Text Book for

INTERMEDIATE

First Year

BOTANY

Permission and Support by

एन सी ई आर टी
NCERT

National Council of Educational Research and Training
New Delhi

Board of Intermediate Education, Andhra Pradesh

Telugu and Sanskrit Akademi, Andhra Pradesh

INTERMEDIATE
First Year Text Book

Botany

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Y.S. JAGAN MOHAN REDDY

CHIEF MINISTER
ANDHRA PRADESH

AMARAVATI

MESSAGE

I congratulate Akademi for starting its activities with printing of textbooks from the academic year 2021 – 22.

Education is a real asset which cannot be stolen by anyone and it is the foundation on which children build their future. As the world has become a global village, children will have to compete with the world as they grow up. For this there is every need for good books and good education.

Our government has brought in many changes in the education system and more are to come. The government has been taking care to provide education to the poor and needy through various measures, like developing infrastructure, upgrading the skills of teachers, providing incentives to the children and parents to pursue education. Nutritious mid-day meal and converting Anganwadis into pre-primary schools with English as medium of instruction are the steps taken to initiate children into education from a young age. Besides introducing CBSE syllabus and Telugu as a compulsory subject, the government has taken up numerous innovative programmes.

The revival of the Akademi also took place during the tenure of our government as it was neglected after the State was bifurcated. The Akademi, which was started on August 6, 1968 in the undivided state of Andhra Pradesh, was printing text books, works of popular writers and books for competitive exams and personality development.

Our government has decided to make available all kinds of books required for students and employees through Akademi, with headquarters at Tirupati.

I extend my best wishes to the Akademi and hope it will regain its past glory.

(Y.S. Jagan Mohan Reddy)

Dr. Nandamuri Lakshmiparvathi
M.A., M.Phil., Ph.D.
Chairperson, (Cabinet Minister Rank)
Telugu and Sanskrit Akademi, A.P.

Message of Chairperson, Telugu and Sanskrit Akademi, A.P.

In accordance with the syllabus developed by the Board of Intermediate, State Council for Higher Education, SCERT etc., we design high quality Text books by recruiting efficient Professors, department heads and faculty members from various Universities and Colleges as writers and editors. We are taking steps to print the required number of these books in a timely manner and distribute through the Akademi's Regional Centers present across the Andhra Pradesh.

In addition to text books, we strive to keep monographs, dictionaries, dialect texts, question banks, contact texts, popular texts, essays, linguistics texts, school level dictionaries, glossaries, etc., updated and printed and made available to students from time to time.

For competitive examinations conducted by the Andhra Pradesh Public Service Commission and for Entrance examinations conducted by various Universities, the contents of the Akademi publications are taken as standard. So, I want all the students and Employees to make use of Akademi books of high standards for their golden future.

Congratulations and best wishes to all of you.

N. Lakshmiparvathi

(Nandamuri Lakshmiparvathi)
Chairperson
Telugu and Sanskrit Academi, A.P

J. SYAMALA RAO, I.A.S.,
Principal Secretary to Government

Higher Education Department
Government of Andhra Pradesh

MESSAGE

I Congratulate Telugu and Sanskrit Akademi for taking up the initiative of printing and distributing textbooks in both Telugu and English media within a short span of establishing Telugu and Sanskrit Akademi.

Number of students of Andhra Pradesh are competing of National Level for admissions into Medicine and Engineering courses. In order to help these students Telugu and Sanskrit Akademi consultation with NCERT redesigned their Textbooks to suit the requirement of National Level Examinations in a lucid language.

As the content in Telugu and Sanskrit Akademi books is highly informative and authentic, printed in multi-color on high quality paper and will be made available to the students in a time bound manner. I hope all the students in Andhra Pradesh will utilize the Akademi textbooks for better understanding of the subjects to compete of state and national levels.

(J. SYAMALA RAO)

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC] and to secure to all its citizens:

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the [unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.

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FOREWORD

The Government of India vowed to remove the educational disparities and adopt a common core curriculum across the country especially at the Intermediate level. Ever since the Government of Andhra Pradesh and the Board of Intermediate Education (BIE) swung into action with the task of evolving a revised syllabus in all the Science subjects on par with that of COBSE, approved by NCERT, its chief intention being enabling the students from Andhra Pradesh to prepare for the National Level Common Entrance tests like NEET, ISEET etc for admission into Institutions of professional courses in our Country.

For the first time BIE AP has decided to prepare the Science textbooks. Accordingly an Academic Review Committee was constituted with the Commissioner of Intermediate Education, AP as Chairman and the Secretary, BIE AP; the Director SCERT and the Director Telugu Akademi as members. The National and State Level Educational luminaries were involved in the textbook preparation, who did it with meticulous care. The textbooks are printed on the lines of NCERT maintaining National Level Standards.

The Education Department of Government of Andhra Pradesh has taken a decision to publish and to supply all the text books with free of cost for the students of all Government and Aided Junior Colleges of newly formed state of Andhra Pradesh.

We express our sincere gratitude to the Director, NCERT for according permission to adopt its syllabi and curriculum of Science textbooks. We have been permitted to make use of their textbooks which will be of great advantage to our student community. I also express my gratitude to the Chairman, BIE and the honorable Minister for HRD and Vice Chairman, BIE and Secretary (SE) for their dedicated sincere guidance and help.

I sincerely hope that the assorted methods of innovation that are adopted in the preparation of these textbooks will be of great help and guidance to the students. I wholeheartedly appreciate the sincere endeavors of the Textbook Development Committee which has accomplished this noble task.

Constructive suggestions are solicited for the improvement of this textbook from the students, teachers and general public in the subjects concerned so that next edition will be revised duly incorporating these suggestions.

It is very much commendable that Intermediate text books are being printed for the first time by the Akademi from the 2021-22 academic year.

Sri. V. Ramakrishna I.R.S.
Director
Telugu and Sanskrit Akademi
Andhra Pradesh

PREFACE

Biology in relation to plants termed 'Botany' as distinctive discipline of science has pervaded every walk of life. It is an indispensable area of human knowledge for the scientific and technical growth in biology. Further, in the present scenario of Indian educational system, senior secondary stage or its equivalent (Intermediate clan in the State of AP) is a crucial step for students to choose and continue academic and professional career in biology at tertiary level. Hence students need to be prepared adequately to make them highly competitive and fully equipped to meet the challenges of life when they enter the world of work. In an attempt to achieve the above said objectives, the present text book of Botany has been prepared as per the prescribed syllabus by adopting NCERT Biology Text Books of Class XI and Class XII and after effecting necessary modifications in the content as per local requirements.

The first Unit deals with diversity of living world and it comprises four chapters. In the first chapter salient features, identification and nomenclature of life forms are included. In Chapter 2, the development of biological classification system and distinctive characteristics of Kingdoms Monera, Protista and Fungi of Whittaker system of classification are provided. The chapter 3 deals with the origin of Botany as distinct discipline of biology, its development, scope and division into branches. In chapter 4, distinctive characteristics of different groups under the Kingdom Plantae viz. Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms are discussed.

The Unit II consists of Chapter 5 and deals with description and diversity of gross morphological features of flowering plants which form basis for further studies in plant reproduction, taxonomy, physiology and evolutionary biology. The Unit III includes two chapters in which a general account of the mode of reproduction and its diversity in bacteria, fungi and green plants are described in Chapter 6, whereas in Chapter 7 of this Unit the nature and development of structures and as well the processes associated with sexual reproduction in flowering plants are discussed. Unit IV includes Chapter 8 and it deals with basic aspects of plant Classification systems, technical description of flowering plants and characteristics of selected families. Unit V comprises three chapters and it deals with structure of cell and its constituents in Chapter 9, general account of macromolecules in Chapter 10 and cell cycle in Chapter 11. In Unit VI, comprising Chapter 12, the internal structure and functional organisation of flowering plants are described. Unit VII relates to plant ecology and it includes fundamentals of plant communities and their ecological adaptations, plant succession and ecosystem services.

In this Text Book each unit begins with an overview of the contents dealt within the chapters included in it. A summary is given at the end of every chapter to provide an easy access for the student to make a comprehensive review after going through the chapter. The text is carefully prepared using suitable and commonly available examples and with plentiful coloured illustrative figures to motivate students to take a lively interest in the subject and as well in the learning process. Interdependency of chapters has been emphasized wherever possible and linkages among them have also been made to establish continuity in learning process. Revision questions have been given at the end of every chapter for self assessment by students and to test their learning ability. Glossary is also included at the end of each chapter to facilitate students for their quick reference and an easy understanding of scientific / technical terms used in the particular chapter. We hope that the scientific scope and style of preparation of this text book will stimulate in students a sprit of inquiry, power of critical observation and an ability to understand facts and perceive broad concepts.

One important precaution to students is that they should read this book thoroughly with an analytical approach. Straight forward/ ready answers to some of the model questions included may not be available in the material of the book. Answers/ solutions to such questions could be obtained by a thorough reading of the matter together with analytical thinking and with the help of the teacher. Such model questions are included in this book with a good intention of inculcating the habit of analytical thinking in the students.

It has been a pleasure working with the members of Text book development committee and the authors, who are talented, dedicated, cooperative and critical in their views. We gratefully thank all of them for their diligence and valuable contributions in preparing this Text Book.

Dr. G. Rajendrudu

Dr. M. V. Subba Rao

Contents

UNIT I

DIVERSITY IN THE LIVING WORLD

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

Ernst Mayr (1904-2004)

Ernst Mayr, the Harvard University evolutionary biologist who has been called "The Darwin of the 20th century", was one of the 100 greatest scientists of all times. He almost single-handedly made the origin of species diversity the central question of evolutionary biology that it is today.

Chapter 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 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?

1.1 What is 'Living'?

When we try to define **'living',** we conventionally look for distinctive characteristics exhibited by living organisms. Growth, reproduction, ability to sense environment and mount a suitable response, metabolism, ability to self-replicate, self-organise, interaction and emergence are some unique features of living organisms. Let us try to understand each.

All living organisms **grow**. Increase in mass and increase in number of individuals are twin characteristics of growth. A multicellular organism grows by cell division. In plants this growth by cell division occurs continuously throughout their life span. In animals, this growth is seen only up to a certain age. However, cell division occurs in certain tissues to replace lost cells. Unicellular organisms also grow in size until they divide by cell division. One can easily observe this in *in vitro* cultures by simply counting the number of cells under the microscope. Non-living objects also grow. Mountains, boulders and sand mounds do grow. However, this kind of growth exhibited by non-living objects is by accumulation of material on the surface. In living organisms, growth is from inside. Growth, therefore, cannot be taken as a defining property of living organisms. A dead organism does not grow.

Reproduction, likewise, is a characteristic of living organisms. In multicellular organisms, reproduction refers to the production of progeny possessing features more or less similar to those of parents. Organisms reproduce sexually and by asexual means also. Fungi multiply and spread easily due to the millions of asexual spores they produce. In lower organisms like yeast and Hydra, we observe budding. The fungi, the filamentous algae, the protonema of mosses, all easily multiply by fragmentation. When it comes to unicellular organisms like bacteria, unicellular algae or *Amoeba*, reproduction is synonymous with growth, i.e., increase in number of cells. In single-celled organisms, we are not very clear about the usage of these two terms – growth and reproduction. Further, there are many organisms which do not reproduce (mules, sterile worker bees, infertile human couples, etc). Hence, reproduction also cannot be an all-inclusive defining characteristic of living organisms. Of course, no non-living object is capable of reproduction.

Another characteristic of life is **metabolism**. All living organisms are made of chemicals. These chemicals, small and big, belonging to various classes, sizes, functions, etc., are constantly being made and changed into some other biomolecules. These conversions are chemical reactions or metabolic reactions. There are thousands of metabolic reactions occurring simultaneously inside all living organisms. The sum total of all the chemical reactions occurring in the body of a living organism is metabolism. All plants, animals, fungi and microbes exhibit metabolism. No non-living object exhibits metabolism. An isolated metabolic reaction(s) outside the body of an organism, performed in a test tube is not a living thing but surely a living reaction. So metabolism is a defining feature of all living organisms without exception. Hence, cellular organisation of the body required for metabolism is the defining feature of life forms.

The most obvious and technically complicated feature of all living organisms is the ability to **sense their surroundings** or environment and respond to these environmental stimuli which could be physical, chemical or biological. This response to environmental stimuli is called irritability. We sense our environment through our sense organs. Plants do respond to external factors like light, water, temperature, other organisms, pollutants, etc. Photoperiod affects reproduction in seasonal breeders, both plants and animals. All organisms are 'aware' of their surroundings and this is called **consciousness**. Consciousness therefore, becomes the defining property of living organisms. Human being is the only one who is aware of himself, i.e., has self-consciousness.

When it comes to human beings, it is all the more difficult to define the pointers to the living state. We observe patients lying in coma in hospitals virtually supported by machines which replace heart and lungs. The patient is otherwise brain-dead. The patient has no self- consciousness but still he is living.

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

1.2 Diversity In The Living World

We see a large variety of living organisms around us, potted plants, insects, birds, pets or other animals and plants. There are also several organisms that we cannot see with our naked eye but they are all around us. If we were to increase the area that we make observations, the range and variety of organisms would also increase. If we were to visit a dense forest, we would probably see a much greater number and kinds of living organisms in it. Each different kind of plant, animal or any organism represents a species. The number of species that are known and described ranges between 1.7-1.8 million. This refers to **biodiversity** or the number and types of organisms present on earth. We should remember here that as we explore new areas, and even old ones, new organisms are continuously being identified.

Identification – Nomenclature

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. Such situations lead to a lot of confusion. 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. Thus **nomenclature** is providing a scientific name to an identified organism. Nomenclature is only possible when the organism is described correctly and accurately identified. **Identification** is to determine whether a collected organism is entirely new or already known. In plants, identification can be done by directly comparing the characters with an authentic herbarium specimen or indirectly with the help of keys in floras.

For plants, scientific names are based on agreed principles and criteria, which are provided in **International Code for Botanical Nomenclature (ICBN)**. The scientific names ensure that each organism has only one name. Description of any organism should enable the people all around the world to arrive at the same name. They also ensure that such a name has not been used for any other organisism. 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 followed by biologists all over. 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*. In this name *Mangifera* represents the genus while *indica*, is a particular species, or a specific epithet. Some of the universal rules of nomenclature include:

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

   Name of the author (the person or scientist who gave that name) 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 wheat or rice. The moment we use any of these terms, we associate certain characters with the organism in that group. 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 taxon (pl.: taxa). Here we must recognise that taxa can indicate categories at very different levels. 'Plants' – also form a taxon. 'Wheat' is also a taxon. They represent taxa at different levels.

Hence, based on characteristics, all living organisms can be classified into different taxa. This process of classification is **taxonomy**. Thus, characterisation, identification, classification and nomenclature are the processes that are basic components to taxonomy.

Taxonomy is not something new. Earliest classifications were based on the uses of various organisms because in early days, human beings needed to find sources for their basic needs of food, clothing and shelter.

The study of different kinds of organisms their diversities and also the relationship among them is referred to as **systematics**. The word systematics is derived from the Latin word 'systema' which means systematic arrangement of organisms. Linnaeus used systema naturae as the title of his publication. The scope of systmatics was later enlarged to include identification, nomenclature and classification. Systematics take into account evolutionary relationships between organisms.

1.3 Taxonomic Categories

Classification 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, represents a rank and is commonly termed as taxon. Thus each *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, division (for plants) or phylum (for animals), class, order, family, genus and species. All organisms, including those in the plant and animal kingdoms have species as the lowest category.

1.3.1 Species

Taxonomic studies consider species as a group of individual organisms with fundamental similarities. One should be able to distinguish one species from other closely related species based on the distinct morphological differences. Let us consider *Mangifera indica* (mango), *Solanum tuberosum* (potato) and *Nicotiana tabacum* (tobacco). All the three names, *indica, tuberosum* and *tabacum,* represent the specific epithets. Each genus may have one or more than one specific epithets representing different organisms, but having morphological similarities. For example, *Solanum* includes species like *tuberosum, nigrum* and *melongena.*

1.3.2 Genus

Genus comprises a group of related species which has more characters in common in comparison to species of other genera. We can say that genera are aggregates of closely related species. Among plants for example, potato and brinjal are two different species but belong to the genus *Solanum.*

1.3.3 Family

The next category, Family, has a group of related genera with still less number of similarities as compared to genus and species. Families are characterised on the basis of both vegetative and reproductive features of plant species. Among plants for example, three different genera *Solanum, Nicotiana* and *Datura* are placed in the family Solanaceae.

1.3.4 Order

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 Polemoniales mainly based on the floral characters.

1.3.5 Class

Class includes related orders. For example, in plant kingdom orders like Malvales, Rosales, Polemoniales etc. are included in the class Dicotyledonae.

1.3.6 Division or phylum

Division includes related classes in the case of plants. Classes like Dicotyledonae and Monocotyledonae with a few similar characters are assigned to a higher category called division Spermatophyta (sub-division angiospermae). In the case of animals related classes are included in a phylum.

1.3.7 Kingdom

All plants belonging to various divisions are assigned to the highest category called Kingdom Plantae in the classification system of plants. The Kingdom

Animalia, on the other hand, is distinct, and comprises all animals from various phyla. Henceforth, we will refer to these two groups as plant and animal 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. 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.

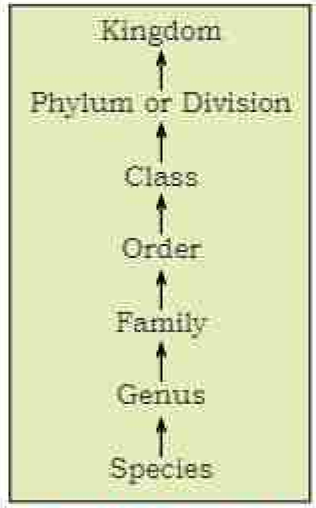


Figure 1.1 Taxonomic categories showing hierarchial arrangement in ascending order

Table 1.1 Organisms with their Taxonomic Caregories

Common Name	Biological Name	Genus	Family	Order	Class	Phylum/ Division
Man	*Homo sapiens*	*Homo*	Hominidae	Primata	Mammalia	Chordata
Housefly	*Musca domestic*	*Musca*	Muscidae	Diptera	Insecta	Arthropoda
Mango	*Mangifera indica*	*Mangifera*	Anacardiaceae	Sapindales	Dicotyledonae	Spermatophyta
Wheat	*Triticum vulgare*	*Triticum*	Poaceae	Poales	Monocotyledonae	Spermatophyta

1.4 Taxonomical Aids

Taxonomic studies of various species of plants, animals and other organisms are useful in agriculture, forestry, industry and in general, in knowing our bio-resources and their diversity. These studies would require correct classification and identification of organisms. Identification of organisms requires intensive laboratory and field studies. The collection of actual specimens of plant and animal species is essential and is the prime source of taxonomic studies.

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

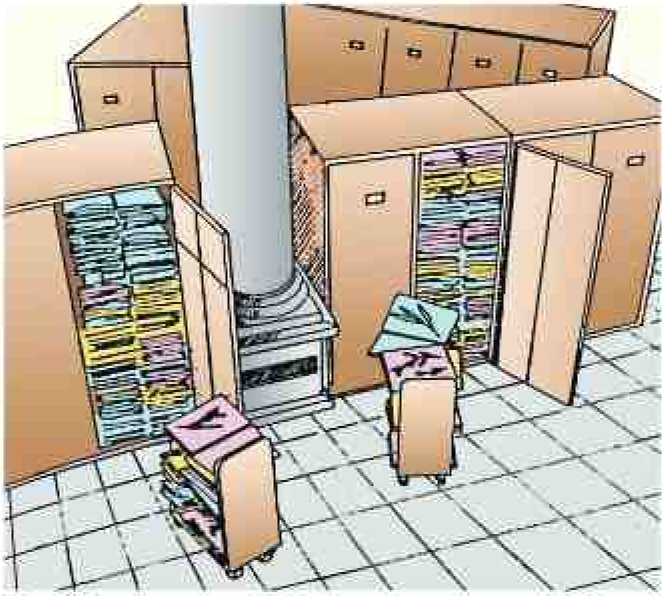


Figure 1.2 Herbarium showing stored specimens

1.4.1 Herbarium

Herbarium is a store house of collected plant specimens that are dried, pressed and preserved on sheets. Further, these sheets are arranged according to a universally accepted system of classification. These specimens, along with their descriptions on herbarium sheets, become a store house or repository for future use (Figure 1.2). The herbarium sheets also carry a label providing information about date and place of collection, English, local and botanical names, family, collector's name, etc. Herbaria also serve as quick referral systems in taxonomical studies. Royal Botanic garden (RBG) at Kew, England has a largest herbarium and is an international centre for plant identification.

In a Digital Herbarium the digital images of the herbarium specimens and the related infirmation is preserved and published on Internet for wider use. This "digital herbarium" is intended to take advantage of newer Internet and digital photography technologies to provide an analogous online facility.

1.4.2 Botanical Gardens

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

1.4.3 Museum

Biological museums are generally set up in educational institutes such as schools and colleges. Museums have collections of preserved plant and animal specimens for study and reference. Specimens are preserved in the containers or jars in preservative solutions. Plant and animal specimens may also be preserved as dry specimens.

1.4.4 Key

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

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

Summary

The living world is rich in variety. Millions of plants and animals have been identified and described but large number still remains unknown. The very range of organisms in terms of size, colour, habitat, physiological and morphological features make us seek the defining characteristics of living organisms. In order to facilitate the study of kinds and diversity of organisms, biologists have evolved certain rules and principles for identification, nomenclature and classification of organisms. The branch of knowledge dealing with these aspects is referred to as taxonomy. The taxonomic studies of various species of plants and animals are useful in agriculture, forestry, industry and in general for knowing our bio-resources and their diversity. The basics of taxonomy like identification, naming and classification of organisms are universally evolved under international codes. Based on the resemblances and distinct differences, each organism is identified and assigned a correct scientific/biological name comprising two words generic name (Genus) and specific name (Species). Live specimens of plants are found in botanical gardens. Taxonomists also prepare and disseminate information through manuals and monographs for further taxonomic studies. Taxonomic keys are tools that help in identification based on characteristics. Herbaria and museums contain dead but preserved specimens.

GLOSSARY

Budding: It is a method of asexual reproduction in unicellular organisms where new individuals develop from parent as an outgrowth of mature organism.

Consciousness: It is the ability of organisms to sense the surroundings.

Fission: It is a method of asexual reproduction in unicellular organisms, involving the division of nucleus and cytoplasm into two or more parts to form new individuals.

Flora: It contains the actual account of habitat, distribution and systematic listing of plants of a given area.

Fragmentation: It is a method of vegetative reproduction commonly found in filamentous forms where the plant body breaks up into smaller pieces or fragments and each fragment develops into a new plant.

Growth: It is a permanent and irreversible increase in the size of a living organism generally accompanied by a change in dry weight.

In vitro: Outside a living organism and in an artificial environment

Manual: It is a small book specially designed for ready reference.

Metabolism: It refers to the sum total of all the chemical reactions occurring in the body of an organism. The constructive metabolic process in which complex molecules are formed from simpler molecules is called anabolism. The destructive metabolic process in which complex molecules are broken down into simpler molecules is called catabolism.

Photoperiodism: The influence of the relative duration of day and night on the flowering response of plants is called photoperiodism.

Phylogeny: It is the evolutionary history of an organism or a group.

Reproduction: It is the production of progeny possessing features more or less similar to those of parents

Spore: It is an asexual unicellular reproductive unit which directly develops in to a new plant. In higher plants, spores develop following meiosis in spore mother cell and they are called meiospores. In Thallophytes, they may be formed following mitosis when they are called mitospores.

Taxon: Any unit or category in a taxonomic system is called a taxon.

Taxonomic hierarchy: It is the arrangement in which the organisms are grouped into an ascending series of successively large and broader categories so that the lower groups are always included in those that are higher in hierarchy.

VERY SHORT ANSWER TYPE QUESTIONS

1. What does ICBN stand for?
2. What is flora?
3. Define metabolism. What is the difference between anabolism and catabolism?
4. Which is the largest botanical garden in the world? Name a few well known botanical gardens in India.
5. Define the terms couplet and lead in taxonomic key.
6. What is meant by manuals and monographs?
7. What is systematics?
8 Why are living organisms classified?
9. What is the basic unit of classification? Define it.
10. Give the scientific name of Mango. Identify the generic name and specific epithet.
11. What is growth? What is the difference between the growth in living organisms and growth in non-living objects?

SHORT ANSWER TYPE QUESTIONS

1. What is meant by identification and nomenclature? How is a key helpful in the identification and classification of an organism?
2. What are taxonomical aids? Give the importance of herbaria and museums
3. Define a taxon. Give some examples of taxa at different hierarchial levels
4. How are botanical gardens useful in conserving biodiversity? Define the terms Flora, manuals, monographs and catalogues.
5. Explain binomial nomenclature.

LONG ANSWER TYPE QUESTIONS

1. What is meant by 'living'? Give a detailed account of any four defining features of life forms.
2. Define the following terms with examples:

   (i) Class

   (ii) Family

   (iii) Order

   (iv) Genus

   (v) Division

EXERCISES

1. Some of the properties of tissues are not constituents of their cells. Give two examples to support the statement.
2. What do we learn from identification of individuals and populations?
3. Given below is the scientific name of Mango. Identify the correctly written name.

