G(2) 2024-25 68 BIOLOGY and for zygomorphic nature of flower. Fusion is indicated by enclosing the figure within bracket and adhesion by a line drawn above the symbols of the floral parts. A floral diagram provides information about the number of parts of a flower, their arrangement and the relation they have with one another (Figure 5.16). The position of the mother axis with respect to the flower is represented by a dot on the top of the floral diagram. Calyx, corolla, androecium and gynoecium are drawn in successive whorls, calyx being the outermost and the gynoecium being in the centre. Floral formula also shows cohesion and adhesion within parts of whorls and between whorls. The floral diagram and floral formula in Figure 5.16 represents the mustard plant (Family: Brassicaceae). 5.9 SOLANACEAE It is a large family, commonly called as the ‘potato family’. It is widely distributed in tropics, subtropics and even temperate zones (Figure 5.17). Vegetative Characters Plants mostly herbs, shrubs and rarely small trees Stem: herbaceous rarely woody, aerial; erect, cylindrical, branched, solid or hollow, hairy or glabrous, underground stem in potato (Solanum tuberosum) Leaves: alternate, simple, rarely pinnately compound, exstipulate; venation reticulate (b) (a) (c) (d) (e) (f) Figure 5.17 Solanum nigrum (makoi) plant : (a) Flowering twig (b) Flower (c) L.S. of flower (d) Stamens (e) Carpel (f) Floral diagram 2024-25 MORPHOLOGY OF FLOWERING PLANTS 69 Floral Characters Inflorescence : Solitary, axillary or cymose as in Solanum Flower: bisexual, actinomorphic Calyx: sepals five, united, persistent, valvate aestivation Corolla: petals five, united; valvate aestivation Androecium: stamens five, epipetalous Gynoecium: bicarpellary obligately placed, syncarpous; ovary superior, bilocular, placenta swollen with many ovules, axile Fruits: berry or capsule Seeds: many, endospermous Floral Formula: ⊕ Economic Importance Many plants belonging to this family are source of food (tomato, brinjal, potato), spice (chilli); medicine (belladonna, ashwagandha); fumigatory (tobacco); ornamentals (petunia).