   Mangifera Indica

   Mangifera indica
4. Can you identify the correct sequence of taxonomical categories?
   (a) Species, Order, Division, Kingdom
   (b) Genus, Species, Order, Kingdom
   (c) Species Genus Order Phylum
5. Define the following terms:

   (i) Species (ii) Class (iii) Family

   (iv) Order (v) Genus
6. Illustrate the taxonomical hierarchy with suitable examples of a plant .
7. What are the distinctive characteristics exhibited by living organisms?. Describe them in brief.
8. Life forms exhibit 'unity in diversity' – Discuss with your teacher.
9. List out the principles followed to provide scientific names for newly found organism?

CHAPTER 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 was used till very recently. 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. This system did not distinguish between the eukaryotes and prokaryotes, unicellular and multicellular organisms and photosynthetic and non-photosynthetic organisms. This system included bacteria, algae, fungi, bryophytes, pteridophytes, gymnosperms and angiosperms under plants. The character that unified this whole kingdom was that all the organisms included had a cellwall in their cells. This placed together groups which widely differed in other characteristics. It brought together the prokaryotic bacteria and the blue-green algae with other groups which are eukaryotic. It

TABLE 2.1 Characteristics of the Five Kingdoms

Characters	Five Kingdoms				
	Monera	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellulosic (Polysaccharide + amino acid)	Present in some	Present (without cellulose)	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multiceullar/ loose tissue	Tissue/ organ	Tissue/organ/ organ system
Mode of nutrition	Autotrophic (chemosyn-thetic and photosynthetic) and Hetero-trophic (sapro-phytic/para-sitic)	Autotrophic (Photosyn-thetic) and Hetero-trophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosyn-thetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

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, through they also showed a characteristic difference in their wall composition-the fungi had chitin in their wall while the green plants had a cellulosic cellwall. Hence the two kingdom classification used for a long time was found inadequate. A need was also felt for including, besides gross morphology, other characteristics like cell structure, nature of wall, mode of nutrition, habitat, methods of reproduction, evolutionary relationships etc. Classification systems for living organisms have hence, undergone several changes over time. Though plant and animal kingdoms have been a constant under all different systems, the understanding of what groups or which 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 time.

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, thallus organisation, mode of nutrition, reproduction and phylogenetic relationships. Table 2.1 gives a comparative account of different characteristics of the five kingdoms.

Let us look at this **five kingdom classification** to understand the issues and considerations that influenced the classification system. All prokaryotic organisms were grouped together under kingdom Monera and the unicellular eukaryotic organisms were placed in the kingdom Protista. Kingdom Protista has brought together *Chlamydomonas*, *Chlorella* (earlier placed in plant kingdom) with Paramoecium and Amoeba (earlier placed in animal kingdom). It has put together organisms which in earlier classifications were placed in different kingdoms. The Fungi were placed in a separate kingdom. 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.

In this chapter we will study characteristics of Kingdoms Monera, Protista and Fungi of the Whittaker system of classification. The Kingdom Plantae will be dealt with separately in Chapter 4 and the kingdom Animalia in zoology text book separately.

2.1 Kingdom Monera

All prokaryotes like Archaebacteria, Eubacteria, Mycoplasma and Actinomycetes etc. are included in Kingdom Monera.

2.1.1 Archaebacteria

These are special Monerans 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. The cell wall does not contain peptidoglycan but contains pseudomurein. The cell membrane contains branched chain lipids. This feature is responsible for their survival in extreme conditions. Methanogens are also 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.

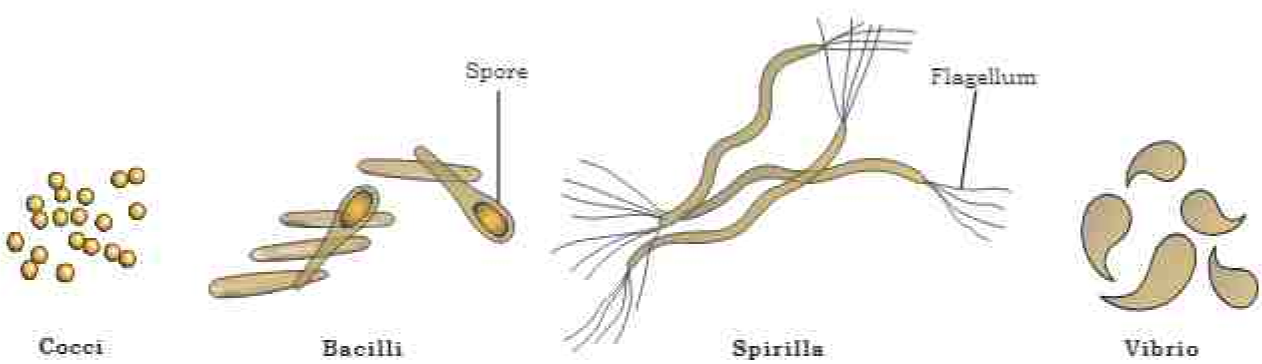


Figure 2.1 Bacteria of different shapes

2.1.2 Eubacteria

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

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).

The bacteria are characterized by the presence of a rigid cell wall consisting of **peptidoglycan**, also called murein or mucopeptide. The infoldings of the cell membrane are called **mesosomes**. The genetic material is basically naked not enveloped by nuclear membrane as in all prokaryotes. Cell organelles are not found in bacteria and all prokaryotic cells except **ribosomes**. Motile bacteria contain one or more flagella.

Though the bacterial structure is very simple, they are very complex in behavior. Compared to many other organisms, bacteria as a group show the most extensive **metabolic diversity**. Some of the bacteria are **autotrophic** i.e they synthesize their own food from simpler inorganic substrates. They may be photosynthetic autotrophic or chemosynthetic autotrophic. The vast majority of bacteria are **heterotrophs** i.e they do not synthesize their own food but depend on other organisms (parasites) or on dead organic matter (saprophytes) for food.

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, aquatic or terrestrial algae. They are the most primitive organisms showing oxygenic photosynthesis. The protoplasm of cyanobacterial cell is differentiated into a central colourless centroplasm with chromatin material and peripheral pigmented chromoplasm. The colonies and trichomes or filaments 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*. They form hormogonia (fragments) or thick walled akinetes during asexual reproduction. Flagella are absent in vegetative or reproductive phases. The red colour of red sea is due to *Trichodesmium erythrium* present in it.

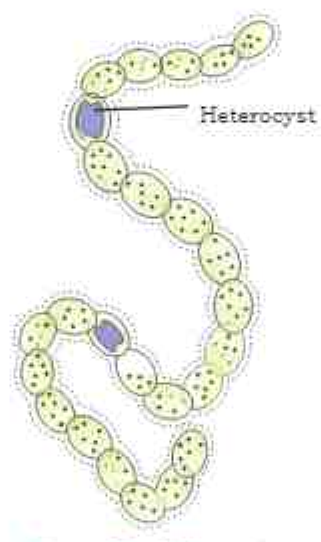


Figure 2.2 A filamentous blue-green alga-*Nostoc*

Chemosynthetic autotrophic bacteria oxidise various inorganic substances such as nitrates, nitrites and ammonia and use the released energy for ATP production. They play a great role in recycling nutrients like nitrogen, phosphorus, iron and sulphur.

The majority of heterotrophic bacteria are saprophytes or **decomposers**. They have a significant impact on human affairs. They are helpful in making curd from milk, production of antibiotics, fixing nitrogen in legume 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.

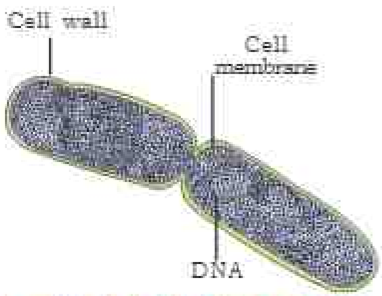


Figure 2.3 A dividing bacterium

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

2.1.3 Mycoplasmas

The **Mycoplasmas** are organisms that completely lack a cell wall and are pleomorphic. They are the smallest living cells known and can survive without oxygen. Many mycoplasmas are pathogenic in animals and plants. They were previously called pleuropneumonia like organisms. They cause **witches broom** in plants, **pleuropneumonia** in cattle and **mycoplasmal urethritis** in humans.

2.1.4 Actinomycetes

The **Actinomycetes** are branched filamentous bacteria which form radiating colonies in culture. The cellwall contains mycolic acid. Most of them are saprophytic and decomposers. Some actinomycetous members like *Mycobacterium* and *Corynebacterium* are parasites. A number of **antibiotics** are produced by actinomycetous members especially the genus *Streptomyces*.

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 cells contain a well defined nucleus and other membrane-bound organelles. Some have flagella or cilia. Protists reproduce asexually by fission or by the formation of spores 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, epitheca over hypotheca 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'** or kieselguhr. Being gritty, this soil is used in polishing, filtration of oils and syrups. Diatoms are the chief 'producers' in the oceans.

Diatoms are divided into two types based on their structural symmetry: the centrale diatoms are radially symmetrical and pennales are bilaterally symmetrical. They reproduce asexually by binary fission and sexually by the formation of gametes. The auxospores are formed as a result of sexual reproduction and they are rejuvenatory spores.

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. The flagella produce spinning movements, so these protists are called whirling whips. The nucleus has condensed chromosomes even in interphase and the chromosomes do not have histones. This is called mesokaryon. Some marine dinoflagellates like *Noctiluca* show bioluminescence. Very often red dinoflagellates like *Gonyaulax* undergo such rapid multiplication that they make the sea appear red (**red tides in Medeterranian sea)**. 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. The anterior part of the cell bears an invagination consisting of cytostome (cell mouth), cytopharynx (gullet) and reservoir. It consists of a photosensitive stigma or eye spot on the membrane of the

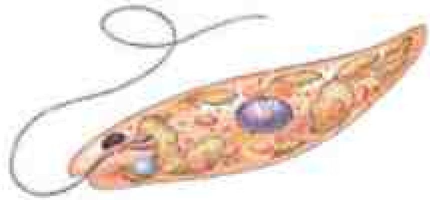


Figure 2.4 Euglena

reservoir. 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 2.4). The reproduction is by longitudinal binary fission and a palmella stage is found in *Euglena*.

2.2.4 Slime Moulds

Slime moulds are saprophytic protists. The multinucleated mass of protoplasm is surrounded by a plasamamembrane. 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. They do not contain cellwall. The protoplasm is surrounded by plasma membrane. There are four major groups of protozoans.

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

Figure 2.5 Paramecium

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: *Paramecium* (Figure 2.5).

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 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. When the bread develops a mould or the orange rots it is because of fungi. The common edible mushroom and toadstools are also fungi. White spots seen on mustard leaves are due to a parasitic fungus (*Albugo*). 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. We keep food in the refrigerator 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. The reserve food material is **glycogen** and oil.

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 **mycorrhizae.**

Reproduction in fungi can take place by **vegetative** means– fragmentation, fission and budding. **Asexual** reproduction is by spores called conidia or sporangiospores or zoospores, and **sexual** reproduction is by oospores, ascospores and basidiospores. The various spores are produced in distinct structures called fruiting bodies. The sexual cycle involves the following three steps:

(i) Fusion of protoplasms between two motile or non-motile gametes called **plasmogamy**.

(ii) Fusion of two nuclei called **karyogamy**

(iii) **Meiosis** in zygote resulting in haploid spores.

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

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

(b) *Aspergillus*

(a) *Mucor*

(c) *Agaricus*

Figure 2.6 Fungi

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. They are also called **algal fungi**. The mycelium is aseptate and coenocytic. Asexual reproduction takes place by zoospores (motile) or by aplanospores (non-motile). These spores are endogeneously produced in sporangium. Zygospores are formed by fusion of two gametes. These gametes may be similar (**isogamous**) or dissimilar (**anisogamous or oogamous**) in morphology. Some common examples are *Mucor* (Figure 2.6a), *Rhizopus* (the bread mould) and *Albugo* (the parasitic fungi on mustard).

2.3.2 Ascomycetes

Commonly known as **sac-fungi**, the ascomycetes are unicellular, e.g., yeast (*Saccharomyces*) or multicellular, e.g., *Penicillium*. They are saprophytic, decomposers, parasitic or coprophilous (growing on dung). Mycelium is branched and septate. The asexual spores are conidia produced exogenously on the special hyphae called conidiophores. Conidia on germination produce mycelium. During sexual reproduction a dikaryotic phase with ascogenous hyphae is formed. Sexual spores are called ascospores which are produced endogenously in sac like asci (singular ascus). Karyogamy and meiosis occur in asci. These asci are arranged in different types of fruiting bodies called **ascocarps**. The globose ascocarp without opening is called cleistothecium. The flask shaped ascocarp with an apical opening is called perithecium and cup or saucer shaped ascocarp is called apothecium. Some examples are *Aspergillus* (Figure 2.6b), *Claviceps, Penicillium 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 are commonly known as club fungi. 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 primary mycelium of different strains or genotypes. The resultant structure is dikaryotic and produces a dikaryotic secondary mycelium which ultimately gives rise to basidia. 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 2.6c), *Ustilago* (smut), *Puccinia* (rust fungus), Polyporus (bracket fungus), Lycoperdon (puff-ball).

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 has 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,* (early blight) *Colletotrichum* (redrot) and *Trichoderma.*

2.4 Kingdom Plantae

Kingdom **Plantae** includes all eukaryotic chlorophyll-containing organisms commonly called plants. A few members are partially heterotrophic such as the insectivorous plants or parasites. Bladderwort and Venus fly trap are examples of insectivorous plants and *Cuscuta* is a parasite. The plant cells have eukaryotic structure with prominent chloroplasts and cell wall is mainly made of cellulose.

The reserve food is generally starch and they show absorptive mode of nutrition. **Plantae includes algae, bryophytes, pteridophytes, gymnosperms and angiosperms.** Further details of these are included in Chapter 4 of this Unit.

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.

2.6 Six Kingdom Classification

Carl Woese proposed six kingdom classification. He replaced kingdom Monera with two distinct kingdoms, Bacteria and Archaea. Thus the six kingdoms include **Bacteria, Archaebacteria, Protista, Fungi, Plantae and Animalia**.

Using a small subunit of ribosomal RNA (16s rRNA) as a marker for studying evolutionary relationship, Carl Woese and coworkers observed that the six kingdoms naturally cluster into **three main categories or Domains**. These domains are **Bacteria, Archaea and Eukarya** and are believed to be originated from a common ancestral group of early living organisms (progenote). Archaea and Eukarya are more closely related to each other than to bacteria

2.7 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.

2.7.1 Viruses

These did not find a place in classification since they are not 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. Once they infect a cell they take over the machinery of the host cell to replicate themselves, killing the host.

The name virus that means venom or poisonous fluid was given by **Pasteur**. Viruses are obligate parasites.

A virus contains nucleic acid and protein. The nucleic acid is infectious It could be either RNA or DNA. No virus contains both RNA and DNA. The protein part forms a cover or coat called capsid and encloses the nucleic acid core. Tobacco mosaic virus (TMV) and Human Immuno Virus (HIV) are examples for RNA containing viruses (Fig. 2.7a). Viruses which infect bacteria are called bacteriophages and contain DNA as their genetic material (Fig. 2.7 b).

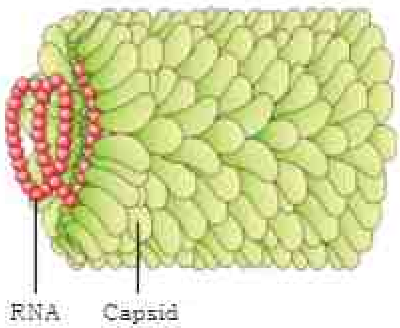


Figure 2.7 (a) Tobacco Mosaic Virus (TMV)

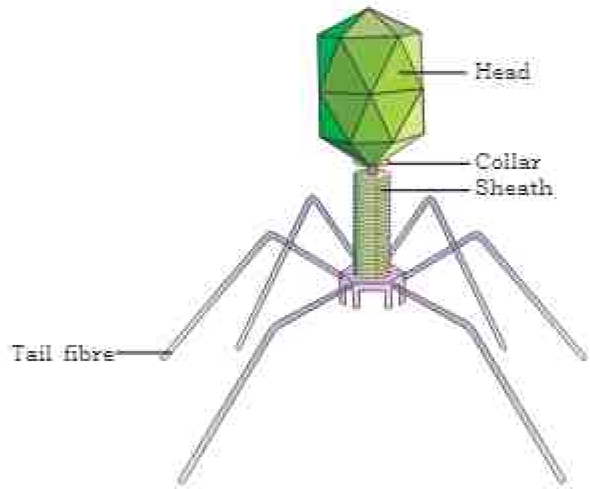


Figure 2.7 (b) Bacteriophage

2.7.2 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 viroid was of low molecular weight.

2.7.3 Prions

There are some infectious agents which possess only proteins but not nucleic acids. Such agents are called prions. They cause 'scrapie disease' of sheep and 'mad cow disease'.

2.7.4 Lichens

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

Summary

Biological classification of plants and animals was first proposed by Aristotle on the basis of simple morphlogical characters. Linnaeus later classified all living organisms into two kingdoms – Plantae and Animalia. Whittaker proposed an elaborate five kindgom 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 structure 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 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. Lichens and some acellular organisms like viruses, viroids and prions are not included in the five kingdom system of classification.

GLOSSARY

Antibiotics: These are the chemical substances produced by micro-organisms which inhibit or kill other microbes.

Aplanospore: A non-motile, thin-walled spore.

Ascocarp: It is the fruiting body of ascomycetous fungi.

Ascospore: A spore produced by an ascus (of an ascocarp)

Autotrophs: They are the organisms which synthesize their own food from inorganic substrates.

Basidiocarp: It is the fruiting body of basidiomycetous fungi.

Basidiospore: A spore produced by a basidium (of a basidiocarp).

Biogas: It is produced by the anaerobic fermentation of biomass like dung of the animals.It consists of 50-70 percent methane, 30-40 percent carbon dioxide and traces of hydrogen,nitrogen and hydrogen sulphide.

Bioluminiscence: It is the emission of light from living organisms.

Chemoautotrophs: They synthesize their food by utilizing the energy released by oxidation of various inorganic substances.

Eukaryotes: Organisms that have "true" nucleus containing genetic material (DNA) organized in the form of chromatin and also have several membrane-bound organelles in their cells.

Habitat: It is the natural area or locality where an organism is commonly found.

Haplontic: A life cycle in which the haploid phase predominates and the diploid stage is limited to the zygote.

Herb: It is a small delicate plant without any woody part.

Heterotrophs: They do not synthesize their own food but depend on other organisms or on dead organic matter for food.

Holophytic nutrition: Autotrophic nutrition is also called holophytic nutrition.

Holozoic nutrition: It is obtaining nourishment by the ingestion of solid organic food matter.

Mycorrhizae: They are formed by an association between fungal members and roots of vascular plants. They increase phosphate absorption by roots.Hence they are used as bio-fertilizers.

Nitrogen fixation: It is the process through which the dinitrogen from the atmosphere is converted into fixed form like ammonia or nitrate.

Obligate parasite: A parasite that cannot lead an independent non-parasitic existence, in contrast to facultative parasite.

Oospore: A fertilised female cell or zygote, especially one with thick chitinous walls.

Palmella stage: A colonial aggregate of immobile non-flagellated individual cells occurring in the life cycle of some flagellated green algae or plantlike flagellates.

Parasites: They depend on other organisms for food.

Photoautotrophs: They synthesize their food from simpler substrates by utilizing sunligt energy.

Planktons: These are small organisms which float passively in water currents.

Plasmodium: The multinucleate mass of protoplasm of slime moulds with plasmamembrane is called plasmodium.

Pleomorphic: when an organism occurs in more than one independent form in the life history, it is said to be pleomorphic.

Predator: The animal which kills another animal for food.

Prokaryotes: Organisms that lack a nucleus or any other membrane-bound organelles in their cells. Their genetic material is not organized in the form of chromatin.

Saprophytes: They depend on dead organic matter for food.

Shrub: It is a woody perennial plant with bushy appearance.

Spore: It is a reproductive structure that is adapated for dispersal and surviving for extended periods of time in unfavorable conditions.

Symbionts: An association between two dissimilar organisms where both the partners are mutually benefited is called symbiosis and the organisms are called symbionts.

Tree: It is a large woody perennial plant.

Zoospre: An asexual spore produced by certain algae and some fungi, capable of moving about by means of flagella.

VERY SHORT ANSWER TYPE QUESTIONS

1. What is the nature of cell-walls in diatoms?
2. How are Viroids different from Viruses?
3. What do the terms phycobiont and mycobiont signify?
4. What do the terms 'algal bloom' and 'red tides' signify?
5. State two economically important uses of heterotrophic bacteria.
6. What is the principle underlying the use of cyanobacteria in agricultural fields for crop improvement?
7. Plants are autotrophic. Name some plants which are partially heterotrophic.
8. Who proposed five kingdom classification? How many kingdoms of this classification contain eukaryotes?
9. Give the main criteria used for classification by Whittaker.
10. Name two diseases caused by Mycoplasmas.
11. What are slime moulds ? Explain what is meant by plasmodium with reference to slime moulds.

SHORT ANSWER TYPE QUESTIONS

1. What are the characteristic features of Euglenoids?
2. What are the advantages and disadvantages of two kingdom classification?
3. Give the salient features and importance of Chrysophytes.
4. Give a brief account of Dinoflagellates.
5. Write the role of Fungi in our daily life.

LONG ANSWER TYPE QUESTIONS

1. Give the salient features and comparative account of different classes of Fungi studied by you.
2. Describe briefly different groups of Monerans you have studied.
3. Enumerate the salient features of different groups in protista.

EXERCISES

1. State two economically important uses of:

   (a) Heterotrophic bacteria

   (b) Archaebacteria
2. Give a comparative account of the classes of Kingdom Fungi on the basis of the following:

   (i) mode of nutrition

   (ii) mode of reproduction
3. Give a brief account of viruses with respect to their structure and nature of genetic material. Also name four common viral diseases.
4. Organise a discussion in your class on the topic – Are viruses living or non- living?
5. Suppose you accidentally find an old preserved permanent slide without a label and in your effort to identify it, you place the slide under microscope and observe the following features :

   a. unicellular body,

   b. well defined nucleus,

   c. biflagellate condition - one flagellum lying longitudinally and the other transversely.

   What would you identify it as ? Can you name the kingdom it belongs to ?
6. Polluted water bodies have usually high abundance of plants like Nostoc and Oscillatoria. Give reasons.
7. Cyanobacteria and heterotrophic bacteria have been clubbed together in Eubacteria of kingdom Monera as per the five kingdom classification, eventhough the two are vastly different from each other. Is this grouping of the two types of taxa in the same kingdom justified ? If so why ?
8. What observable features in *Trypanosoma* would make you classify it under kingdom Protista ?
9. At a stage of their life cycle, ascomycetous fungi produce the fruiting bodies like cleistothecium, perithecium or apothecium. How are these three types of fruiting bodies differ from each other ?

Chapter 3

Science of Plants - Botany

3.1 Origin
3.2 Development
3.3 Scope
3.4 Branches

The study of living organisms is called 'Biology'. In Greek language *'BIOS'* means **life** and *LOGOS'* means **discourse.** The foundation for Biology was laid from the time human beings started observing the living things around them. Biology is the story of evolution of living organisms on earth. Biology is fast developing like many other sciences. It is not an exaggeration to state that what has been progressed in biology during the past three decades is far greater than what has been made during the past twenty centuries. This is made possible after the advent of new biophysical and biochemical techniques like Chromatography, Centrifugation, Electrophoresis, Spectroscopy and several other modern techniques into biology. In fact, we are now in the **Golden Era of Biology.** In this chapter, the origin of **Botany** as a distinct discipline of biology and its development, scope and division into specific branches are presented in brief.

3.1 Origin

Biology in relation to plants is generally called 'Plant Science' but particularly emerged as 'Botany'. In Greek language, 'Bous' refers to cattle and 'Bouskein' to cattle feed. In course of time 'Bouskein' gave rise to 'Botane' which gave birth to the present widely used title 'Botany'.

3.2 Development

Observation and usage of plants began in ancient times, ever since human beings started depending on them for food, shelter, cloths and medicines etc. These evidences suggest that elaborate information was gathered by people of ancient times about plants used for food and medicines, even before the beginning of the Christian era, making Botany one of the oldest sciences. ***Egyptians*** and ***Assyrians*** (4000 B.C) recorded information related to crop plants and fruit trees in the form of pictures *(Hieroglyphics)*. By 2500 B.C the **Chinese** learned how to cultivate plants. In our country, the **'Atharvana Veda'** written during 2000 B.C contains wealth of information on several medicinal plants and their uses. During 1300 B.C **Parasara** in his book ***'Krishi Parasaram'***, the oldest book on agriculture, dealt about agriculture and about weeds. He also wrote another book ***'Vrikshayurveda'*** and described different types of forests, external and internal characters of plants including medicinal plants. Greek philosophers like **Socrates, Plato** and **Aristotle** were responsible for the development of Botany into a science. **Theophrastus** (340 B.C), regarded as **'Father of Botany'** described the external and internal characters of some 500 plants in his book ***de Historia Plantarum.***

Experimental studies on plants living in natural surroundings had acquired significance during the Renaissance period of **16^{th} and 17^{th} centuries,** the period of herbalists. They identified and described medicinal palnts in their books called herbals. During this period **Gaspard Bauhin** (1623) published the description and identification of 6000 plants introducing Binomial Nomenclature for the first time.

Botany emerged as a specific science during the **17^{th} century** with the discovery of the cell by **Robert Hooke** (1665 who published the book **'Micrographia'**); study of bacterial cell for the first time in living condition by **Anton Van Leeuwenhoek'** (1675); anatomical study of plant tissues by **Nehemiah Grew & Marcello Malpighi** and discovery of sexual reproduction in plants by **Camerarius** (1694).

In **18^{th} century,** there was progress in the areas of Taxonomy and Physiology. The Sweedish Botanist **Carolus Von Linnaeus** popularised the **Binomial Nomenclature System** and also proposed the **sexual system of classification.** During this period, contemporary physiologists, **Stephen Hales** observed for the first time conduction of water through xylem by root pressure and **Joseph Priestly** discovered the absorption of toxic gases and release of pure gas by green plants.

During the **19^{th} Century,** there was considerble progress in different branches of Botany. Hybridization experiments on Pea plants conducted by **Grogor Johann Mendel** (Czechoslovakia) marked the beginning of Genetics. He introduced the laws of inheritance (1866) and became popular as the 'Father of Genetics'. Ecological studies began with the works of scientists like **Haeckel** and others. Different types of plant classification were proposed by the famous Taxonomists, **de Candolle, Endlicher, Bentham** and **Hooker**. Charles Darwin put forward the 'Theory of evolution'. **Buchner** (1898) discovered the enzyme zymase in yeast cells.

During **20th Century,** rapid development was apparent in different disciplines of Botany, in particular Cell Biology. Discoveries or innovations viz., mutations in plants by **Hugo de Vries** (1901); role of chromosomes in heredity by **Suttion and Boveri** (1902); double helical structure of DNA by **Watson and Crick** (1953); discovery of the genetic nature of RNA by **Frankel Conrat** (1956); artificial synthesis of the gene by **H.G. Khorana**; technique of plant tissue culture by **Hanning, Shimakura, Skoog, White, Nitsch, Maheswari** and others were significant developments in Botany during this period. Electron microscope was invented by Knoll and Ruska during this century.

Twentieth Century also witnessed great advances in Plant Physiology through pioneering contributions viz., identification of auxins by **F.W. Went** (1928); discovery of citric acid cycle, also called Tricarboxylic acid (TCA) cycle by **Hans Krebs** (1937), crystallization of the enzyme urease by **J.B. Sumner**; understanding the mechanism of light reaction of photosynthesis by **Robert Hill, Ruben, Arnon, Emerson** and others; discovery of the C_3-pathway of Carbon assimilation by **Melvin Calvin, Benson** and **Bassham** and C_4-pathway by **Hatch** and **Slack** (1976). Indian Scientist **Prof. V.S. Rama Das** and his students also made significant contributions to C_4-photosynthesis.

Scientists like **Wodehouse, P.K.K. Nair, C.G.K. Ramanujam** developed the science of pollen namely Palynology and modern taxonomists viz. **Bessey, Rendle, Hutchinson, Takhtajan, Cronquist** have proposed the phylogenetic classifications during the 20th Century.

3.3 Scope

From ancient times, man realized the importance of plants and their products. Man's domestication of plants (crop cultivation) refers to origin of human civilization. The problems like decreasing resources and increasing population could be solved to great extent by enhancing crop yield through Green Revolution and also by developing disease, pest resistance crops, utilizing the **principles of biotechnology**.

Progress in applied fields like Agriculture, Forestry, Horticulture, Floriculture etc., is possible through experiments in **hybridization and genetic engineering**. New techniques of **plant breeding** are useful to develop hybrid varieties in crop plants like rice, wheat, maize, sugarcane etc.

Knowledge of **Plant Physiology**, for example, the role of minerals in plant nutrition is useful in rational usage of chemical fertilizers and control of mineral deficiencies to improve agricultural productivity. Similarly, the knowledge on the role of plant hormones in plant growth and development is highly significant to improve agriculture and horticulture through herbicidal control of weeds, breaking of seed dormancy, enhancement of shelf life period of leafy vegetables like spinach, artificial ripening of fruits like apple, banana and watermelons and rooting of stem cuttings for vegetative propagation.

Knowledge gained through researches in **Phytopathology** is helpful in the prevention and eradication of several plant diseases. Experiments in **tissue and organ culture** have made it possible to produce large number of plants in the laboratory (micro propagation) within a short duration of time. Industries like cloth mills, paper mills, ayurvedic pharmacies, sugar mills etc., could be developed due to Botany.

Knowledge of plants which yield commercially important products viz., timber, fibres, beverages like coffee and tea, condiments, rubber, gums, resins, dyes, essential and aromatic oils is of great importance for their exploitation. Studies on many other plants viz., *Arnica, Cinchona, Neem, Datura, Digitalis, Rauwolfia, Withania, Ocimum, Belladona, Aloe* etc., having medicinal value are also important to explore them for human health care.

Production of antibiotics (Penicillin), bioinsecticides, single cell proteins (*Spirulina, Chlorella*) etc., is also made possible by thorough study of these product yielding plants. Fuels like coal, coke, gasoline, petrol etc., are past formed products of fossil plants. Recently bio-diesel is also produced from **petro-plants**, such as *Jatropa* and *Pongamia* which are rich in hydrocarbons.

The scope of Botany also extends to solve environmental issues viz., control of green house effect by intensive tree plantation and soil pollution by bio-remediation, recycling of nutrients by saprophytic organisms, usage of biofertilizers (*Azolla, Nostoc, Anabaena, Rhizobium* etc.) to avoid soil and water pollution caused by chemical fertilizers and prevention of soil erosion by sand binding plants. Usage of algae (*Chlorella*) as food for astronauts in space research programmes and extraction of iodine, agar agar etc., from several sea weeds also indicate the wide scope of Botany for the contemporary world and in the present day context.

3.4 BRANCHES

Biology, basing on the application of physical and chemical principles, developed into new disciplines (branches) of science viz., **Biophysics, Biochemistry** and **Molecular Biology etc.,** pertinent to both plant and animal sciences. During the 19th and 20th centuries, Botany expanded rapidly and accumulated vast amount of knowledge in various aspects of plant life. This resulted in division of Botany into different specific branches to make an easy study. Some of the branches are outlined below:

Branches of Botany

1. **Morphology** deals with the study and description of different organs of a plant. It is a fundamental requisite for classification of plants. It can be divided into two parts.

   a. **External Morphology** is the study and description of external characters of plant organs like root, stem, leaf, flower, fruit and seed etc.

   b. **Internal Morphology** is the study of internal structure of different plant organs. It has two branches.

      i. **Histology** is the study of different tissues present in the plant body.

      ii. **Anatomy** deals with the study of gross internal details of plant organs like root, stem, leaf, flower etc.

2. **Cytology or Cell Biology** is the study of structure and functions of cell and cell organelles and their multiplication.

3. **Embryology** deals with the study of development of male and female gametophytes, formation of gametes, process of fertilization, development of embryo, endosperm and seed.

4. **Palynology** is the study of the development, structure and all other aspects related to microspores or pollen grains.

5. **Taxonomy or Systematic Botany** deals with the identification, nomenclature and classification of plants into related groups on the basis of information obtained from different fields of Botany.

6. **Physiology** deals with the study of different vital activities of plants like absorption of water and minerals, photosynthesis, respiration, nitrogen metabolism, growth etc.

7. **Plant Ecology** is the study of reciprocal relationship between the plants and the environment in which they are living.

8. **Palaeobotany** deals with the study of fossil plants. It helps us in understanding the course of evolution in plants.

9. **Genetics** deals with all aspects related to genes such as their structure, synthesis, inheritance, mutation etc.

10. **Phytogeography** is the study of geographical distribution of plants in the past and present.

11. **Plant pathology** is the study of causes, symptoms and methods of control of plant diseases.

12. **Phycology** is the study of all aspects related to algae which are chlorophyllous and autotrophic thallophytes.

13. **Mycology** deals with the study of fungi which are non-chlorophyllus heterotrophic thallophytes.

14. **Lichenology** is the study of lichens which are a special group of plants in which an algal member and a fungal member live together as symbionts.

15. **Bryology** is the study of bryophytes (amphibians of plant kingdom).

16. **Pteridology** is the study related to pteridophytes, also known as vascular cryptogams.

Summary

The study and observation of plants began from ancient times. Elaborate information was gathered about crop plants and medicinal plants by people of ancient times, even before the beginning of Christian era. Experimental studies in Botany were started during the renaissance period of 16th and17th centuries. It emerged as a specific science, Botany, during 17th century with the development of allied sciences. During 18th century, there was progress in the areas of Taxonomy and Physiology. During 19th century, there was a considerable amount of progress in different branches of Botany. During the 20th century there was a rapid progress of the different branches of Botany.

Botany has several achievements to its credit as on this day. The problems like decreasing resources and increasing population could be solved to a great extent by enhancing crop yield through green revolution. Applied fields like Agriculture, Forestry, Horticulture, Floriculture etc. have recorded great progress through experiments in hybridization and genetic engineering. The efforts made in plant physiology helped the development of agriculture by providing knowledge about the role of minerals and hormones in plant growth. Researches made in plant pathology have helped the prevention and eradication of several plant diseases. Beverages, timber, fibres, condiments, rubber, gums, resins, dyes, medicines etc., are the products of plants. Bio-diesel is produced from plants like *Jatropa* and *Pongamia*. Some bacteria and blue-green algae are used as bio-fertilizers. Agar-agar and iodine are also obtained from plants.

To facilitate an easy study and understanding, Botany is divided into different branches.

GLOSSARY

Agar-agar: It is an inert polysaccharide extracted from red algae. It is an ingredient of semisolid culture media.

Beverages: These are refreshing drinks which may be non-alcoholic or alcoholic.

Bio-fertilizers: They represent nutrient input for plant growth which is of biological origin.

Herbals: These are books containing the description of medicinal plants.

Plant tissue and organ culture: It is the technique of growing, culturing and maintaining cells, tissues and organs *in vitro* on an artificial nutrient medium

Single cell proteins: Dried biomass of a single species of microbe that can be used as a protein source in the diet.

Spices and condiments: Spices are the substances used to flavor different food products and to increase the flow of gastric juices. Condiments are the spices usually added to food after it has been cooked.

VERY SHORT ANSWER TYPE QUESTIONS

1. Explain how the term Botany has emerged.
2. Name the books written by Parasara and mention the important aspects discussed in those books.
3. Who is popularly known as father of Botany? What was the book written by him?
4. Who are Herbalists? What are the books written by them?
5. What was the contribution of Carolus Von Linnaeus for the development of plant taxonomy?
6. Why is Mendel considered as the father of Genetics?
7. Who discovered the cell and what was the book written by him?
8. What is Palaeobotany? What is its use?
9. Name the branches of Botany which deal with the chlorophyllous autotrophic thallophytes and non-chlorophyllous heterotrophic thallophytes.
10. What are the groups of plants that live as symbionts in lichens? Name the study of lichens.
11. Which group of plants is called vascular cryptogams? Name the branch of Botany which deals with them?
12. Which group of plants is called amphibians of plant kingdom? Name the branch of Botany which deals with them.

SHORT ANSWER TYPE QUESTIONS

1. Explain in brief the scope of Botany in relation to agriculture, horticulture and medicine.
2. Explain the scope of Botany taking plant physiology as example.
3. What are the different branches of Botany that deal with morphology of plants? Give their salient features.

LONG ANSWER TYPE QUESTIONS

1. Give a comprehensive account on the scope of Botany in different fields giving an example for each.

Chapter 4

Plant Kingdom

Our understanding of the plant kingdom has changed over time. Heterotrophic Fungi prokaryotic Monera and unicellular eukaryotic Protista possessing cell walls have now been excluded from Plantae though earlier classifications put them in the same kingdom. So, the cyanobacteria that are also referred to as blue green algae are not 'algae' any more. The kingdom Plantae now contains all eukaryotic generally multicellular chlorophyll-containing organisms having cellulosic cellwall and showing autotrophic mode of nutrition. In this chapter, we will describe **Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms** under plantae. Algae, Bryophytes and Pteridophytes are **Cryptogams** or non-flowering plants while Gymnosperms and Angiosperms are **Phanerogams** or flowering plants, also called **Spermatophytes** (or seed bearing plants).

4.1 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: on moist stones, wood and in soil. 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 (Figure 4.1). The size ranges from the microscopic **unicellular** forms like *Chlamydomonas*, to **colonial** forms like *Volvox* and to the **filamentous** forms like *Ulothrix* and *Spirogyra*. A few of the marine forms such as kelps, form **massive plant bodies.** The **cell wall** consists of cellulose and other carbohydrates. In addition to chlorophylls and carotenoids, some algae contain special pigments, phycobilins. The **reserve food** is generally starch.

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, give rise to new plants. **Sexual** reproduction takes place through **fusion of two gametes**. These gametes can be flagellated and similar in size (as in *Chlamydomonas*) 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 some species of *Chlamydomonas* is termed as **anisogamous**. Fusion between one large, non-motile (static) female gamete and a smaller, motile male gamete is termed **oogamous,** e.g., *Volvox, Fucus*. **Life cycle** is generally haplontic and the zygote acts as meiocyte.

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* is used to grow microbes and in preparations of ice-creams and jellies. **Iodine** is extracted from kelps like *Laminaria*. *Chlorella* and *Spirullina* are unicellular algae and are used as food supplements even by space travellers. On the basis of pigmentation and type of stored food the algae are divided into **three main classes**: Chlorophyceae, Phaeophyceae and Rhodophyceae.

4.1.1 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**.

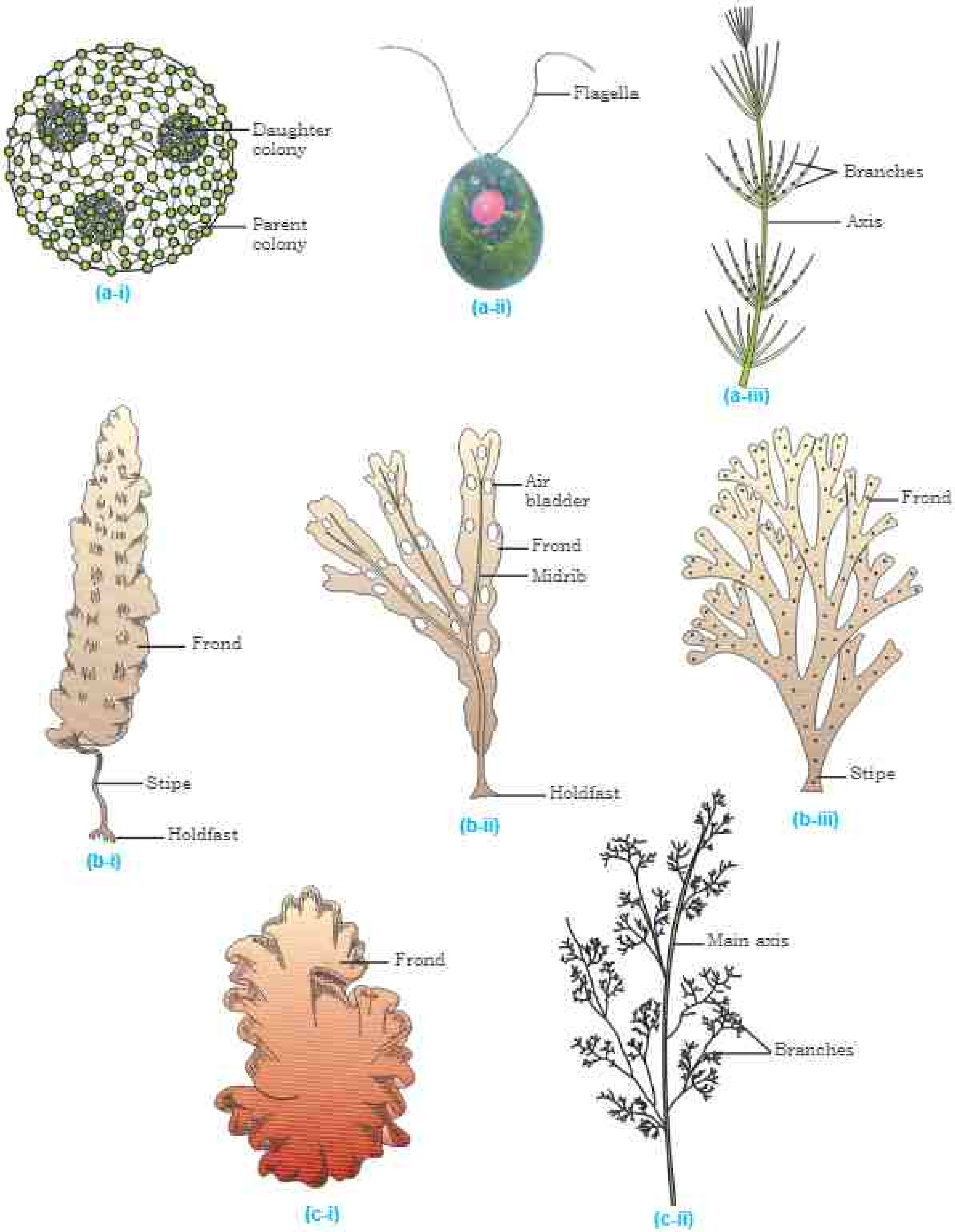


Figure 4.1 Algae : (a) Green algae (i) *Volvox* (ii) *Chlamydomonas* (iii) *Chara*
(b) Brown algae (i) *Laminaria* (ii) *Fucus* (iii) *Dictoyota*
(c) Red algae (i) *Porphyra* (ii) *Polysiphonia*

Vegetative reproduction usually takes place by **fragmentation**. 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 4.1a).

4.1.2 Phaeophyceae

The members of **phaeophyceae** or **brown algae** are found primarily in marine habitats. They show great variation in size and form. They range from simple branched, filamentous forms (*Ectocarpus*) to profusely branched forms as represented by kelps, which may reach a height of 100 metres. They possess **chlorophyll a, c, carotenoids and xanthophylls**. They vary in colour from olive green to various shades of brown depending upon the amount of the xanthophyll pigment, **fucoxanthin** present in them. Food is stored as complex carbohydrates, which may be in the form of **laminarin or mannitol**. The vegetative cells have a cellulosic wall usually covered on the outside by a gelatinous coating of **algin**. The protoplast contains, in addition to plastids, a centrally located vacuole and nucleus. The plant body is usually attached to the substratum by a **holdfast**, and has a stalk, the **stipe** and leaf like photosynthetic organ – **the frond**. Vegetative reproduction takes place by **fragmentation**. Asexual reproduction in most brown algae is by **biflagellate zoospores** that are pear-shaped and have two unequal laterally attached flagella.

Sexual reproduction may be isogamous, anisogamous or oogamous. Union of gametes may take place in water or within the oogonium (oogamous species). **The gametes** are pyriform (pear-shaped) and bear **two laterally attached flagella**. The common forms are *Ectocarpus, Dictyota, Laminaria, Sargassum* and *Fucus* (Figure 4.1b).

4.1.3 Rhodophyceae

Rhodophyceae members 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 more numbers found in the warmer areas. They occur in both higher light intensity regions close to the surface of water and also at great depths in oceans where relatively little light penetrates.

The thalli of most of the red algae are multicellular. Some of them have complex body organisation. The major pigments are **chlorophylls a, d and phycoerythrin.** 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 gametes. The female sex

Table 4.1 Divisions of Algae and their Main Characteristics

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

organ is a flask shaped **carpogonium** and non-flagellated male gamete is called **spermatium**. Sexual reproduction is oogamous and accompanied by complex post-fertilisation developments. The common members are: *Polysiphonia*, *Porphyra* (Figure 4.1c), *Gracilaria* and *Gelidium*.

4.2 Bryophytes

Bryophytes include the various **liverworts, hornworts and mosses** that are found commonly growing in moist shaded areas in the hills (Figure 4.2). Bryophytes are archegoniate, embryophytic and atracheophytic cryptogams.

They are also called **amphibians** of the plant kingdom because these plants live in moist soil and are dependent on water for sexual reproduction. They are the **primitive land plants** and 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. The mosses possess root-like rhizoids, leaf-like phylloids and stem-like cauloids. The plant body consists of **parenchymatous** tissue. The main plant body of the bryophyte is haploid. It produces gametes, hence is called a **gametophyte**. The sex organs in bryophytes are **multicellular, jacketed and stalked**. 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

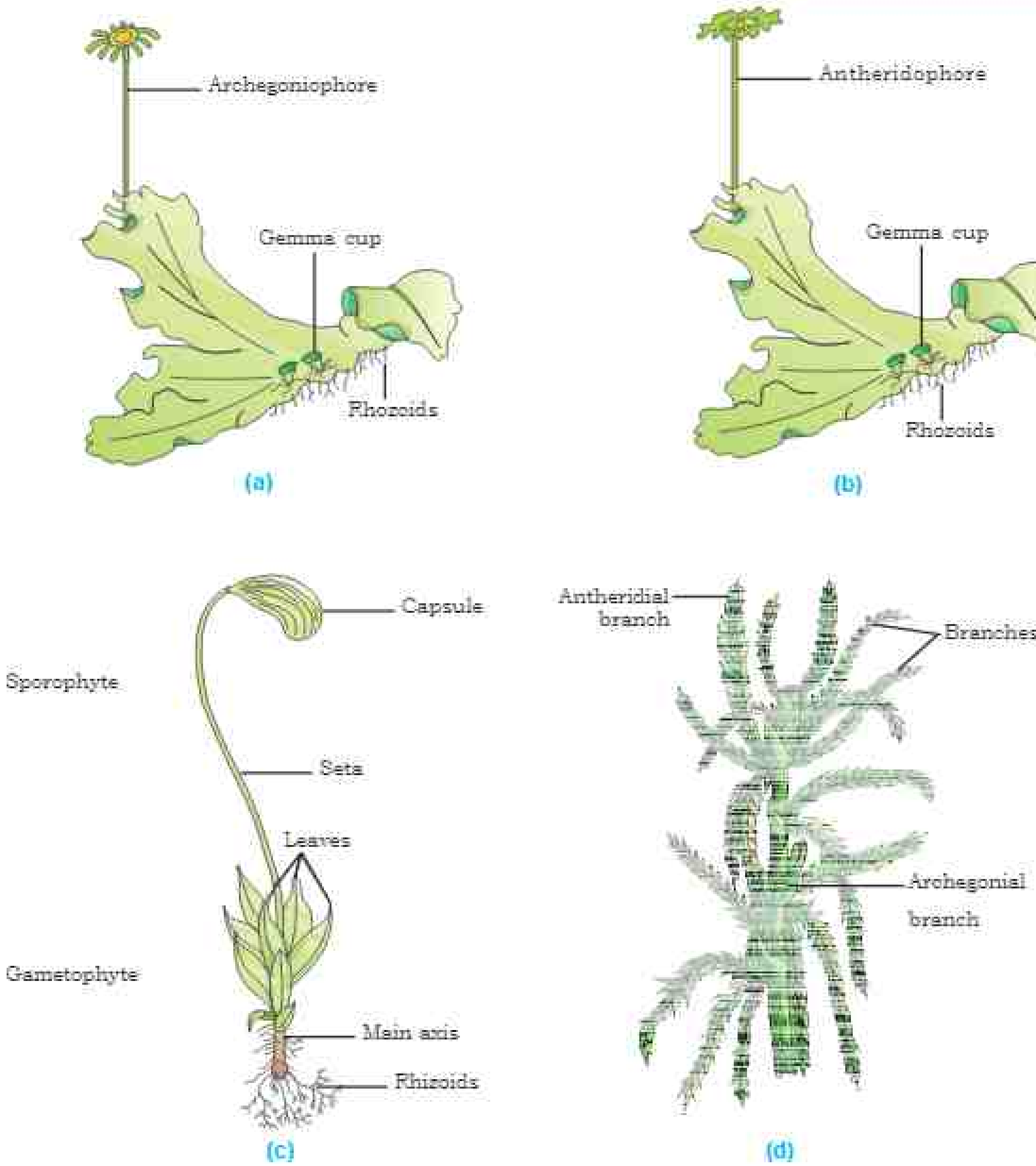


Figure 4.2 Bryophytes : A liverwort - *Marchantia* (a) Female thallus (b) Male thallus Moses - (c) *Funaria*, gametophyte and sporophyte (d) *Sphagnum* gametophyte

produce the zygote. This is called **zooidogamous oogamy**. 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 called **spore mother**

cells undergo reduction division (meiosis) to produce haploid spores. These spores germinate to produce gametophyte. All bryophytes are **homosporous.** They show heteromorphic alternation of generations (because gametophytic and sporophytic bodies are conspicuously different) and the life cycle is **haplo-diplontic.**

Bryophytes in general are of relatively, little economic importance but some mosses provide food for herbaceous mammals, birds and other animals. Species of ***Sphagnum,*** a moss, provide peat that has long been used as fuel, and because of its capacity to hold water as packing material for trans-shipment of living material. 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, hence play significant role in plant succession. Since mosses form dense mats on the soil, they reduce the impact of falling rain and prevent soil erosion. The bryophytes are divided into **three Classes viz.,** Hepaticopsida (Liverworts), Anthocerotopsida (Hornworts) and Bryopsida (Mosses)

4.2.1 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 prostrate, dorsiventral and closely appressed to the substrate. The leafy members have tiny leaf-like appendages in two rows on the stem-like structures.

Vegetative reproduction in liverworts takes place by **fragmentation** of thalli (sing. thallus) 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 (antheridia) and female (archegonia) sex organs, are produced 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. Some members like *Marchantia* also produce **elaters** in the capsule which help in spore dispersal. The spores germinate to form free-living gametophytes.

4.2.2 Hornworts

The plant body of **Hornworts** like *Anthoceros* is also thalloid consisting of rhizoids. They possess elongated horn-like sporophytes. The sporophyte consists of foot**, intercalary meristematic zone** and capsule. The capsule produces spores and **pseudo-elaters**.

4.2.3 Mosses

The predominant stage of the life cycle of a moss is the gametophyte which consists of two stages. The first stage, also called juvenile stage, is the **protonema**, which develops directly from a spore. It is a creeping, green, branched and frequently filamentous stage. The second stage is the adult leafy stage called **gametophore**, which develops from the protonema as a lateral adventitious 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, gemmae formation and budding in the secondary protonema**. In sexual reproduction, the sex organs antheridia and archegonia are produced at the apex of the leafy shoots intermixed with multicellular, uniseriate filamentous, sterile hairs called **paraphyses**. 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 from spore mother cells. The mosses have an elaborate mechanism of spore dispersal. They contain **peristomial teeth** which help in dispersal of spores. Common examples of mosses are *Funaria* (cord moss), *Polytrichum* (haircap moss) and *Sphagnum* (peat moss) (Figure 4.2 c, d)

4.3 Pteridophytes

The Pteridophytes include **club mosses, horsetails, ferns** etc. 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**. They are embryophytic archegoniate vascular (trachaeophytic) cryptogams. 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 (haploid) plant body. However, in Pteridophytes the main plant body is a **sporophyte** which is differentiated into true roots, stem and leaves (Figure 4.3). These organs possess well-differentiated vascular tissues. The roots are **adventitious**. The stem internally shows epidermis, cortex and stele. The **stele** may be protostele (central core of xylem surrounded by phloem) or siphonostele (medullated protostele) or solenostele (siphonostele with scattered leaf gaps) or dictyostele (dissected siphonostele with overlapping leaf gaps). 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**. The development of the sporangium may be **lepto-sporangiate** or **eusporangiate**. The

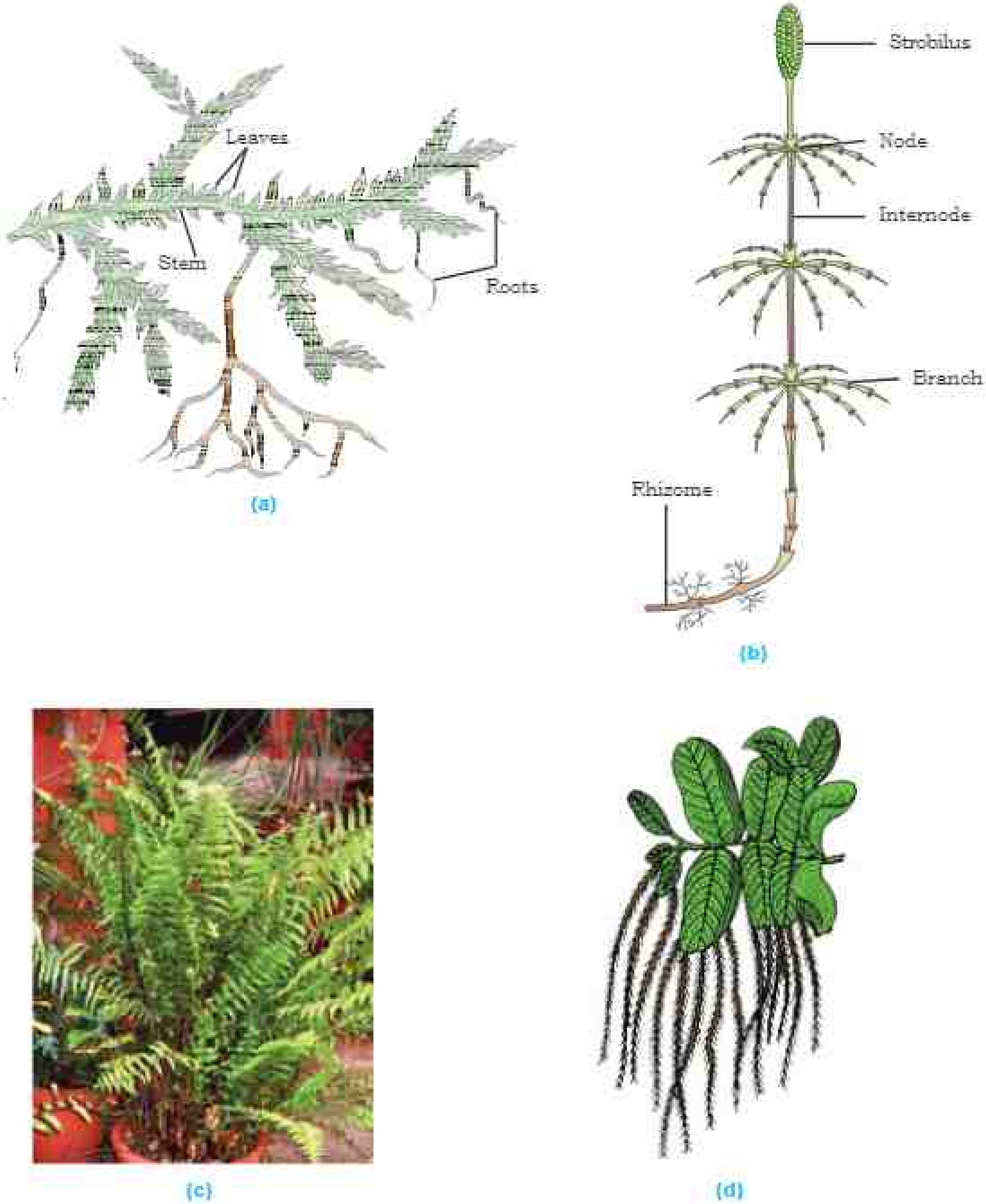


Figure 4.3 Pteridophytes: (a) *Selaginella* (b) *Equisetum* (c) Fern (d) *Salvinia*

sporangia produce spores by meiosis in spore mother cells. In majority of the pteridophytes all the spores are of similar kind; such plants are termed **homosporous**. Genera like *Selaginella* and *Salvinia*, which produce two kinds of spores, macro or mega spores and microspores are described as **heterosporous**. In some cases, sporophylls may form distinct compact structures called **strobili** or cones (*Selaginella, Equisetum*). The spores germinate to give rise to inconspicuous, small but multicellular free living, mostly photosynthetic thalloid gametophytes called **prothalli** (sing. Prothallus). These gametophytes require cool, damp, shady places to grow. Because of this specific 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. The sex organs are **multicellular, jacketed** and **sessile**. In heterosporous plants, the megaspores and microspores germinate and give rise to female and male gametophytes 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 results in the formation of zygote. This is called **zooidogamous oogamy**. The female gametophytes in these plants are retained on the parent sporophyte for variable periods. The development of zygotes into young embryos takes place within the female gametophytes. This event is a precursor to the **seed habit,** considered an important step in evolution. The embryo, thereafter, produces a multicellular well-differentiated sporophyte which is the dominant phase in the Pteridophytes.

In ferns like *Dryopteris***,** the stem is an underground rhizome. The large aerial leaves, generally pinnately compound, are called **fronds**. Young leaves show **circinate vernation** (coiling from the tip to the base). The petioles are covered with brown multicellular hairs called **ramenta**. The leaflets show **open dichotomous** or furcate venation. The sporangia are formed on the ventral or lower surface of the leaf (sporophyll) in groups and these are called sori. Each sorus is covered by a membranous sheath of its own and it is called true **indusium**. The antherozoids in ferns are generally spirally coiled and **multiciliate**. In some ferns like *Pteris,* each sorus is protected by the reflexed margin of the fertile leaflet which is called **false indusium**.

The Pteridophytes are further classified into **four Classes** namely Psilopsida (*Psilotum*), Lycopsida (*Selaginella, Lycopodium*), Sphenopsida (*Equisetum*) and Pteropsida (*Dryopteris, Pteris, Adiantum* etc., commonly called ferns).

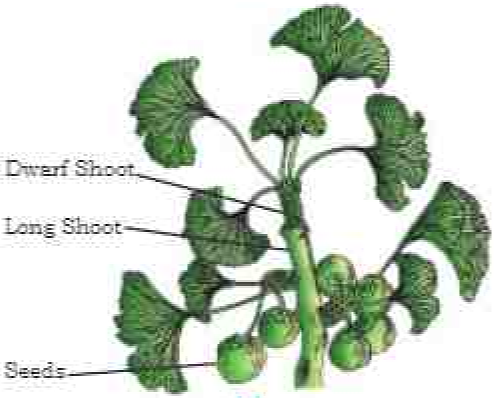
4.4 Gymnosperms

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 are embryophytic, trachaeophytic **archegoniate, phanerogams.** They include medium-sized trees or tall trees and shrubs (Figure 4.4). One of the gymnosperms, the giant redwood tree *Sequoia* is one of the tallest tree species. *Ginkgo* is considered to be a living fossil (Figure 4.4.c). 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 N_2- fixing cyanobacteria (*Nostoc* and *Anabaena*).The stems are unbranched (*Cycas* Figure 4.4(a) or branched (*Pinus, Cedrus* Figure 4.4(b). 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.

Anatomically the stem shows **eustele**. The vascular bundles are conjoint collateral and open. Vessels are generally absent in xylem and companion cells are absent in phloem. **Secondary growth** occurs in stem and roots. 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 compact strobili or cones. The **strobili** (sing. strobilus) bearing microsporophylls and microsporangia are called microsporangiate or male strobili (similar to male flower).

(a)

(b)



(c)

Figure 4.4 Gymnosperms: (a) *Cycas* (b) *Pinus* (c) *Ginkgo*

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 takes place within the microsporangia. The cones bearing megasporophylls with **ovules** or integumented megasporangia are called macrosporangiate or female strobili (similar to female flower). The microsporophylls (male) or mega sporophylls (female) may be borne on the same tree (*Pinus*) or on different trees (*Cycas*).

The megaspore mother cell is differentiated from one of the cells of the **nucellus**. The nucellus is protected by envelopes or integuments and the composite structure is called an ovule. The megaspore mother cell divides meiotically to form four megaspores. One of the megaspores enclosed within the megasporangium (nucellus) develops into a multicellular female gametophyte that bears two or more archegonia or female sex organs. The multicellular female gametophyte is retained within megasporangium and is also called **endosperm**.

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. The **pollination is direct and anemophilous**. They are carried by 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 discharges the contents near the mouth of the archegonia. This is called **siphonogamous oogamy**. *Cycas* shows both siphonogamy and zooidogamy because male gametes are multiciliate but carried by pollen tube. In others male gametes are non-motile. Zygote develops into an embryo and the ovules into seeds. These seeds are naked and not covered by fruit wall.

In addition to multiciliate male gametes Cycas shows some other fern characters like circinnate vernation of young leaves, presence of ramenta and presence of archegonia. Gymnosperms are divided into **three Classes**-Cycadopsida (*Cycas*), Coniferopsida (*Pinus*) and Gnetopsida (*Gnetum*).

4.5 Angiosperms

Unlike the gymnosperms where the ovules are naked, in the angiosperms (commonly called flowering plants) the ovules are present inside the ovary of the gynoecium. The pollen grains and ovules are developed in specialised structures called **flowers**. In angiosperms, the seeds are enclosed in fruits. The angiosperms are **embryophytic, non-archegoniate, vascular, fruit-bearing phanerogams** or spermatophytes. The angiosperms are an exceptionally large group of plants occurring in wide range of habitats. They range in size from tiny, almost microscopic *Wolfia* to tall trees of *Eucalyptus* (over 100 metres). They provide us with food, fodder, fuel, medicines and several other commercially important products to meet our day to day life. The root system of these plants is taproot or adventious type. The main conducting elements of the xylem are **vessels** and phloem consists of **companion** cells. They develop flowers with usually conspicuous **perianth**. The male sex organs in a flower are the **stamens**. Each stamen consists of a slender filament with an anther at the tip. In the anthers, microspore mother cells undergo meiosis and produce pollen grains. The female sex organ in a flower is the **pistil or the carpel**. Pistil consists of an ovary enclosing one to many ovules. Within ovules a megaspore mother cell undergoes meiosis and produces four megaspores. Usually only one megaspore develops into a highly reduced female gametophyte termed **embryo- sac**. Each of the cells of an embryo-sac is haploid. Each embryo-sac has a three-celled egg apparatus comprising one egg cell with two synergids; three antipodal cells and two polar nuclei. The polar nuclei eventually fuse to produce a diploid secondary nucleus.

The pollen grains after dispersal from the anther are carried by wind (anemophily) or water (hydrophily) or various other biotic agencies like animals (zoophily) to the stigma of a pistil. This is termed as **pollination**. Unlike in Gymnosperms, here the transfer of pollen to the ovule in the ovary is not direct and hence called indirect pollination. The pollen grains germinate on the stigma and the resulting pollen tubes grow through the tissues of stigma and style and reach the ovule. The pollen tubes enter the embryo-sac where two male gametes are discharged.

One of the male gametes fuses with the egg cell to form a zygote **(syngamy).** The other male gamete fuses with the diploid secondary nucleus to produce the triploid primary endosperm nucleus (PEN). This is called **triple fusion**. Because of the involvement of two fusions,

(a)

(b)

Figure 4.5 Angiosperms:
(a) A dicotyledon (b) A monocotyledon

this event is termed as **double fertilisation**, an event unique to angiosperms. The fertilization is **siphonogamous oogamy**. The zygote develops into an embryo (with one or two cotyledons) and the PEN develops into endosperm which provides nourishment to the developing embryo. The synergids and antipodals degenerate after fertilisation. During these events the **ovules develop into seeds and the ovaries develop into fruit**.

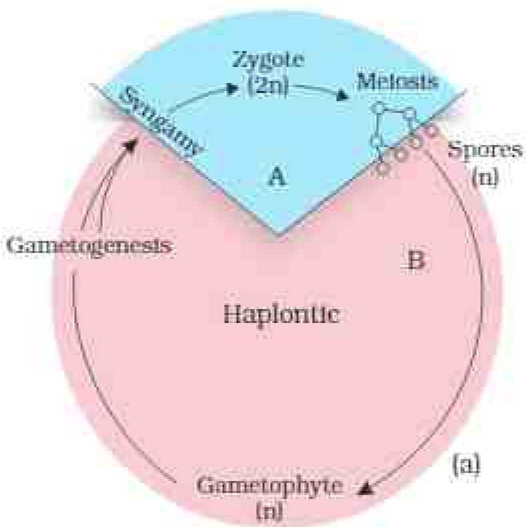
Based on the number of cotyledons in the seed, angiosperms are divided into **two classes,** dicotyledons and monocotyledons (Figure 4.5) The **dicotyledons** are characterized by having two cotyledons and **monocotyledons** by having only one cotyledon in their seeds.

4.6 Plant Life Cycles and Alternation of Generations

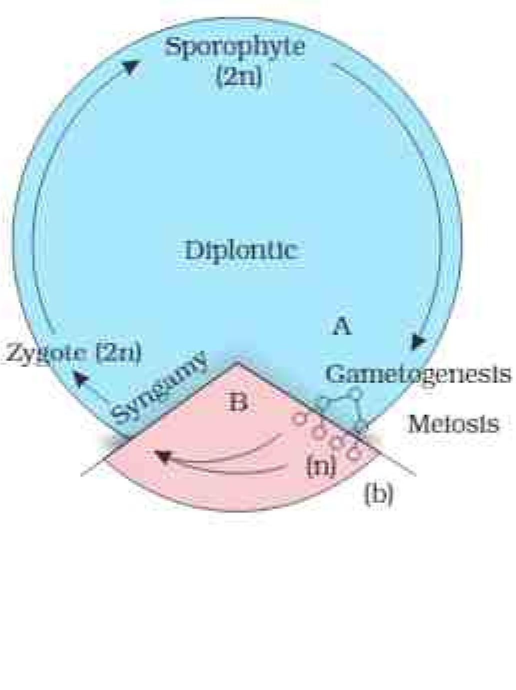
In plants, both haploid and diploid cells can divide by mitosis. This ability leads to the formation of different plant bodies - haploid and diploid. The haploid plant body produces gametes by mitosis. This plant body represents a gametophyte. Following fertilisation the zygote also divides by mitosis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

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

1. Sporophytic generation is represented only by the one-celled zygote. There are no free-living sporophytes. Meiosis in the zygote results in the formation of haploid spores. The haploid spores divide mitotically and form the gametophyte. The dominant, photosynthetic phase in such plants is the free-living gametophyte. This kind of life cycle is termed as **haplontic**. Many algae



(a)



(b)

such as *Volvox, Spirogyra* and some species of *Chlamydomomas* represent this pattern (Figure 4.6 a).

2. On the other extreme, is the type wherein the diploid sporophyte is the dominant, photosynthetic, independent phase of the plant. The haploid phase is represented by gametes only. This kind of lifecycle is termed as **diplontic** (Figure 4.6 b).

   When the gametophyte is represented by few celled or many celled stage, life cycle is called **diplo-haplontic**. Pteridophytes and all seed-bearing plants follow this pattern.

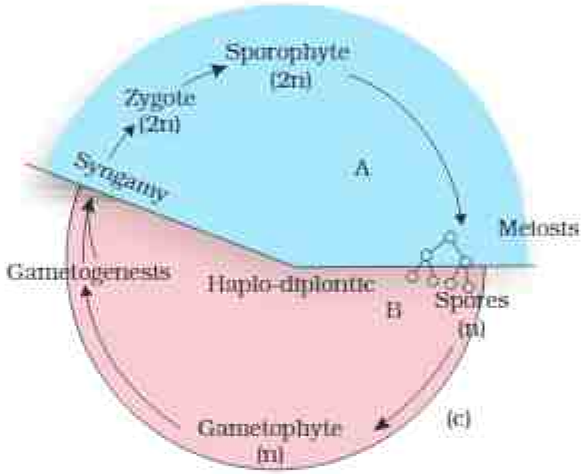


Figure 4.6 Life cycle patterns
(a) Haplontic (b) Diplontic (c) Haplo-diplontic

3. Bryophytes, interestingly, exhibit an intermediate condition (Haplo-diplontic); both phases are multicellular with dominant gametophytic generation and dependant sporophytic generation (Figure 4.6 c).

Interestingly, while most algal genera are haplontic, some of them such as *Ectocarpus, and* kelps (*Laminaria*) are haplo-diplontic. *Fucus,* is diplontic and *Polysiphonia* is diplo-biontic.

Summary

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

Bryophytes are plants which can live in soil but are dependent on water for sexual reproduction. Their plant body is more differentiated than that of algae. It is thallus-like and prostrate or erect and attached to the substratum by rhizoids. They possess root-like, leaf-like and stem-like structures. The bryophytes are divided into liverworts, hornworts and mosses. The plant body of liverworts and hornworts is thalloid and dorsiventral whereas mosses have upright, slender axes bearing spirally arranged leaves. The main plant body of a bryophyte is gamete-producing and is called a gametophyte. It bears the male sex organs called antheridia and female sex organs called archegonia. The male and female gametes produced fuse to form zygote which produces a multicellular body called a sporophyte. It produces haploid spores. The spores germinate to form gametophytes.

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

The gymnosperms are the plants in which ovules are not enclosed by any ovary wall. After fertilisation the seeds remain exposed and therefore these plants are called naked-seeded plants. The gymnosperms produce microspores and megaspores which are produced in microsporangia and megasporangia borne on the sporophylls. The sporophylls – microsporophylls and megasporophylls – are arranged spirally on axis to form male and female cones, respectively. The pollen grain germinates and pollen

tube releases the male gamete into the ovule, where it fuses with the egg cell in archegonia. Following fertilisation, the zygote develops into embryo and the ovules into seeds.

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

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

GLOSSARY

Anisogamy: It is the fusion of morphologically and physiologically dissimilar gametes in which both the gametes may be either motile or non-motile.

Archegoniates: These are Bryophytes, Pteridophytes and Gymnosperms where the female gametangium is archegonium.

Colonial form: In a colonial form the plant body is a colony or coenobium which is hollow at the centre and the cells are arranged in a single layer within the peripheral colonial matrix.

Cryptogams: These are flowerless and seedless spore plants.

Embryophytes: These are Bryophytes, Pteridophytes, Gymnosperms and Angiosperms consisting of embryo which develops from zygote by mitotic divisions.

Eusporangiate development: The sporangium develops from a group of superficial cells.

Gametophyte: It is the haploid,gamete producing stage or sexual stage in the life cycle of a plant

Heterospory: It is the condition where different types of spores are produced by a species.

Homospory: It is the production of only one type of spores by a species

Isogamy: It is the fusion of morphologically and physiologically similar gametes.

Kelps: Large algal members of Phaeophyceae where the plant body is differentiated into a holdfast, stipe and lamina.

Leptosporangiate development: The sporangium develops from a single superficial cell.

Oogamy : It is the fusion of a small motile or non-motile male gamete (spermatozoid or sperm) with a large non-motile female gamete (egg or ovum).

Phanerogams: These are flower-bearing and seed producing tracheophytes.

Siphonogamy : The fusion of male gamete carried out by a pollen tube with an egg.

Spermatophytes: These are seed plants with or without fruits.

Sporophyte: It is the diploid spore-producing stage or asexual stage in the life cycle of a plant.

Strobilus: It is a structure consisting of closely packed sporophylls.

Thallus: It is a plant body which is not differentiated into roots,stem and leaves.

Tracheophytes: These are Pteridophytes, Gymnosperms and Angiosperms which contain vascular tissues.

Zooidogamy: The fusion of motile male gamete with non-motile egg.

Zoospores: Flagellated motile spores

VERY SHORT ANSWER TYPE QUESTIONS

1. What is the basis of classification of Algae ?
2. When and where does reduction division take place in the life cycle of a liverwort, a moss, a fern, a gymnosperm and an angiosperm ?
3. Differentiate between syngamy and triple fusion.
4. Differentiate between antheridium and archegonium.
5. What are the two stages found in the gametophyte of mosses ? Mention the structures from which these two stages develop?
6. Name the stored food materials found in Phaeophyceae and Rhodophyceae.
7. Name the pigments responsible for brown colour of Phaeophyceae and red colour of Rhodophyceae.
8. Name different methods of vegetative reproduction in Bryophytes.
9. Name the integumented megasporangium found in Gymnosperms. How many female gametophytes are generally formed inside the megasporangium?
10. Name the Gymnosperms which contain mycorrhiza and corolloid roots respectively.
11. Mention the ploidy of any four of the following :
    a. Protonemal cell of a moss
    b. Primary endosperm nucleus in a dicot
    c. Leaf cell of a moss
    d. Prothallus of a fern
    e. Gemma cell in Marchantia
    f. Meristem cell of monocot
    g. Ovum of a liverwort and
    h. Zygote of a fern.
12. Name the four classes of Pteridophyta with one example each.
13. What are the first organisms to colonise rocks? Give the generic name of the moss which provides peat?
14. Mention the fern characters found in Cycas.
15. Why are Bryophytes called the amphibians of the plant kingdom ?
16. Name an alga which show
    (a) Haplo-diplontic and
    (b) Diplontic types of life cycles.
17. Give examples for unicellular, colonial and filamentous algae.

SHORT ANSWER TYPE QUESTIONS

1. Differentiate between red algae and brown algae
2. Differentiate between liverworts and mosses
3. What is meant by homosporous and heterosporous pteridophytes? Give two examples.
4. What is heterospory? Briefly comment on its significance. Give two examples.
5. Write a note on economic importance of Algae and Bryophytes
6. How would you distinguish monocots from dicots?
7. Give a brief account of prothallus.
8. Draw labelled diagrams of:
    a) Female thallus and male thallus of a liverwort
    b) Gametophyte and sporophyte of Funaria.

LONG ANSWER TYPE QUESTIONS

1. Name three groups of plants that bear archegonia. Briefly describe the life cycle of any one of them.
2. Describe the important characteristics of Gymnosperms.
3. Give the salient features of Pteridophytes.
4. Give an account of plant life cycles and alternation of generations
5. Both Gymnosperms and Angiosperms bear seeds, then why are they classified separately?

EXERCISES

1. How far does *Selaginella*, one of the few living members of Lycopodiales (Pteridophytes) fall short of seed habit.
2. Each plant or group of plants has some phylogenetic significance in relation to evolution. *Cycas*, one of the few living members of Gymnosperms is called as the'relic of past'. Can you establish a phylogenetic relationship of *Cycas* with any other group of plants that justifies the above statement ?
3. The male and female reproductive organs of several Pteridophytes and Gymnosperms are comparable to floral structures of angiosperms. Make an attempt to compare the various reproductive parts of Pteridophytes and Gymnosperms with reproductive structures of Angiosperms.
4. The plant body in higher plants is well differentiated and well developed. Roots are organs used for the purpose of absorption. What are the equivalent of roots in the less developed lower plants?

UNIT II

STRUCTURAL ORGANISATION IN PLANTS-MORPHOLOGY

CHAPTER 5
Morphology of Flowering Plants

The description of the diverse forms of life on earth was made only by observation – through naked eyes or later through magnifying lenses and microscopes. The description presented in this unit is mainly of gross external structural features. In addition, observable and perceivable living phenomena were also recorded as part of this description. Before experimental biology or more specifically, physiology, was established as a part of biology, naturalists described only biology. Hence, biology remained as a natural history for a long time. The description, by itself, was amazing in terms of detail. While the initial reaction of a student could be boredom, one should keep in mind that the detailed description, was utilised in the later day reductionist biology where living processes drew more attention from scientists than the description of life forms and their structure. Hence, this description became meaningful and helpful in framing research questions in physiology or evolutionary biology.

Theophrastus
[c.371 BC - c.287 BC]

Theophrastus, the ancient Greek philosopher who studied in Plato's school, was the successor to Aristotle. The interests of Theophrastus were wide ranging, extending from biology and physics to ethics and metaphysics. His two surviving botanical works, **Enquiry into Plants** [*Historia Plantarum*] and **On the Causes of Plants** [*Causae Plantarum*] constituted the most important contribution to botanical science during antiquity and the Middle ages. They also depicted the first systemization of the botanical world; on the strength of these works, he is aptly regarded as the "**Father of Botany**".

The opening sentence of the ***Enquiry into Plants*** reads like a botanical manifesto: "*We must consider the distinctive characters and the general nature of plants from the point of view of their morphology, their behaviour under external conditions, their mode of generation and the whole course of their life*". He described several plants in detail, often including descriptions of habitat and geographic distribution and recognised some plant groups that can be compared to modern-day plant families. His second book ***Causes of Plants*** not only gives extensive information about the various categories of plants he explored, but also his inquisitive observation of different organs of plants. These lecture notes of Theophrastus comprise the first clear exposition of the rudiments of plant morphology, anatomy, ecology and physiology - presented in a way that would not be matched for another eighteen centuries".

CHAPTER 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 the presence of roots, stems, leaves, flowers and seeds enclosed in fruits.

For any successful attempt at classification and 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). Generally the root shows positive geotropism while the stem shows positive phototropism.

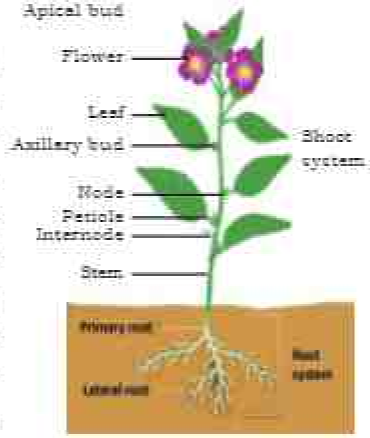


Figure 5.1 Parts of a flowering plant

a. Tap root system b. Fibrous root system c. Adventitious root system

Figure 5.2 Different types of root systems

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 into the soil. It bears lateral roots of several orders that are referred to as **secondary roots, tertiary roots** etc. The primary roots and its branches constitute the **tap root system** (Figure 5.2 a). 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 monocots (Figure 5.2 b). In some plants, like *Monstera* and the banyan tree, roots arise from parts of the plant other than the radicle and are called **adventitious roots** (Figure 5.2 c). 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 some plant growth regulators.

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 millimeters 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.

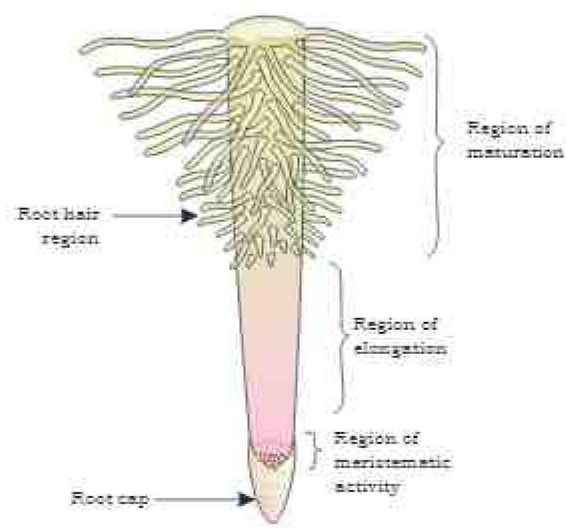
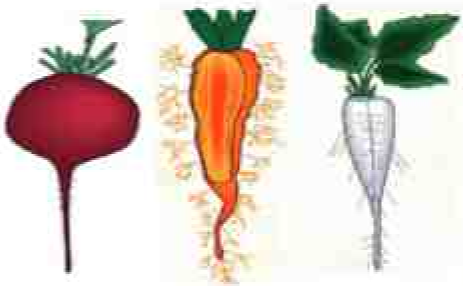


Figure 5.3 The regions of the root tip

(a) *Asparagus*



(b) Turnip (c) Carrot (d) Radish

Figure 5.4 Storage roots

(a) Prop roots of banyan

(b) Stilt roots of maize

Figure 5.5 Modification of root for support

Figure 5.6 (a) Pneumatophores of *Avicennia*

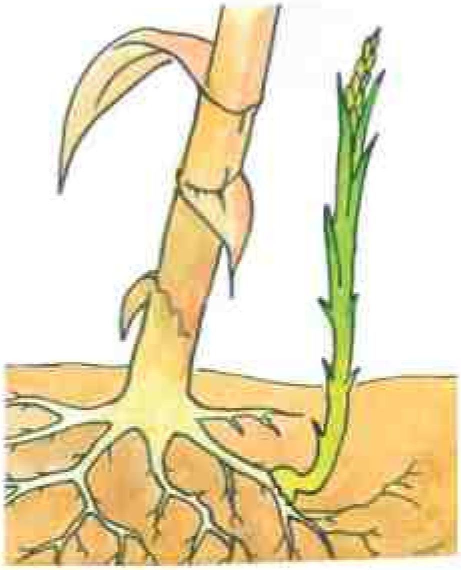
Figure 5.6 (b) Velamen roots of *Vanda*

5.1.2 Modifications of Root

Roots in some plants change their shape and structure and become modified to perform functions other than absorption and conduction of water and minerals. They are modified for storage of food and respiration etc. Tap roots of carrot, turnip, adventitious roots of sweet potato and fibrous roots in *Asparagus* become swollen due to storage of food (Figure 5.4).

Have you ever wondered what could be those hanging structures that support a banyan tree?

These are called **prop roots** or **pillar roots** (Figure 5.5 a). Similarly, the stems of maize and sugarcane have supporting roots coming out of the lower nodes of the stem. These are called **stilt roots**. (Figure 5.5 b). Can you give some more such examples? In mangrove plants such as *Rhizophora* and *Avicinnea* growing in swampy areas, many roots come out of the ground and grow vertically upwards. Such roots, called **pneumatophores**, (Figure 5.6 a) help to get oxygen for respiration. In plants that grow on other plants (**epiphytes**) like *Vanda* (Figure 5.6 b), the adventitious roots are specialized to absorb moisture from atmosphere. Such roots are called **velamen roots**. Some plants like *Viscum* and *Striga* (called partial parasites) send **haustorial roots** into the xylem of the host plant to get water and minerals while others (complete parasitic plants) like *Cuscuta* and *Rafflesia* extend their haustorial roots into both xylem and phloem to obtain both water and food from the host plants (Figure 5.7). In members of Fabaceae, bacteria known as *Rhizobium* inhabit the root



(a) Striga

(b) Cuscuta

Figure 5.7 Haustorial (parasitic) roots

Not all plants prepare their own food. Some plants 'steal' food and water from other plants. Such plants are called parasitic plants.

a. Nodular roots of ground nut

b. Photosynthetic roots of *Taeniophyllum*

Figure 5.8

system to fix atmospheric nitrogen by forming nodules. Such roots are called **nodular roots** (Figure 5.8 a). In some plants the roots are chlorophyllous and perform **photosynthesis** as in *Taeniophyllum* (Figure 5.8 b).

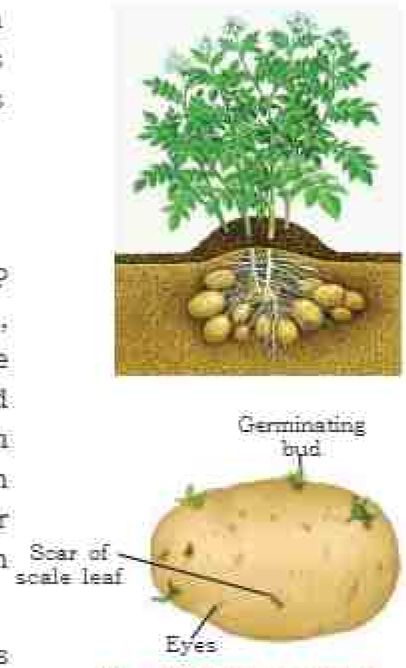
5.2 The Stem

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 becomes woody and dark brown.

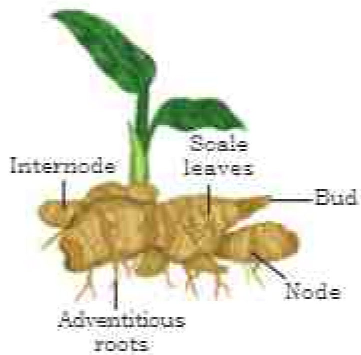
The main function of the stem is to spread out branches that bear leaves, flowers and fruits. It conducts water, minerals and photosynthates. Stems in some plants perform other functions such as storage of food, vegetative propagation, giving mechanical support and protection.

5.2.1 Modifications of Stem

The stems may not always be typically like what they are expected to be. They are modified to perform different functions. In some plants, the stem grows into soil contrary to its normal aerial habit. Such plants which show these **underground stem modifiacations** (Figure 5.9) not only store food materials but also act as organs of perennation to tide over conditions unfavourable for growth. They also help in vegetative propagation. The **stem tuber** of potato, **rhizome** of

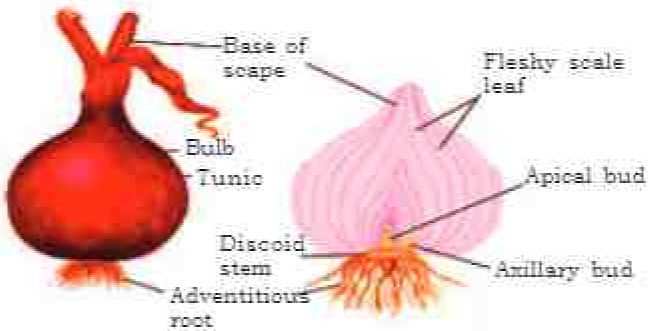


(a) Stem tuber of potato



(b) Rhizome of ginger


(c) Corms of *Colocasia*



(d) Bulb of onion

Figure 5.9 Underground stem modifications

(a) Stem tendrils of *Cucurbita*

(b) Thorn of *Bougainvillea*

(c) *Opuntia* Phylloclade

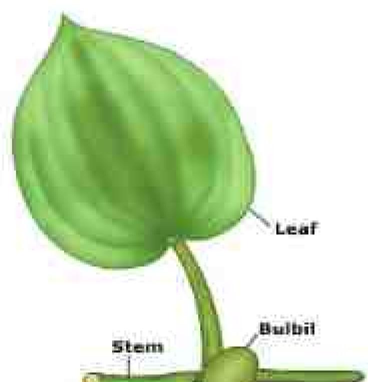
Zingiber (ginger) and *Curcuma* (turmeric), **corm** of *Amorphophallus* (zaminkand) and *Colocasia* and bulb of onion are a few examples of plants that show such modifications.

Aerial stems of several plants show many modifications (Figure 5.10) such as **Stem tendrils** which help in climbing. These are the slender, spirally coiled structures which may develop either from axillary buds as in gourds (cucumber, pumpkins, watermelon) or terminal buds as in grapevines. The buds of stems may also get modified into woody, straight and pointed **thorns**. Thorns are found in many plants such as *Citrus* and *Bougainvillea*. They protect plants from grazing animals. Some plants of arid regions modify their stems into fleshy flattened (*Opuntia*), or fleshy cylindrical (*Euphorbia*) or needle like (*Casuarina*) structures called **phylloclades**. They contain chlorophyll and carry out photosynthesis as their leaves are modified to spines or scale leaves to reduce transpiration. In *Asparagus*, the branches of limited growth that are modified to perform photosynthesis are called **cladophylls**. In some plants, the vegetative buds as in *Dioscorea* or floral buds as in *Agave* store food materials. When they detach from the parent plants, they develop adventitious roots and help in vegetative reproduction. These structures are called **bulbils**.

Underground stems in some grasses and strawberry and sub-aerial stems in *Oxalis* spread to new niches and form new plants when older parts die. Such plants are called **runners.** In plants like *Nerium* and jasmine a slender lateral branch called **stolon** arises from the base of the main axis, and after growing aerially for some time, arches downwards to touch the ground and produce adventitious roots. In some

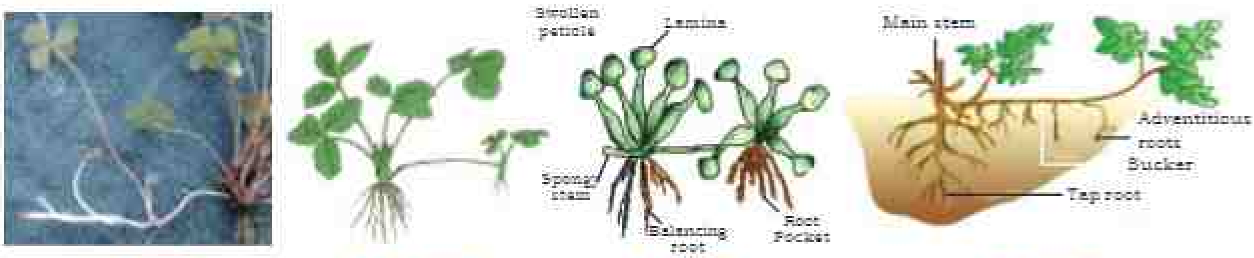
(d) *Casuarina* Phylloclade

(e) Cladophylls of *Asparagus*



(f) Bulbil of *Dioscorea*

Figure 5.10 Aerial stem modifications



(a) Runner (b) Stolon (c) Offset (d) Sucker

Figure 5.11 Sub - aerial Stem modifications

aquatic plants like *Pistia* and *Eichhornia*, a lateral branch of one internode length called **offset** which bears a rosette of leaves at each node and a tuft of balancing roots arising from the base of the discoid stem is found. In banana, pineapple and *Chrysanthemum*, the lateral branches originate from the basal and underground portion of the main stem, grow horizontally beneath the soil and then come out obliquely upward giving rise to leafy shoots. These branches are called **suckers**. All these sub-aerial stem modifications (Figure 5.11) are also useful for 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 meristem and are arranged in an acropetal order. They are the most important vegetative organs for photosynthesis.

A typical leaf consists of three main parts: leaf base, petiole and lamina (Figure 5.12 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 leaf base may become swollen, which is called **pulvinus**. The **petiole** helps in exposing the lamina 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 vein lets. 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 vary in different leaves.

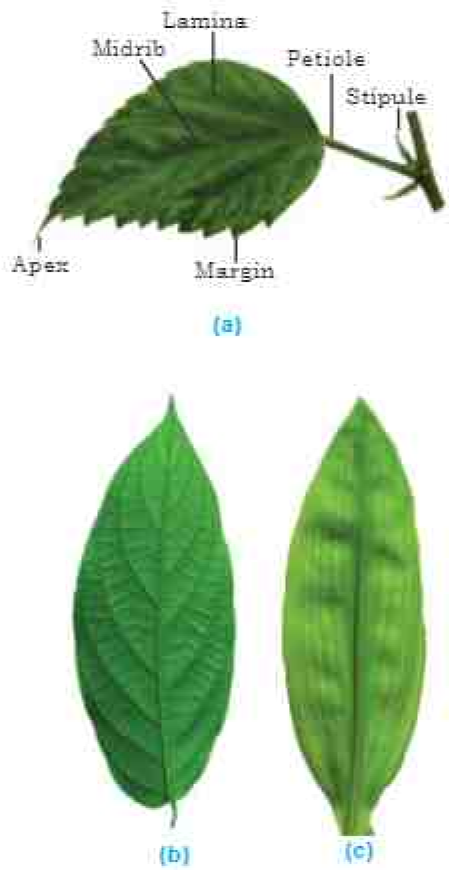


Figure 5.12
(a) Parts of a leaf
(b) Reticulate venation
(c) Parallel venation

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 5.12 b). When the veins run parallel to each other within a lamina, the venation is termed as **parallel** (Figure 5.12 c). Leaves of dicotyledonous plants generally possess reticulate venation, while parallel venation is the characteristic of most monocotyledons.

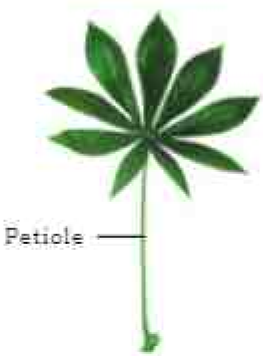
5.3.2 Types of Leaves

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 (lobes) 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 5.13). In a **pinnately compound leaf** a number of leaflets are present on a common axis called rachis. E.g., neem.

In **palmately compound leaves**, the leaflets are attached at a common point, i.e., at the tip of petiole, as in *Bombax ceiba* (silk cotton).

(a) Pinnately compound leaf

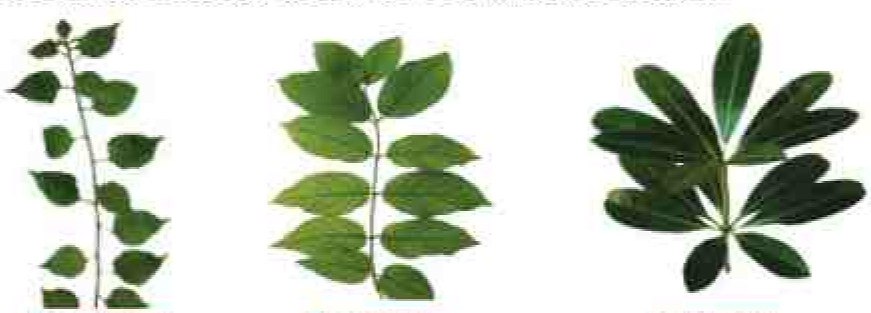


(b) Palmately compound leaf

Figure 5.13 Types of leaves

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 5.14). In **alternate** type of phyllotaxy, a single leaf arises at each node in alternate manner, as in *Hibiscus rosa-sinensis* (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 found in *Nerium* and *Alstonia*.



(a) Alternate (b) Opposite (c) Whorled

Figure 5.14 Different types of phyllotaxy

5.3.4 Modifications of Leaves

Leaves are often modified to perform functions other than photosynthesis. They are converted into **tendrils** for climbing as in peas or into **spines** for reduction in transpiration and for defence as in cacti (Figure 5.15 a, b). The fleshy leaves of onion and garlic store food (Figure 5.15 c). In some plants such as Australian acacia, the leaves are pinnetely compound in which the leaflets are small and short-lived. The petioles in these plants expand, become green and synthesise food. These are called **phyllodes** (Figure 5.15 d). **Insectivorous leaves** of Pitcher plant *Nepenthes* (Figure 5.15 e) and *Dionea* (Venus Fly-trap) are modified leaves to trap insects for their nitrogen requirement. Leaves may also be modified to help in **vegetative propagation**. In *Bryophyllum* (Figure 5.15 f), epiphyllous buds which arise from the notches of leaves develop adventitious roots and when they detach, develop into individual plants.

(a) Leaf tendrils of *Pisum*

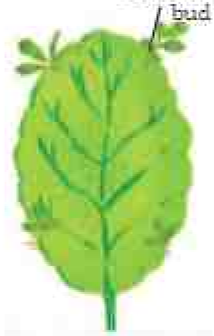
(b) Spines of *Opuntia*

(c) Storage leaves of *Allium*

It may sound un-realstic, but it is a fact that there are certain plants which kill insects and 'eat' them. Such plants, known as insectivorious plants obtain their nitrogen requirement from insects as they grow on nitrogen deficient soils.

(d) Phyllodes of *Acacia*

(e) Trap leaves of *Nepenthes*



(f) Reproductive leaf of *Bryophylium*

Figure 5.15 Leaf modifications

5.4 The Inflorescence

A thing of beauty is a joy forever. The beauty of flowers lies not only in the colour of petals but also in the mode of arrangement of flowers on the floral shoot.

The arrangement of flowers on the floral axis is termed as **inflorescence.** A flower is a modified shoot wherein the shoot apical meristem changes to floral meristem. Internodes do not elongate and the axis (called peduncle) gets condensed. The apex produces different kinds of floral appendages laterally at successive nodes instead of leaves. Depending on whether the apex gets converted 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 and the flowers are borne laterally in an acropetal succession on the main peduncle (called simple inflorescence) or on its branches (called compound inflorescence) which also arise in acropetal succession.

There are several sub-types in the racemose category (Figure 5.16 A and B). Commonly occuring ones are described below. In *Crotalaria* and *Mangifera*, the pattern is **simple raceme**, while in members of *Cassia* and in cauliflower, it is called **Corymb** in which all the flowers are brought to the same height due to varied lengths of the pedicels even though they are borne at different nodes. In onion and members of Apiaceae (Umbelliferae) like carrot, the flowers appear to have arisen from the same point of the peduncle and such inflorescence is called **Umbel type**. It is covered by a whorl of bracts alled 'involucre'. Acropetal arrangement of sessile flowers on the peduncle is seen in **spikes** of *Achyranthes* and members of Poaceae (Graminae) like grasses.

(a) *Crotolaria* (b) *Cassia* (c) *Allium cepa* (Onion) (d) *Oryza sativa*

Figure 5.16 A. Racemose inflorescences

Plants such as *Musa, Cocos* and *Colocasia,* show sessile unisexual and neuter flowers arranged in acropetal succession protected by modified bract called 'spathe'. Such inflorescence is called **spadix**. Some times, unisexual and bisexual sessile flowers develop centripetally on a condensed peduncle as in member of Asteraceae (Compositae) like *Tridax* and sunflower. Such an arrangement of flowers is called **Head inflorescence**.

(e) *Colocasia*

(f) *Helianthus annus* (Sunflower)

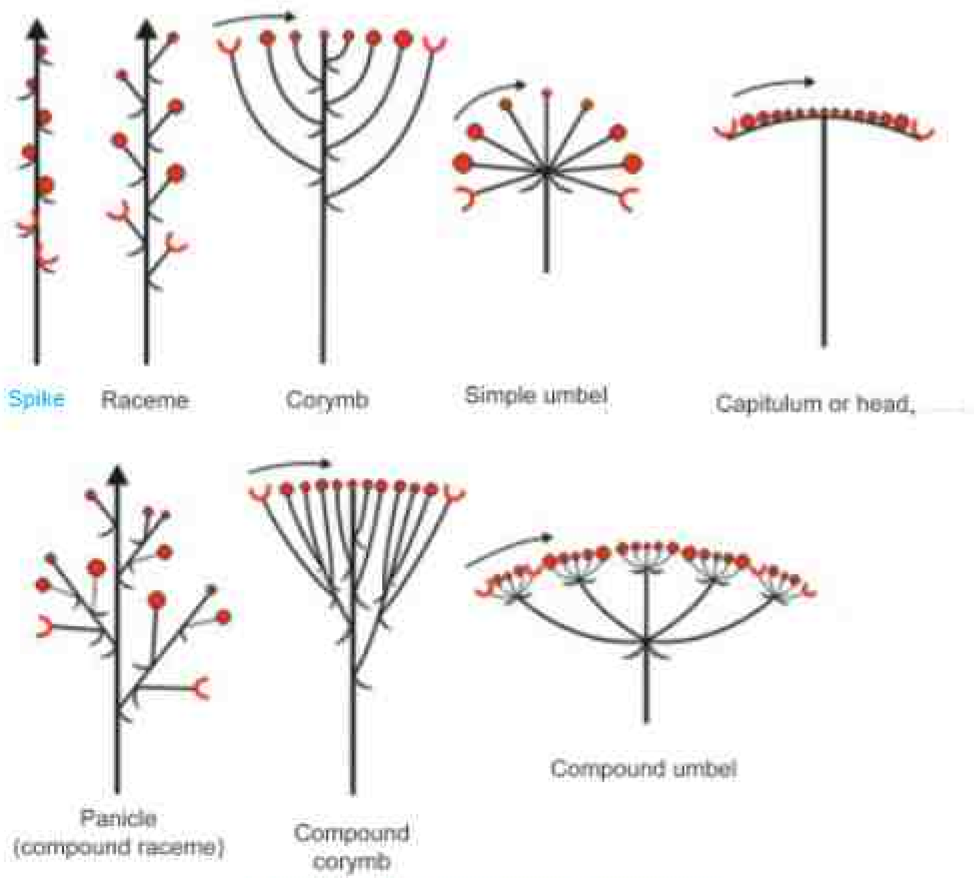
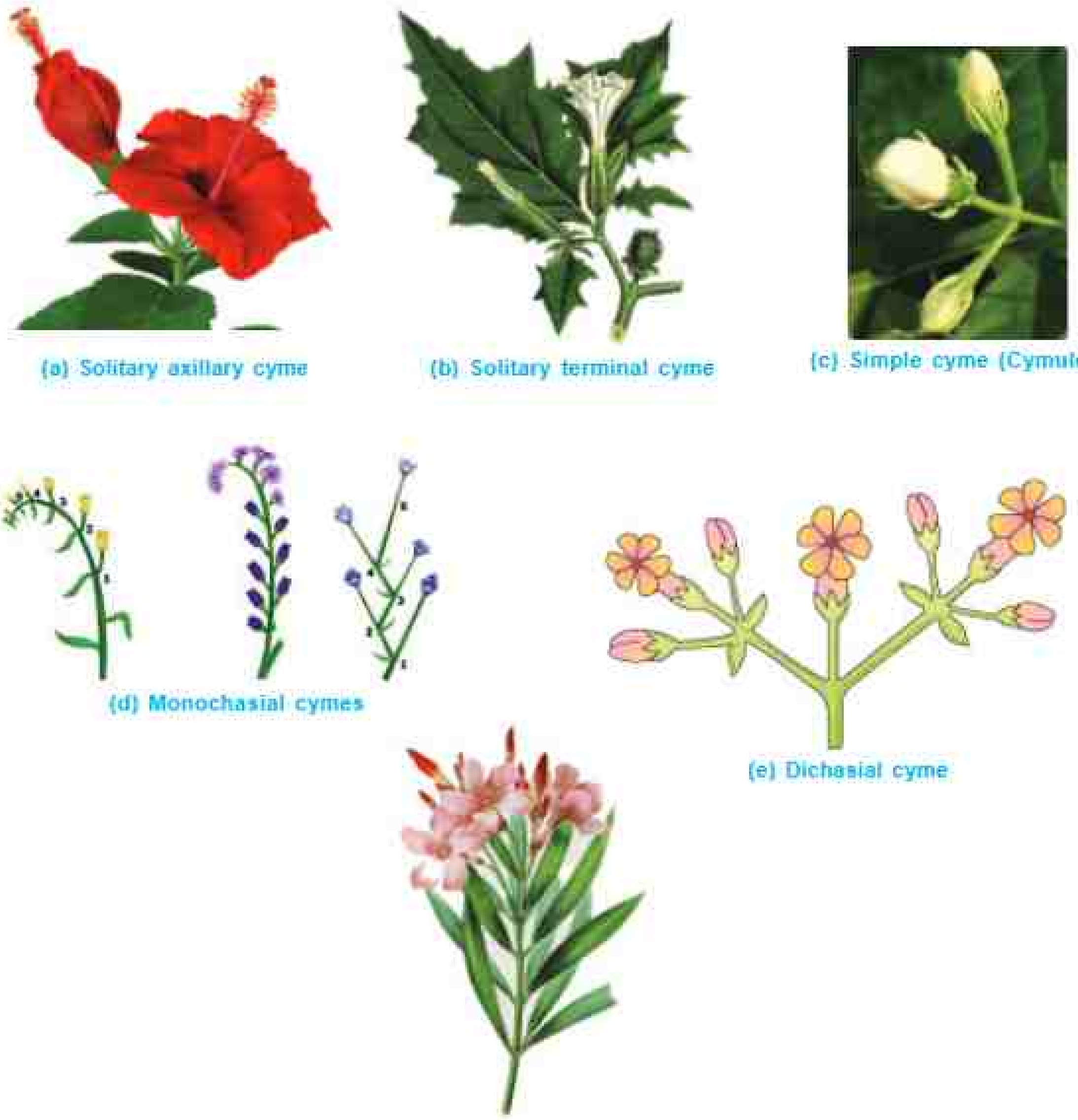


Figure 5.16 B. Racemose inflorescences (Schematic representation)

In **cymose** type of inflorescence, the main axis terminates into a flower, hence it shows limited growth. The flowers are borne in a basipetal order (Figure 5.17) either on a branched or unbranched peduncle. In *Hibiscus rosa-sinensis* and *Datura,* the peduncle is unbranched and bears a single flower. It is called **Solitary Cyme**. A three flowered cymose inflorescence found in plants like *Bougainvillea* and jasmine is known as **Cymule**. When the peduncle is branched, the cymose type is further divided based on the number of branches formed. These are called **monochasial cyme** (with one branch each time, eg. *Hamelia* and *Solanum*), **dichasial cyme** (with two branches each time, eg. *Ipoemoea)* and **polychasial cyme** (more than two branches each time, eg. *Nerium*).



(a) Solitary axillary cyme

(b) Solitary terminal cyme

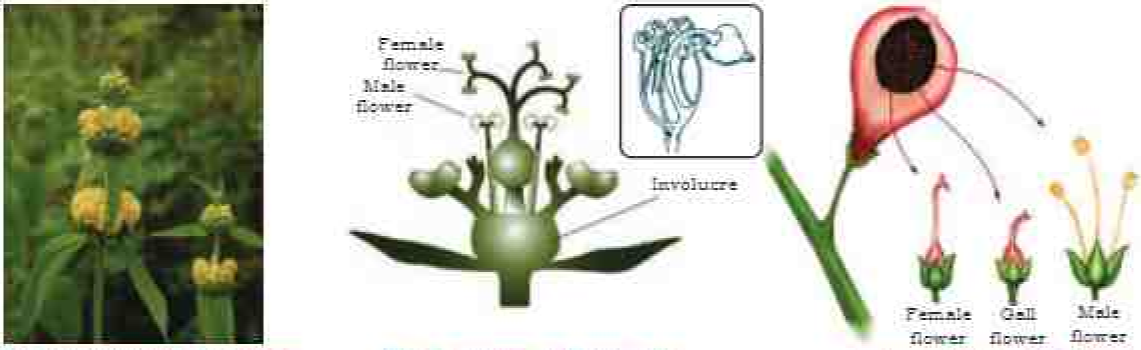
(c) Simple cyme (Cymule)

(d) Monochasial cymes

(e) Dichasial cyme

(f) Polychasial cyme

Figure 5.17 Cymose inflorescences



(a) Verticellaster of *Leucas* (b) Cyathium of Euphorbia (c) Hypanthodium of *Ficus*

Figure 5.18 Special inflorescences

Apart from the above types, there are certain special types of inflorescences found in some angiosperms (Figure 5.18). Members of Lamiaceae (Labiatae) show **Verticellaster** in which the inflorescence begins as a dichasial cyme but eventually turns monochasial forming a false whorl around the node. Similarly in members of Euphorbiaceae family, a special type of inflorescence called **Cyathium** is found in which the naked (achlymadeous), stalked and unisexual flowers are arranged in cymose manner inside cup like involucre of bracts. In it many male flowers, each represented by single stamen, are arranged in monochasial pattern around a single tricarpellary female flower. Members of *Ficus* (Fig tree) show yet another type of special inflorescence called **Hypanthodium** in which the peduncle is modified into a deep cup like fleshy structure in which many sessile unisexual flowers are irregularly arranged. The male flowers are located near the opening and the female flowers at the bottom while in between them are the sterile female flowers called gall flowers. Pollination in these plants takes place by an insect called *Blastophaga* which lay its eggs in the gall flowers. After fertilization the whole inflorescence becomes the fig fruit.

5.5 The Flower

The flower is the reproductive unit in the angiosperms. It is meant for sexual reproduction. A typical flower (Figure 5.19) 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 stamens or carpels is called **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

> Largest flowers are found in a complete root parasite *Rafflesia*, while the smallest flowers are found the smallest angiosperm *Wolfia*, a free floating hydrophyte.

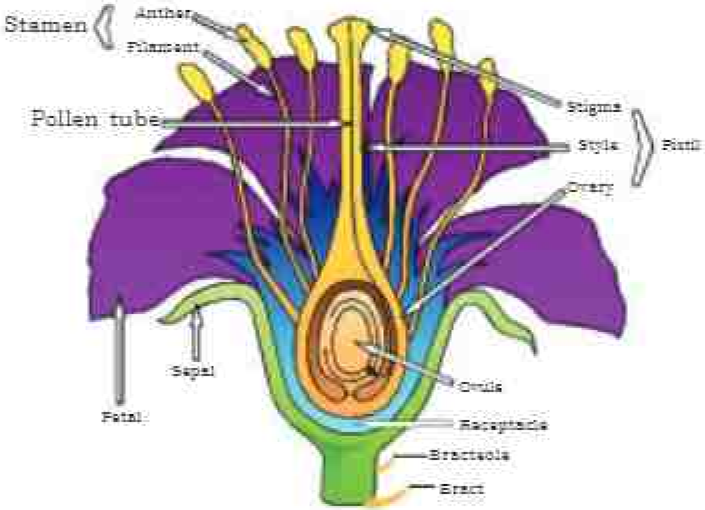


Figure 5.19 Parts of a typical angiospermic flower

particular vertical plane, it is called **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 found at the base of the pedicel are called **bracteate** and those without bracts are called **ebracteate**.

Based on the position of calyx, corolla and androecium on thalamus in respect of the ovary, the flowers are described as hypogynous perigynous and epigynous (Figure 5.20). 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**, or **half superior** e.g., plum, rose, peach. In **epigynous** flowers, the margin of thalamus grows upward enclosing the ovary completely and getting fused with it, while other parts of the 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.

(a) Hypogynous (b) Perigynous (c) Epigynous

Figure 5.20 Position of floral parts on thalamus

5.5.1 Parts of a Flower

Each flower normally has four floral whorls, viz., calyx, corolla, androecium and gynoecium (Figure 5.19) present at different nodes on the thalamus.

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 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 as in disc florets of Asteraceae members, or funnel-shaped as in *Datura*, or bi-lipped as in case of *Ocimum*. or wheel-shaped or bell-shaped.

Aestivation: The mode of arrangement of sepals or petals in floral bud is known as aestivation. The main types of aestivation are valvate, twisted, imbricate and vexillary (Figure 5.21). 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)

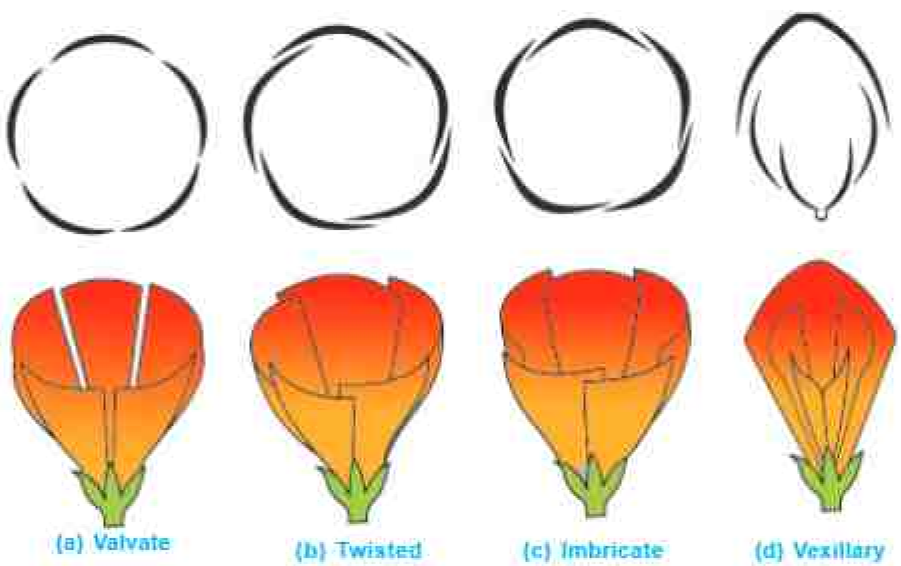


Figure 5.21 Types of aestivation in corolla

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 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 a 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 Brassica* (mustard).

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 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 is of different types namely, marginal, axile, parietal, basal, central and free central (Figure 5.22). In **marginal** placentation, the placenta

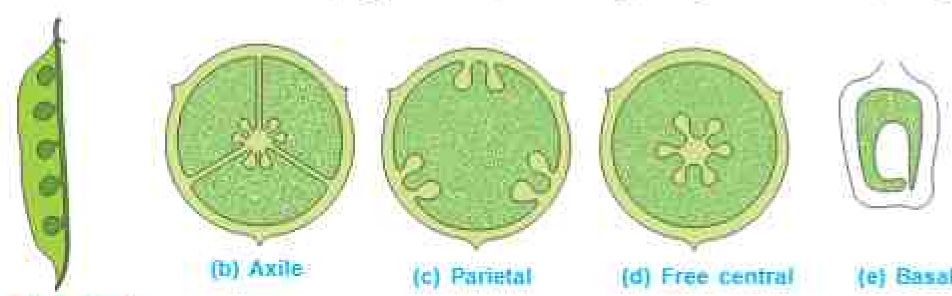


Figure 5.22 Types of placentations

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 two-chambered due to the formation of the false septum, e.g., mustard and *Argemone*. When the ovules are borne on central axis without septa, 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 and marigold.

5.6 Fruits

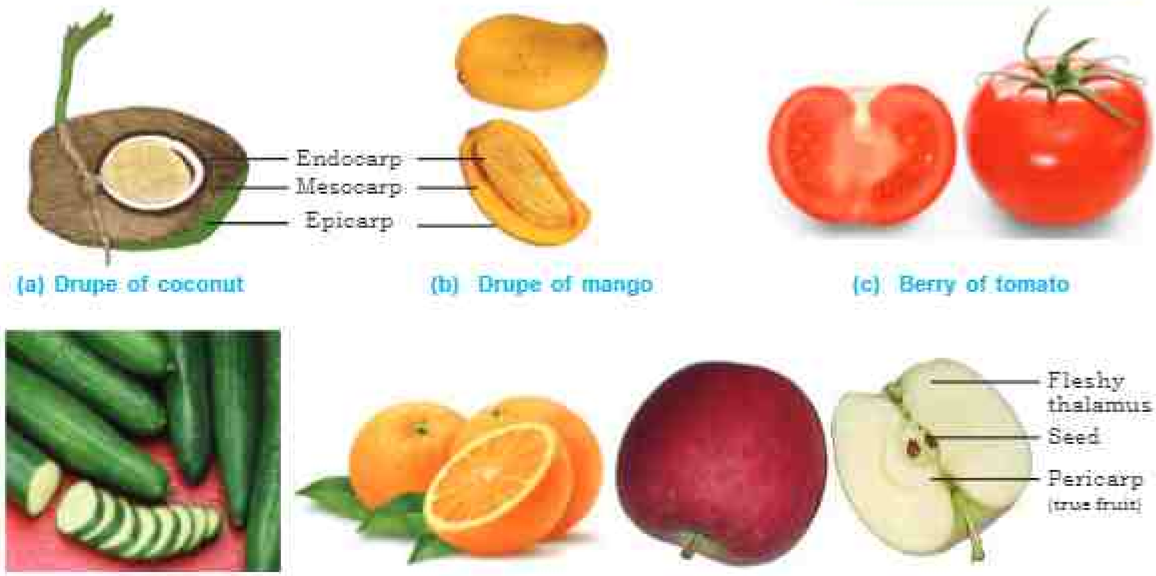
The fruit is a characteristic feature of the flowering plants. It is a mature or ripened ovary, developed after fertilisation. If a fruit is formed without fertilisation of the ovary, it is called a **parthenocarpic fruit**. Banana is one such example.

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**.

Do you know that all the fruits that we eat are not the 'real' ones!

In most plants, by the time the fruit develops from the ovary, other floral parts degenerate and fall off. However, in a few plants such as apple, cashew, strawberry etc., the thalamus or the pedicel also contribute to fruit formation. Such fruits are called **false fruits**. Most fruits however develop only from the ovary and are called **true fruits**. As ovules mature into seeds, the ovary develops into a fruit, i.e., the transformation of ovules into seeds and ovary into fruit proceed simultaneously.

There is a great variation in the nature of pericarp in fleshy fruits. True fruits can be classified into two types based on nature of the pericarp. **Fleshy fruits** will have pericarp divisible into epicarp, mesocarp and endocarp while **dry fruits** have dry and indivisible pericarp. Pericarp nature is one of the characters used to identify the fleshy fruits into five sub-types such as berry, drupe, hesperidium, pepo and pome (Figure 5.23). In mango and coconut, the fruit is known as a **drupe**. They develop from monocarpellary superior ovaries and/or one-seeded. In mango, the pericarp is well differentiated into an 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.



(a) Drupe of coconut (b) Drupe of mango (c) Berry of tomato

(d) Pepo of cucumber (e) Hesperidium of orange (f) Pome of apple

Figure 5.23 Types of Fleshy fruits

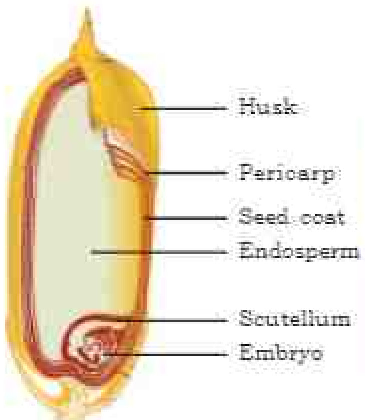
In a **berry** (eg. guava, grapes, tomato), the mesocarp and endocarp are fused to form the pulp, and the seeds are hard. Generally, berries develop from bi- or multicarpellary syncarpous gynoecium. In **pepo** (eg. Cucumber), the epicarp is like a rind, the mesocarp is fleshy and the endocarp is smooth. It develops from a tricarpellary unilocular inferior ovary. A **hesperidium** (eg- *Citrus*) is characterized by leathery epicarp with many volatile oil glands, papery mesocarp, and endocarp wall bears juicy hairs. The hesperidium develops from a multicarpellary, syncarpous, multilocular and superior ovary. In **pome** (eg. Apple), the fruit develops from inferior ovary of bi- or multicarpellary gynoecium and is surrounded by fleshy thalamus. The endocarp is cartilagenous.

When the pericarp is dry or non-fleshy, the fruits are called **dry fruits** as in groundnut, and mustard, etc. These dry fruits may break open (**dehiscent types**) and liberate the seeds (Figure 5.24) or may remain unopened (**indehiscent types**) and liberate the seeds only after disintegration of pericarp. The fruits of pea and beans dehisce dorsiventrally into two halves and are called **legumes**. A **capsule** dehisces in different ways to liberate the seeds.eg., Cotton, *Datura*.

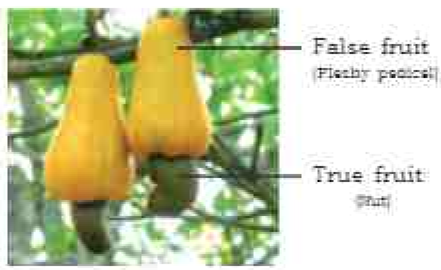
(a) Legume of *Pisum* (b) Capsule of *Datura*

Figure 5.24 Dry dehiscent fruits

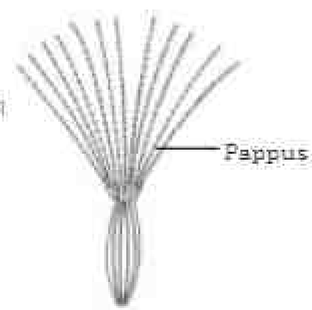
Dry indehiscent fruits (Figure 5.25) are usually single-seeded and are of different types. The pericarp and seed coat fuse together in grasses such as rice and it is known as **caryopsis**. In cashew, the fruit is called **nut**, which develops from multi-carpellary, syncarpous, unilocular ovary and the pericarp is stony. The single seeded fruit in *Tridax* is characterized by persistent pappus like calyx and is called **Cypsela**.



(a) Caryopsis of *Oryza*



(b) Nut of *Anacardium* (cashew)



(c) Cypsela of *Tridax*

Figure 5. 25 Dry indehiscent fruits

The fruits of *Acacia* (Figure 5.26) and castor split into one-seeded bits called mericarps and are known as **Schizocarpic** fruits.

In custard apple (*Annona squamosa*), the carpels are many and free and each carpel of such apocarpous gynoecium develops into a fruitlet; such bunch of fruitlets are called aggregate fruits (Figure 5.27). In Pineapple (Figure 5.28) and jack fruit, entire inflorescence develops into a fruit known as composite fruit.

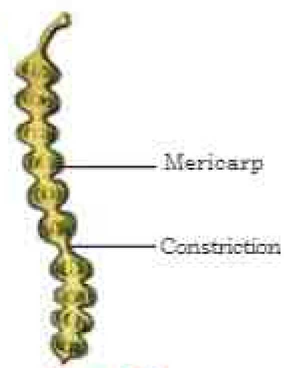


Figure 5.26 Schizocarp of *Acacia*

Figure 5.27 Aggregate fruit of custurd apple

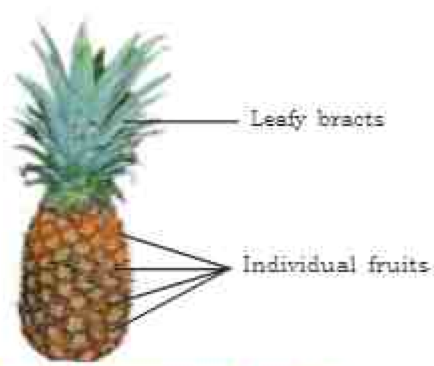


Figure 5.28 Compound fruit of pineapple

5.7 The Seeds

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 an embryonal axis and one (as in wheat, maize) or two cotyledons (as in gram and pea). A detailed account of the development of the different structures within a seed and their significance is described in Chapter 7 of the next Unit.

LIST OF SOME IMPORTANT EDIBLE FRUITS

Sl. No.	Botanical Name	Common Name	Family	Type of fruit	Morphology of chief edible part
1	*Anacardium occidentale*	Cashew	Anacardiaceae	Nut	Cotyledons and fleshy pedicel (false fruit)
2	*Ananas sativus*	Pineapple	Bromeliaceae	Sorosis (Compound fruit)	Inflorescence axis and juicy succulent bracts
3	*Annona squamosa*	Custurd apple	Annonaceae	Aggregate of berries	Mesocarp and endocarp of each fruitlet
4	*Arachis hypogea*	Ground nut	Fabaceae	Legume	Cotyledons
5	*Artocarpus integrifolia*	Jack fruit	Moraceae	Sorosis (Compound fruit)	Succulent perianth
6	*Citrus sinensis*	Sweet orange	Rutaceae	Hesperidium	Juicy succulent placental hairs of endocarp
7	*Cocos nucifera*	Coconut	Arecaceae / Palmaceae	Drupe	Endosperm
8	*Cucurbita maxima*	Cucumber	Cucurbitaceae	Pepo	Mesocarp, endocarp and placenta
9	*Dolichos lablab*	Bean	Fabaceae	Legume	Cotyledons
10	*Ficus benghalensis*	Fig	Moraceae	Syconus (Compound fruit)	Fleshy peduncle
11	*Lycopersicon esculentum*	Tomato	Solanaceae	Berry	Mesocarp, Endocarp and placenta
12	*Mangifera indica*	Mango	Anacardiaceae	Drupe	Mesocarp
13	*Oryza sativa*	Rice (Paddy)	Poaceae	Caryopsis	Endosperm
14	*Pisum sativum*	Garden pea	Fabaceae	Legume	Cotyledons
15	*Pyrus malus*	Apple	Rosaceae	Pome	Fleshy thalamus (false fruit)

SUMMARY

Flowering plants exhibit enormous variation in shape, size, structure, mode of nutrition, life span, habit and habitat. They have well developed root and shoot systems. Root system is either tap root or fibrous. Generally, dicotyledonous plants have tap roots while monocotyledonous plants have fibrous roots. The roots in some plants get modified for storage of food, mechanical support and respiration. The shoot system is differentiated into stem, leaves, flowers and fruits. The morphological features of stems like the presence of nodes and internodes, multicellular hair and positively phototropic nature help to differentiate the stems from roots. Stems also get modified to perform diverse functions such as storage of food, vegetative propagation and protection under different conditions. Leaf is a lateral outgrowth of stem developed exogeneously at the node. These are green in colour to perform the function of photosynthesis. Leaves exhibit marked variations in their shape, size, margin, apex and extent of incisions of leaf blade (lamina). Like other parts of plants, the leaves also get modified into other structures such as tendrils, spines for climbing and protection respectively.

The flower is a modified shoot, meant for sexual reproduction. The flowers are arranged in different types of inflorescences. They exhibit enormous variation in structure, symmetry, position of ovary in relation to other parts, arrangement of petals, sepals, ovules etc. After fertilisation, the ovary is converted into fruit and ovule into seed. A fruit developing from fertilized ovary is called a true fruit. Rarely a fruit may develop from an unfertilized ovary and is called parthenocarpic fruit. If any part of the flower, other than ovary, develops into a fruit-like structure, it is called false fruit. Based on the nature of fruit wall, true fruits may be fleshy or dry. Fleshy fruits may be berries, drupes, pomes, pepos or hesperidiums. Dry fruits are further identified into dehiscent, indehiscent or schizocarpic types. Seeds either may be monocotyledonous or dicotyledonous. They vary in shape, size and period of viability.

GLOSSARY

Achlamydeous: A flower without the non-essential organs (or perianth). It is also called naked flower.

Acropetal arrangement: Formation of lateral structures from the base towards apex of an axis.

Actinomorphic flower: A flower that can be cut into two equal halves in any vertical plane.

Adventitous root: The root that emerges from a place other than radicle.

Androecium: The whorl of stamens in a flower that represents the male reproductive structure.

Axil: The upper angle between the leaf and the stem where axillary bud is present.

Basipetal arrangement: Formation of lateral structures from the apex towards base of an axis.

Bract: A thin, membranous leaf like structure in whose axil the flower arises. It protects the flower in bud condition.

Bracteoles: Thin, membranous structures that are formed on the pedicels of some flowers.

Complete flower: A flower consisting of two whorls of perianth along with at least one whorl each of stamens and carpels.

Corm: An underground stem that grows vertically downwards.

Endosperm: The triploid nutritive tissue found around the embryo of angiosperms.

Epiphyllous buds: The adventitious buds that are formed on leaves. They help is vegetative reproduction.

Epiphyllous stamens: Stamens attached to perianth.

Fibrous roots: The bunch of roots that originate from a place other than radicle.

Geotropism: The influence of gravity on growth.

Gynoecium: The last whorl of flower represented by carpels.

Haustoria: The special adventitious roots that are modified to absorb minerals and/or organic matter from the host.

Incomplete flower: A flower that does not contain any one of the whorls of perianth or stamens or carpels.

Involucre: The whorl of bracts around the inflorescence which help in protection. It may have fused bracts as in Euphorbiaceae members or the bracts may be free as in Umbelliferae members.

Locule: The chambers inside the ovary that arise due to formation of septa.

Mericarp: The one seeded bits of schizocarpic fruits.

Meristem: The tissue that forms new cells in plants.

Modification: A permanent morpho-logical change in an organ in order to perform a special function.

Offset: A branch of single internode length which bears adventitious roots and a rosette of leaves at each node.

Papilionaceous corolla: The type of arrangement of petals in Papilionaceae (Fabaceae) members. It consists of a posterior standard petal called vexillum that attracts insects, two lateral wing petals called alae on which the insects land and two boat shaped anterior petals called keel or carina which enclose the essential organs.

Pappus: The persistent calyx (sepals) of Asteraceae members which helps in seed or fruit dispersal by wind.

Parthenocarpy: The phenomenon of formation of fruits without fertilization or seeds.

Pedicel: The stalk of the flower.

Peduncle: The inflorescence axis on which flowers are borne.

Perianth: The outer most two whorls of a flower represented by sepals and petals.

Pericarp: The wall of fruit which is differentiated into outer epicarp, middle mesocarp and inner endocarp when the fruit is fleshy.

Petiole: The stalk of the leaf.

Phototropism: The influence of light on growth.

Pistillate flower: A unisexual flower that contains carpels but lacks stamens. It is also called female flower.

Plumule: The tip of the embryonic axis which emerges out after the emergence of radical and gives rise to shoot system.

Rachis: The extension of petiole that represents the axis of a pinnately compound leaf. It is absent in palmately compound leaves.

Radicle: The tip of the embryonic axis which emerges out first during seed generation and gives rise to root system.

Rhizome: An underground stem that is dorsi-ventrally flattened and grows horizontally in soil.

Runner: The weak stem or its branch which grows horizontally on soil and forms adventitious roots at every node.

Schizocarp: A dry fruit that dehisces into single seeded bits called mericarps. It also shows indehiscent character in liberating the seeds only after disintegration of pericarp of the mericarp.

Sessile condition: A leaf or flower is said to be sessile if the stalk is absent.

Sorosis : The compound (multiple) fruit that develops from catkin, spike or spadix inflorescence.

Staminate flower: A unisexual flower that contains stamens but lacks carpels. It is also called male flower.

Stem tuber: Tip of an underground branch that becomes swollen due to storage of food materials.

Stolon: An obliquely downward growing branch of an aerial stem that develops adventitious roots at the point of contact with the soil.

Sucker: An obliquely upward growing branch of an underground stem which when detached develops into an individual plant.

Syconus: The compound (multiple) fruit that develops from hypanthodium inflorescence.

Thalamus: The dilated tip of the pedicel.

Transpiration: The phenomenon of loss of water in the form of vapour from the surface of plants mainly through tiny pores called stomata present on leaves.

Velamen root: The root that appears in epiphytic plants and is responsible for absorption of moisture from atmosphere.

Zygomorphic flower: A flower that can be cut into two equal halves in one vertical plane.

VERY SHORT ANSWER QUESTIONS

1. Differentiate fibrous roots from adventitious roots.
2. Define modification. Mention how root is modified in banyan tree and mangrove plants?
3. What type of specialized roots are found in epiphytic plants? What is their function?
4. How does the sucker of *Chrysanthemum* differ from the stolon of jasmine?
5. What is meant by pulvinus leaf base? In members of which angiospermic family do you find them?
6. Define venation. How do dicots differ from monocots with respect to venation?
7. How is a pinnately compound leaf is different from a palmately compound leaf? Explain with one example each.
8. Which organ is modified to trap insects in insectivorous plants? Give two examples.
9. Differentiate between Racemose and Cymose inflorescenes.
10. What is the morphology of cup like structure in Cyathium? In which family it is found?
11. What type of inflorescence is found in fig trees? Why does the insect *Blastophaga* visits the inflorescence of fig tree?
12. Differentiate actinomorhic from zygomorphic flower.
13. How do the petals in pea plant are arranged? What is such type of arrangement called?
14. What is meant by epipetalous condition? Give an example.
15. Differentiate between apocarpous and syncarpous ovary.
16. Define placentation. What type of placentation is found in *Dianthus*?
17. What is meant by parthenocarpic fruit? How is it useful?
18. What is the type of fruit found in mango? How does it differ from that of coconut?
19. Why certain fruits are called false fruits? Name two examples of plants having false fruits.
20. Name any two plants having single seeded dry fruits.
21. Define schizocarpic dry fruits. Give an example.
22. Define mericarp. In which plant you find it?
23. What are aggregate fruits? Give two examples.
24. Name a plant that has single fruit developing from the entire inflorescence. What is such a fruit called?
25. What is meant by scutellum? In which type of seeds is it present?
26. Define with examples endospermic and non-endospermic seeds.

SHORT ANSWER QUESTIONS

1. Explain different regions of root with neat labeled diagram.
2. Justify the statement: "Underground parts of plants are not always roots".
3. Explain with examples different types of phyllotaxy.
4. How do leaf modifications help plants?
5. Describe any two special types of inflorescences.
6. Describe the arrangement of floral members in relation to their insertion on thalamus.
7. 'The flowers of many angiospermic plants which show sepals and petals, differ with respect to the arrangement of sepals and petals in respective whorls'. Explain.
8. Describe any four types of placentations found in flowering plants.
9. Describe in brief fleshy fruits you studied.
10. Describe with examples the various dry fruits you studied.

LONG ANSWER QUESTIONS

01. Define root. Mention the types of root systems. Explain how root is modified to perform different functions.
02. Explain how stem is modified variously to perform different functions.
03. Explain different types of racemose inflorescences.

EXERCISES

1. In which plant, the underground stem grows horizontally in soil and helps in perennation?
2. Needle like phylloclades are found in which plant?
3. Why do plants like *Nepenthes* trap insects?
4. What is the characteristic inflorescence found in members of Asteraceae?
5. Can you name a plant that has least number of flowers in its inflorescence?
6. Which family shows naked flowers?
7. In which flowers of the fig trees does the insect *Blastophaga* lay its eggs?
8. What type of symmetry is shown by the flowers of *Canna*?
9. On which side of the flower do the flowers of pea have the keel petals?
10. What is the ratio of overlapping margins of petals to overlapped ones in imbricate aestivation?
11. How many ovules are found attached in basal placentation?
12. Which part of the flower in cashew plant forms the false fruit?
13. Which plant has hard, stony endocarp and fleshy edible mesocarp?
14. What is the morphology of 'spathe' in Spadix inflorescence?
15. What is the type of fruit known as if it develops from apocarpus ovary of a single flower?

UNIT III

REPRODUCTION IN PLANTS

Biology in essence is the story of life on earth. While individual organisms die without fail, species continue to live through millions of years unless threatened by natural or anthropogenic extinction. Reproduction becomes a vital process without which species cannot survive for long. Each individual leaves its progeny by asexual or sexual means. Sexual mode of reproduction enables creation of new variants, so that survival advantage is enhanced. This unit examines the general principles underlying the various reproductive processes in plants and then explains the details of sexual reproduction in Angiosperms.

Panchanan Maheshwari
(1904-1966)

Born in November 1904 in Jaipur (Rajasthan) Panchanan Maheshwari rose to become one of the most distinguished botanists not only of India but of the entire world. He moved to Allahabad for higher education where he obtained his D.Sc. During his college days, he was inspired by Dr W. Dudgeon, an American missionary teacher, to develop interest in Botany and especially morphology. His teacher once expressed that if his student progresses ahead of him, it will give him a great satisfaction. These words encouraged Panchanan to enquire what he could do for his teacher in return.

He worked on embryological aspects and popularised the use of embryological chracters in taxonomy. He established the Department of Botany, University of Delhi as an important centre of research in embryology and tissue culture. He also emphasised the need for initiation of work on artificial culture of immature embryos. These days, tissue culture has become a landmark in science. His work on test tube fertilisation and intra-ovarian pollination won worldwide acclaim. He was honoured with fellowship of Royal Society of London (FRS), Indian National Science Academy and several other institutions of excellence. He encouraged general education and made a significant contribution to school education.

Chapter 6

Modes of Reproduction

6.1 Reproduction and its types

Each and every organism can live only for a certain period of time. The period from birth to the natural death of an organism represents its life span. Life spans of a few plants are given in figure 6.1. Several other plants are drawn for which you should find out their life spans and write in the spaces provided. Examine the life spans of organisms represented in figure 6.1.

Isn't it both interesting and intriguing to note that it may be as short as a few days or as long as a few thousand years? Between these two extremes are the life spans of most other living organisms. A mango tree has a much shorter life span as compared to a peepal tree. Whatever be the life span, death of every individual organism is a certainty, i.e., no individual is immortal, except single-celled organisms. Why do we say there is no natural death in single-celled organisms? Given this reality, have you ever wondered how vast number of plant species has existed on earth for several thousands of years? There must be some processes in living organisms that ensure this continuity. Yes, we are talking about reproduction, something that we take for granted.

Banyan tree (________)

Wolffia (________)

Royal Fern (*Osmunda*___)
100 + years

Pinus (________)

Carrot (________)

Banana plant (______)

Moss plant
(Few weeks)

Rice plant (______)

Rose plant (______)

Figure 6.1 Approximate life spans of plants

Reproduction is defined as a biological process in which an organism gives rise to young ones (offspring) similar to itself. The offspring grow, mature and in turn produce new offspring. Thus, there is a cycle of birth, growth and death. Reproduction enables the continuity of the species, generation after generation. You will study later in (Principles of Inheritance and Variation) how genetic variation is created and inherited during reproduction.

There is a large diversity in the biological world and each organism has evolved its own mechanism to multiply and produce offspring. The organism's habitat, its internal physiology and several other factors are collectively responsible for how it reproduces. Based on whether there is participation of one organism or two in the process of reproduction, it is of two types. When offspring is produced by a single parent with or without the involvement of gamete formation, the reproduction is asexual. When two parents (opposite sex) participate in the reproductive process and also involve fusion of male and female gametes, it is called sexual reproduction.

6.2 Asexual Reproduction

In this method, a single individual (parent) is capable of producing offspring. As a result, the offspring produced are not only identical to one another but are also exact copies of their parent.

Are these offspring likely to be genetically identical or different?

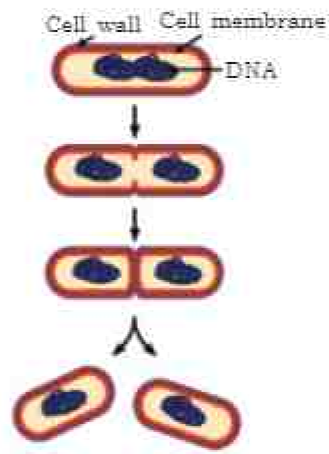


Figure 6.2 (a) Binary fission in bacteria

Asexual reproduction is common among single-celled organisms, and in plants with relatively simple organisations. In Protists and Monerans, the organism or the parent cell divides into two to give rise to new individuals (Figure 6.2a-binary fission). Thus, in these organisms cell division is itself a mode of reproduction. Many single-celled organisms reproduce by binary fission, where a cell divides into two halves and each rapidly grows into an adult (e.g., *Euglena*, bacteria). In yeast, asexual reproduction takes by budding where the division is unequal. Small **buds** are produced that remain attached initially to the parent cell which, eventually get separated and mature into new yeast organisms (cells) (Fig.6.2b).

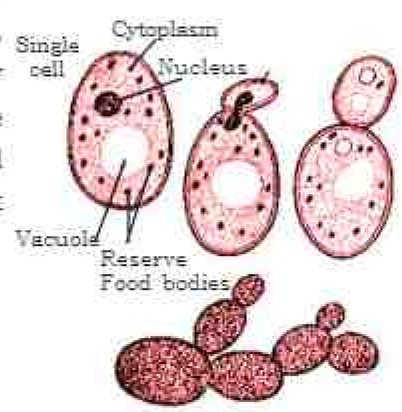


Figure 6.2 (b) Budding in yeast

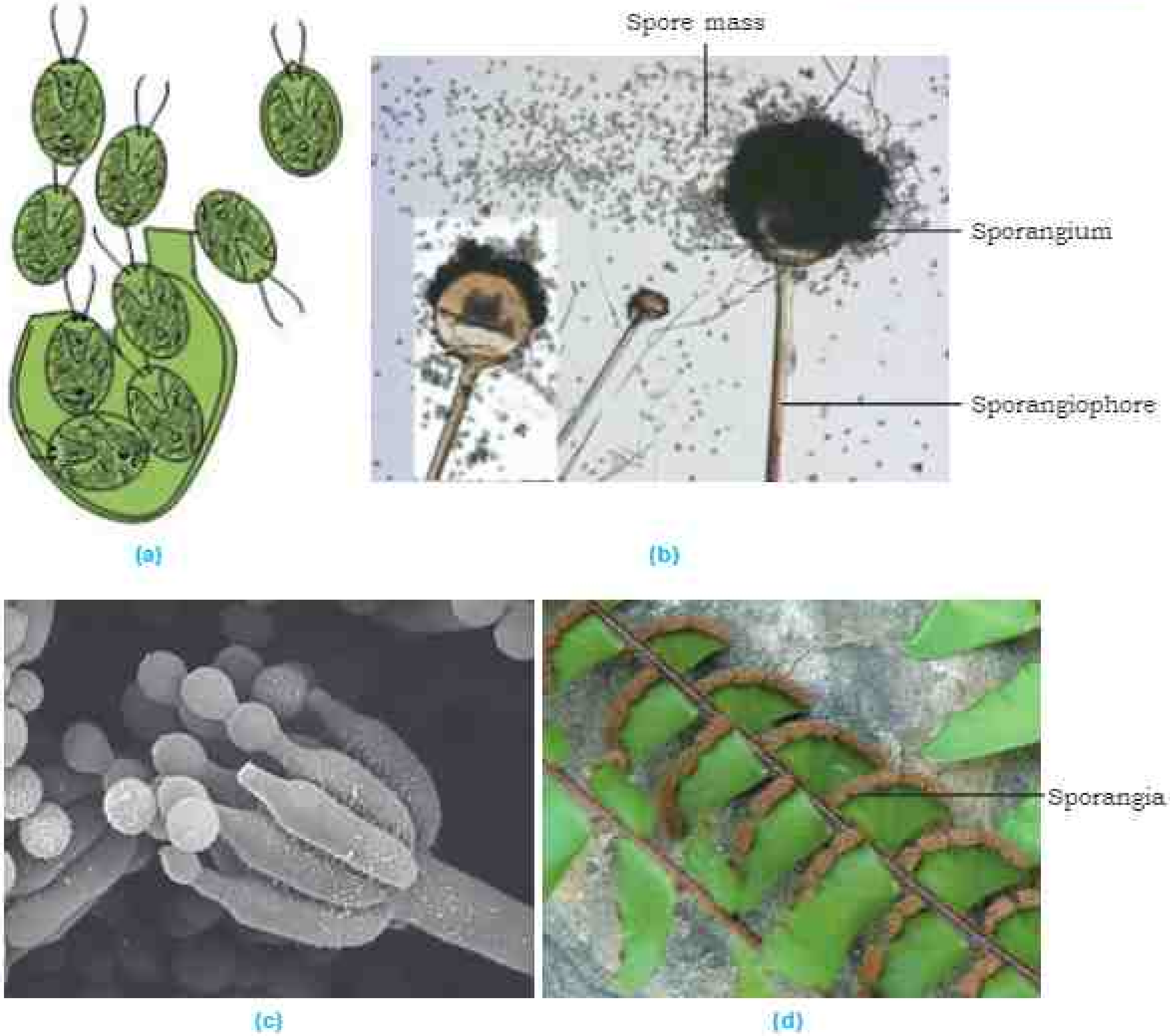


Figure 6.3 Asexual reproductive structure
(a) Zoospores of *Chlamydomonas*, (b) Spores of *Rhizopus*, (c) Conidia of *Penicillium*, (d) Sporophyll of pteridophyte with sporangia

Several members of the Kingdom Fungi and simple plants such as Algae reproduce through special asexual reproductive structures (Figure 6.3). The most common of these structures are **spores** that usually are microscopic, adapted for dispersal, and can survive extended periods of unfavourable conditions. The spores produced by mitosis in some algae such as *Chlamydomonas*, which are motile are known as zoospores (Fig.6.3 a). The spores produced by the common bread mold are non-motile. These spores are produced in the sporangia e.g., *Rhizopus* (Fig 6.3 b). In some Fungi, the reproductive spores are produced on specialized sporangiophores and are known as conidia e.g., *Penicillium* (6.3 c).

Did you identify the differences in the spore production of Rhizopus and Penicillium?

In *Bryophytes and Pteridophytes* the spores produced are haploid in nature. On germination they produce gametophyte that is necessary to complete the life cycle.

Another type of asexual reproduction seen in plants is **vegetative reproduction**. In multicellular or colonial forms of algae, moulds and mushrooms, the body may split/ break or get seperated into smaller portions and each fragment thus formed develops into a mature individual. This process of vegetative reproduction is called **fragmentation**. Some plants have specialized structures for reproduction via fragmentation e.g., Gemmae in liver worts (Fig 6.4).

Figure 6.4 Gemmae in liver worts

In flowering plants, the units of **vegetative propagation** such as **runner, stolon, sucker, offset, rhizome, corm , tuber, bulb, bulbil, reproductive leaves** (described in Chapter 5) are all capable of giving rise to new offspring (Fig 6.5). These structures are called **vegetative propagules.** Obviously, since the formation of these structures does not involve two parents, the process involved is asexual. Plants produced vegetatively or asexually are called **clones**.

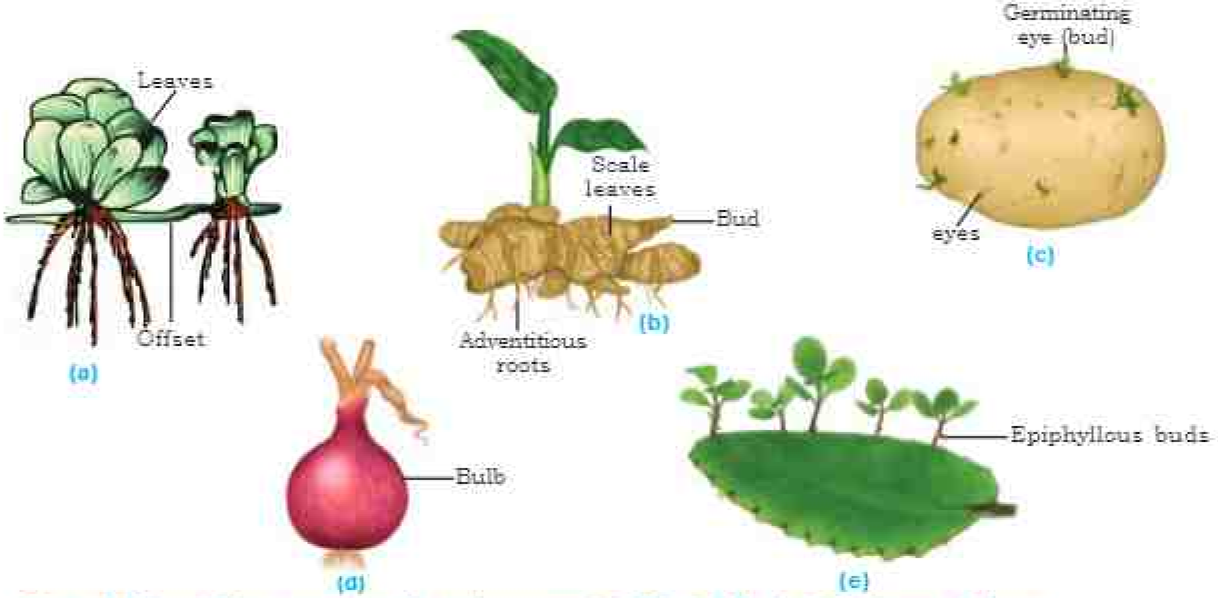


Figure 6.5 Vegetative propagules in angiosperms (a) Offset of *Pistia* (b) Rhizome of ginger (c) Tuber of potato with eyes (d) Bulb of onion (e) leaf buds of *Bryophyllum*

You must have heard about the scourge of the water bodies or about the 'terror of Bengal'. This is nothing but the aquatic plant '**water hyacinth**' (Fig 6.6), which is one of the most invasive weeds found growing wherever there is standing water. It drains oxygen from the water, which leads to death of fishes. You may find it

Figure 6.6 Water hyacinth

interesting to know that this plant was introduced in India because of its beautiful flowers and shape of leaves. Since it can propagate vegetatively at a phenomenal rate and spread all over the water body in a short period of time, it is very difficult to get rid off them.

Are you aware how plants like potato, sugarcane, banana, ginger, dahlia are cultivated? Have you seen small plants emerging from the buds (called eyes) of the potato tuber, from the rhizomes of banana and ginger? When you carefully try to determine the site of origin of the new plantlets in the plants listed above, you will notice that they invariably arise from the **nodes** present in the modified stems of these plants. When the nodes come in contact with damp soil or water, they produce roots and new plants. Similarly, adventitious buds arise from the notches present at margins of leaves of *Bryophyllum*. This ability is fully exploited by gardeners and farmers for commercial propagation of such plants.

It is interesting to note that asexual reproduction is the common method of reproduction in organisms that have a relatively simple organisation, like algae and fungi and that they shift to sexual method of reproduction just before the onset of adverse conditions. *Find out how sexual reproduction enables these organisms to survive during unfavourable conditions? Why is sexual reproduction favoured under such conditions?*

Asexual (vegetative) as well as sexual modes of reproduction are exhibited by the higher plants.

6.3 Sexual Reproduction

Sexual reproduction involves formation of the male and female gametes, either by the same individual or by different individuals of the opposite sex. These gametes fuse to form the zygote which develops to form the new organism. It is an elaborate, complex and slow process as compared to asexual reproduction. Because of the fusion of male and female gametes, sexual reproduction results in offspring that are not identical to the parents or amongst themselves.

A study of diverse organisms–plants, animals, protists, prokaryotes and fungi–show that though they differ so greatly in external morphology, internal structure and physiology, when it comes to sexual mode of reproduction, surprisingly, they share a similar pattern. Let us first discuss what features are common to these diverse organisms.

All organisms have to reach a certain stage of growth and maturity in their life, before they can reproduce sexually and this stage is known as **vegetative phase** in plants. This phase is of variable durations in different organisms. The end of **juvenile/**

vegetative phase which marks the beginning of the reproductive phase can be seen easily in the higher plants when they come to flower. *How long does it take for marigold/rice/wheat/coconut/mango plants to come to flower? In some plants, where flowering occurs more than once, what would you call the inter-flowering period – juvenile or mature?*

Observe a few trees in your area. *Do they flower during the same month year after year? Why do you think the availability of fruits like mango, apple, jackfruit, etc., is seasonal? Are there some plants that flower throughout the year and some others that show seasonal flowering?*

Plants–the annual and biennial types, show clear cut vegetative, reproductive and senescent phases, but in the perennial species it is very difficult to clearly define these phases. A few plants exhibit unusual flowering phenomenon; some of the grasses such as rice, maize, wheat (annuals), and bamboo species (perennial) flower only once in their life time. Commonly known Century plant (*Agave americana*) and bamboo flower at the end of the life. Bamboo flowers generally after 50-100 years and *Agave* after 10-30 years of life produce large number of fruits and die. Another plant, *Strobilanthus kunthiana* (neelakuranji), flowers once in 12 years. As many of you would know that this plant flowered during September-October 2006. Its mass flowering transformed large tracks of hilly areas in Kerala, Karnataka and Tamil Nadu into blue stretches and attracted a large number of tourists. The reproductive phase is also of variable duration in different organisms. In plants, hormones are responsible for the sexual reproduction. Interaction between hormones and certain environmental factors regulate the reproductive process and associated expressions.

6.3.1 Events in sexual reproduction

After attainment of maturity, all sexually reproducing organisms exhibit events and processes that have remarkable fundamental similarity, even though the structures associated with sexual reproduction are indeed very different. The events of sexual reproduction though elaborate and complex, follow a regular sequence. Sexual reproduction is characterised by the fusion (or fertilisation) of the male and female gametes, the formation of zygote and embryogenesis. For convenience sake, these sequential events may be grouped into three distinct stages namely, the **pre-fertilisation, fertilisation** and the **post-fertilisation** events.

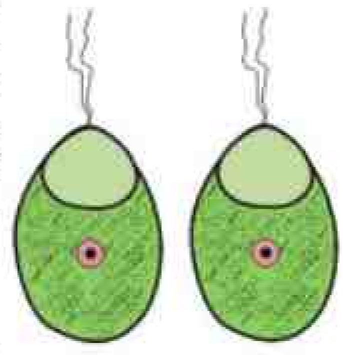


Figure 6.7 (a) Isogametes of *Cladophora* (an alga)

6.3.1.2 Pre-fertilisation Events

These include all the events of sexual reproduction prior to the fusion of gametes. The two main pre-fertilisation events are gametogenesis and gamete transfer.

6.3.1.2 Gametogenesis

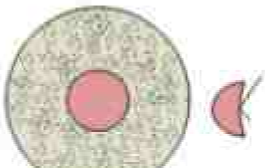


Figure 6.7 (b): Heterogametes of *Fucus* (an alga)

Gametogenesis refers to the process of formation of the two types of gametes – male and female. Gametes are haploid cells. In some algae the two gametes are so similar in appearance that it is not possible to categorize them into male and female gametes. They are hence, are called **homogametes** (**isogametes**), eg., *Cladophora* (Figure 6.7a). However, in a majority of sexually reproducing organisms the gametes produced are of two morphologically distinct types (**heterogametes**) (Figure 6.7b). In such organisms, the male gamete is called the antherozoid or sperm and the female gamete is called the egg, eg. *Funaria, Pteris, Cycas*.

Sexuality in Organisms: Sexual reproduction in organisms generally involves the fusion of gametes from two different individuals. But this is not always true. From your recollection of examples studied earlier , can you identify cases where self-fertilisation is observed?

Plants may have both male and female reproductive structures in the same plant (bisexual) (Figure 6.8 a, c) or on different plants (unisexual) (Figure 6.8 b, d). In several fungi and plants, terms such as **homothallic** (Fungi) and **monoecious** (Plants) are used to denote the bisexual condition and **heterothallic** (Fungi) and

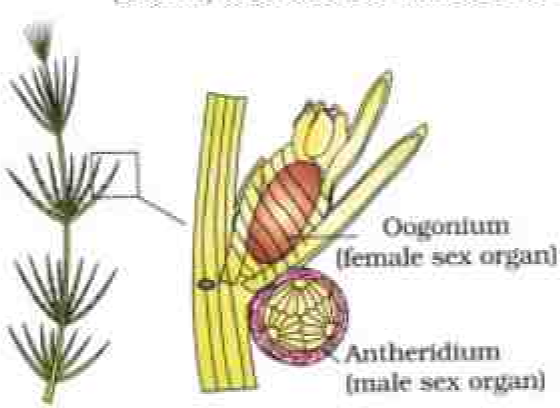


Figure 6.8 (a) Monoecious plant (*Chara*)

Figure 6.8 (b) Dioecious plant (*Marchantia*)

Figure 6.8 (c) Monoecious plant (Maize)

Figure 6.8 (d) Dioecious plant (Papaya)

dioecious (plants) are the terms used to describe unisexual condition. In flowering plants, the unisexual male flower is **staminate**, i.e., bearing stamens, while the female is **pistillate** i.e., bearing pistils. In some flowering plants, both male and female flowers may be present on the same individual (monoecious) or on separate individuals (dioecious).

Among flowering plants some examples of monoecious plants are cucurbits and coconuts and of dioecious plants are papaya and date palm.

Name the type of gametes that are formed in staminate and pistillate flowers.

Cell division during gamete formation: Gametes in all heterogametic species are of two types namely, male and female. Gametes are haploid though the parent plant body from which they arise may be either haploid or diploid. A haploid parent produces gametes by mitotic division. Does this mean that meiosis never occurs in organisms that are haploid?

Carefully examine the flow charts of life cycles of algae that you have studied in earlier chapters to get a suitable answer.

Several organisms belonging to monera, fungi, algae and bryophytes have **haploid** plant body, but in organisms belonging to pteridophytes, gymnosperms, angiosperms the plant body is **diploid**. It is obvious that meiosis, the reduction division, has to occur if a diploid body has to produce haploid gametes. In diploid organisms, specialized cells called **meiocytes** (gamete mother cells) undergo meiosis. At the end of meiosis, only one set of chromosomes gets incorporated into each **gamete**.

6.3.1.3 Gamete Transfer

After their formation, male and female gametes must be physically brought together to facilitate fusion (fertilisation). *Have you ever wondered how the gametes meet?* In a majority of organisms, male gamete is motile and the female gamete is stationary. Exceptions are a few fungi and algae in which both types of gametes are motile (Figure 6.9 a). There is a need for a medium through which the male gametes move. In several simple plants like algae, bryophytes and pteridophytes, water is the medium through which this gamete transfer takes place. A large number of the male gametes, however, fail to reach the female gametes. To compensate this loss of male gametes during transport, the number of male gametes produced is several thousand times the number of female gametes produced.

In seed plants, pollen grains are the carriers of male gametes and ovule has the egg. Pollen grains produced in anthers therefore, have to be transferred to the stigma before it can lead to fertilisation (Figure 6.9 b). In bisexual, self-fertilising plants, e.g., peas, transfer of pollen grains to the stigma is relatively easy as anthers and stigma are located close to each other; pollen grains soon after they are shed, come in contact with the stigma. But in cross pollinating plants (including dioecious plants), a specialized event called **pollination** facilitates transfer of pollen grains to the stigma. Pollen grains germinate on the stigma and the pollen tubes carrying the male gametes reach the ovule and discharge male gametes near the egg.

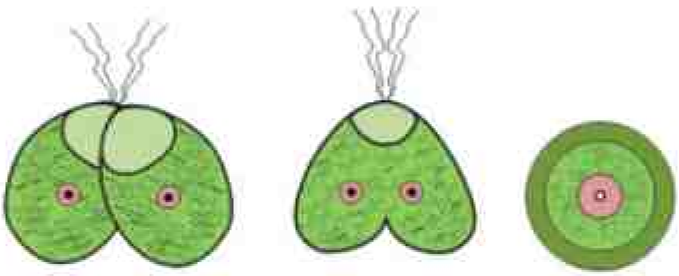


Figure 6.9 (a) Homogametic contact in alga

Figure 6.9 (b) Germinating pollen grains on the stigma of a flower

6.3.1.4 Fertilisation

The most vital event of sexual reproduction is perhaps the fusion of gametes. This process called **syngamy** results in the formation of a diploid **zygote**. The term fertilisation is also often used for this process. The terms syngamy and fertilisation are frequently used though interchangeably. Some times fruits are produced from flower with out fertilisation. It is the development of an embryo from an unfertilised female gamete, and this phenomenon is known as **Parthenogenesis.**

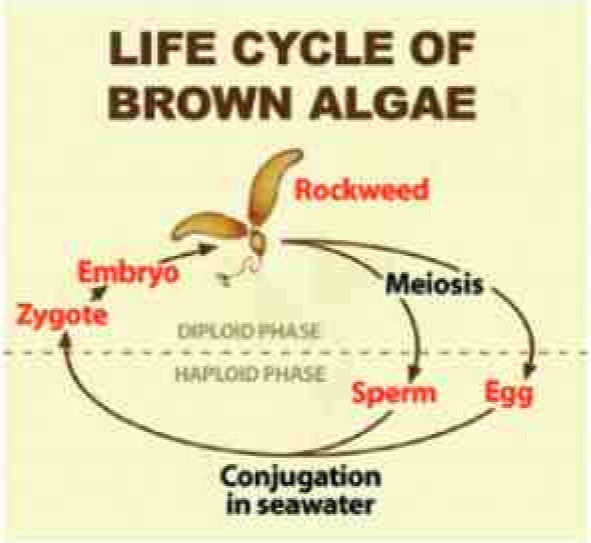


Figure 6.10 Life cycle of Brown Algae (Diplontic Life cycle)

Where does syngamy occur? In most aquatic organisms, such as a majority of algae, syngamy occurs in the external medium (water), i.e., outside the body of the organism. This type of gametic fusion is called **external fertilisation** (Figure 6.10). Organisms exhibiting external fertilisation show great synchrony between the sexes and release a large number of gametes into the surrounding medium (water) in order to enhance the chances of syngamy. In many terrestrial organisms, belonging to fungi, and in a majority of plants (bryophytes, pteridophytes, gymnosperms and angiosperms), syngamy occurs inside the body of the organism, hence the process is called **internal fertilisation**. In organisms exhibiting internal fertilisation, egg is formed inside the female body; the male gamete is motile and has to reach the egg in order to fuse with it. In these, even though the number of sperms/ male gametes produced is very large, there is a significant reduction in the number of eggs produced. In seed plants, however, the non-motile male gametes are carried to female gamete by pollen tubes.

6.3.1.5 Post-fertilisation Events

Events in sexual reproduction after the formation of zygote are called post-fertilisation events.

The Zygote

Formation of the diploid zygote is universal in all sexually reproducing organisms. In organisms with external fertilisation, zygote is formed in the external medium (usually water), whereas in those exhibiting internal fertilisation, zygote is formed inside the body of the organism.

Further development of the zygote depends on the type of life cycle the organism has and the environment it is exposed to. In organisms belonging to fungi and algae, zygote develops a thick wall that is resistant to dessication and damage. It undergoes a period of rest before germination. In these organisms with haplontic life cycle, zygote divides by meiosis immediately after karyogamy to form haploid spores that grow into haploid individuals.

Find out what kinds of development take place in the zygote in organisms with other types of life cycles (Refer chapter 4).

Zygote is the vital link that ensures continuity of species between organisms of one generation and the next. Every sexually reproducing organism, begins life as a single cell–the zygote.

Embryogenesis

Embryogenesis refers to the process of development of **embryo** from the zygote. During embryogenesis, zygote undergoes cell division (mitosis) and cell differentiation. While cell divisions increase the number of cells in the developing embryo; **cell differentiation** helps groups of cells to undergo certain modifications to form specialized tissues and organs to form an organism.

In flowering plants, the zygote is formed inside the ovule. After fertilisation the sepals, petals and stamens of the flower wither and fall off.

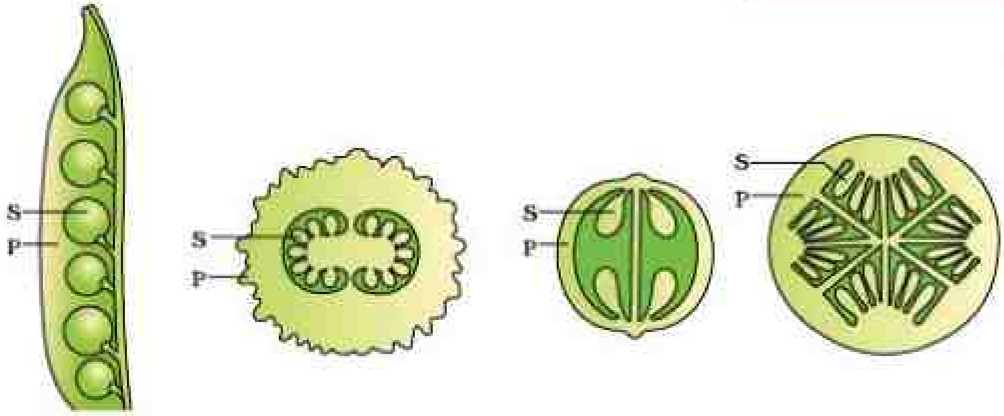


Figure 6.11 A few kinds of fruits showing seeds (S) and protective pericarp (P)

Figure 6.12 Vivipary in *Rhizophora*

Can you name some plants in which the sepals remain attached? The pistil however, remains attached to the plant. The zygote develops into the embryo and the ovules develop into the seed. The **ovary** develops into the **fruit** which develops a thick wall called **pericarp** that is protective in function (Figure 6.11). After dispersal, seeds germinate under favourable conditions to produce new plants. However, in some plants such as mangroves, the seeds germinate while still attached to the mother plant which is known as **vivipary** (Fig 6.12). It is a strategy to lower the environmental stress and ensuring successful establishment of plantlet.

6.4 An Overview Of The Angiosperm Life Cycle

Unlike the gymnosperms where the ovules are naked, in the angiosperms or flowering plants, the pollen grains and ovules are developed in specialized structures called flowers. In angiosperms, the seeds are enclosed by fruits. The angiosperms are an exceptionally large group of plants occurring in wide range of habitats. They range in size from tiny, almost microscopic *Wolfia* to tall trees of *Eucalyptus* (over 100 metres). The male sex organ in a flower is the stamen. Each stamen consists of a slender filament with an anther at the tip. The anthers, following meiosis, produce pollen grains. The female sex organ in a flower is the pistil or the carpel. Pistil consists of an ovary enclosing one to many ovules. Within ovules are present highly reduced female gametophytes termed embryosacs. The embryo-sac formation is preceded by meiosis. Hence, each of the cells of an embryo-sac is haploid. Each embryo-sac has a three-celled egg apparatus – one egg cell and two synergids, three antipodal cells and two polar nuclei. The polar nuclei eventually fuse to produce a diploid secondary nucleus.

Pollen grains, after dispersal from the anthers, are carried by wind or various other agencies to the stigma of a pistil. This is termed as pollination. The pollen grains germinate on the stigma and the resulting pollen tubes grow through the tissues of stigma and style and reach the ovule. The pollen tubes enter the embryo-sac where two male gametes are discharged. One of the male gametes fuses with the egg cell to form a zygote (syngamy). The other male gamete fuses with the diploid secondary nucleus to produce the triploid primary endosperm nucleus (PEN). Because of the involvement of two fusions, this event is termed as double fertilisation, an event unique to angiosperms. The zygote develops into an embryo (with one or two cotyledons) and the PEN develops into endosperm which provides nourishment to the developing embryo. The synergids and antipodals degenerate after fertilisation. During these events the ovules develop into seeds and the ovaries develop into fruit. The life cycle of an angiosperm is shown in Figure 6.13. Plants have multicellular diploid sporophyte stage as the dominant phase in their life cycle. Gametophytic stage, though multicellular, is a much reduced structure and is totally dependent on the sporophyte.

Fertilization gives rise to a multicellular diploid sporophyte, which produces haploid spores via meiosis and a few celled gametophytes. This type of life cycle is called a diplo-haplontic life cycle.

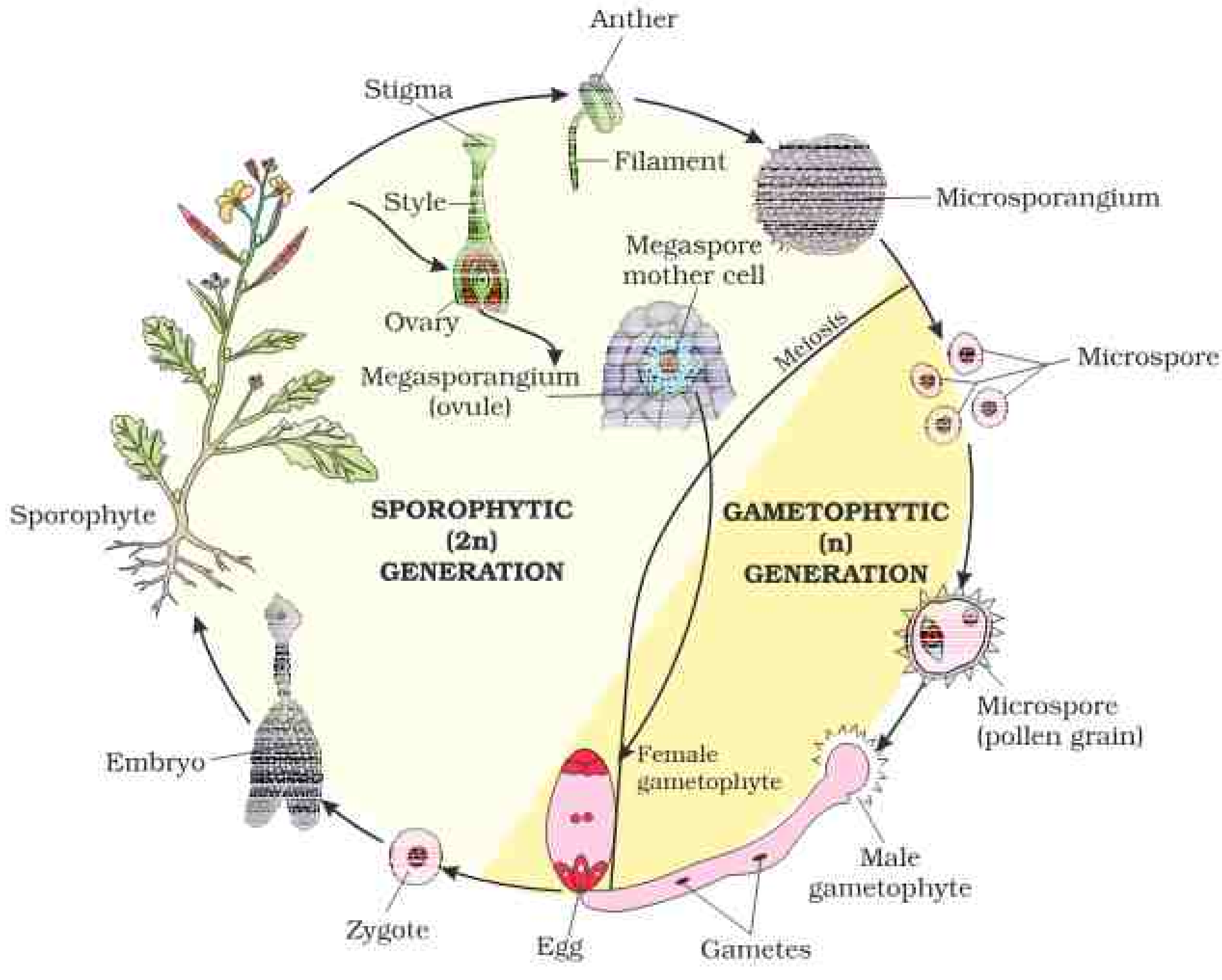


Figure 6.13 Life cycle of an angiosperm

Summary

Reproduction enables a species to live generation after generation.Reproduction in organisms can be broadly classified into asexual and sexual reproduction. Asexual reproduction does not involve the formation or fusion of gametes. It is common in organisms that have a relatively simple organisation such as the fungi and algae. The offspring formed by asexual reproduction is identical and are referred to as clones. Zoospores, conidia, etc., are the most common asexual structures formed in several algae and fungi. Prokaryotes and unicellular organisms reproduce asexually by cell division or binary fission of the parent cell. In several aquatic and terrestrial species of angiosperms, structures such as runners, rhizomes, suckers, tubers, offsets, etc., are capable of giving rise to new offspring. This method of asexual reproduction is generally referred to as vegetative propagation.

Sexual reproduction involves the formation and fusion of gametes. It is a complex and slower process as compared to asexual reproduction. Events of sexual reproduction may be categorised into pre-fertilisation, fertilisation and post-fertilisation events. Pre-fertilisation events include gametogenesis and gamete transfer while post-fertilisation events include the formation of zygote and embryogenesis.Organisms may be bisexual or unisexual. Sexuality in plants is varied, particularly in angiosperms, due to the production of diverse types of flowers. Plants are defined as monoecious and dioecious. Flowers may be bisexual or unisexual flowers. Gametes are haploid in nature and usually a direct product of meiotic division except in haploid organisms where gametes are formed by mitosis. Transfer of male gametes is an essential event in sexual reproduction. It is relatively easy in bisexual organisms. In angiosperms, a special process called pollination ensures the transfer of pollen grains to the stigma. Syngamy (fertilisation) occurs between the male and female gametes. Syngamy may occur either externally, (outside the body of organisms) or internally, (inside the body). Syngamy leads to the formation of a specialized cell called zygote.The process of development of embryo from the zygote is called embryogenesis. Zygote starts developing soon after its formation.

In flowering plants, after fertilisation, ovary develops into fruit and ovules mature into seeds. Inside the mature seed is the progenitor of the next generation, the embryo.

GLOSSARY

Apomixis: Replacement of the normal sexual reproduction by asexual reproduction, without fertilisation.

Asexual reproduction: Reproduction not involving the fusion of male and female gametes, as in vegetative reproduction, fission, or budding.

Budding: Reproduction of some unicellular organisms (such as yeasts) by growth and specialization followed by the separation by constriction of a part of the parent

Clone: Asexually reproduced offspring

Conidiophore: Specialized stalks on which conidiospores are formed.

Conidiospore/ conidium: Asexual non-motile spores of a fungus; also called as **mitospores** produced by conidiophore.

Dioecious: Presence of only one kind of sex organs either male or female on a single plant body.

Fission: A form of asexual reproduction in single-celled organisms; involves a division into two or more equal parts that develop into new cells.

Fragmentation: It is a form of asexual reproduction, where plant body breaks into fragments by mechanical methods.

Gamete: A cell that fuses with another cell during fertilisation in organisms that reproduce sexually.

Gametogenesis: It is a process by which diploid or haploid precursor cells undergo cell division and differentiation to form mature haploid gametes.

Gemmae: Cup like asexual reproductive structures in plants and fungi.

Heterothallic: Male and female reproductive organs develop on different thalli.

Homothallic: Having both male and female reproductive organs on the same thallus.

Karyogamy: It is the fusion of nuclei or genetic material of two cells, as part of syngamy, fertilisation, or bacterial conjugation.

Monoecious: Presence of both male sex organs and female sex organs on the same plant body.

Parthenogenesis: In plants, it is the development of an embryo from an unfertilized egg cell and is a form of asexual reproduction.

Propagule: Plant material or units used for the purpose of vegetative propagation.

Sporangium (pl., **sporangia**) (modern Latin, from Greek spora 'spore' + angeion 'vessel.') is an enclosure in which spores are formed.

Spore : It is a reproductive structure that is adapted for dispersal and surviving for extended periods of time in unfavorable conditions. Spores form part of the life cycles of many bacteria, plants, algae, fungi and some protozoans.

Syngamy: The fusion of two gametes in fertilisation.

Vegetative propagation: A form of asexual reproduction in plants, in which multicellular structures become detached from the parent plant and develop into new individuals that are genetically identical to the parent plant.

Zoospore : It is a motile asexual spore that uses a flagellum for locomotion, also called a swarm spore, these spores are created by some algae, bacteria and fungi to propagate themselves.

VERY SHORT ANSWER TYPE QUESTIONS

1. What is the dominant phase in the life cycle of an angiosperm?
2. What is meant by heterospory? Mention the two types of spores developed in an angiospermic plant?
3. Mention the modes of reproduction in Algae and Fungi .
4. How do Liver worts reproduce vegetatively?
5. Mention any two characteristics of bacteria and yeast that enable them to reproduce asexually.
6. Why do we refer to offspring formed by asexual method of reproduction as clones?
7. Between an annual and a perinneal plant, which one has a shorter juvenile phase? Give one reason.
8. Rearrange the following events of sexual reproduction in the sequence in which they occur in a flowering plant: embryogenesis, fertilisation, gametogenesis, pollination.
9. Is there a relationship between the size of an organism and it's life span?
10. Give reasons as to why cell division can or cannot be a type of reproduction in multicellular organisms.
11. Which of the following are monoecious and dioecious organisms:

    a) Date palm b) Coconut

    c) *Chara* d) *Marchantia*
12. Match the following given in coloumn A with the vegetative propagules given in coloumn B

Column A	Column B
i. *Bryophyllum*	a. Offset
ii. *Agave*	b. Eyes
iii. Potato	c. leaf buds
iv. Water hyacinth	d. fragmentation
v. *Chara*	e. sucker
vi. *Mentha*	f. bulbils

13. What do the following parts of a flower develop into after fertilisation?

    a) ovary b) stamens

    c) ovules d) calyx
14. Define vivipary with an example.

SHORT ANSWER TYPE QUESTIONS

1. In haploid organisms that undergo sexual reproduction,name the stage in the lifecycle where meiosis occurs. Give reasons for your answer.
2. The number of taxa exhibiting asexual reproduction is drastically reduced in higher plants (angiosperms) when compared to the lower groups of plants. Analyse the possible reasons for this situation.
3. Is it possible to consider vegetative propogation observed in plants like bryophyllum, water hyacinth,and ginger as a type of asexual reproduction? Give two/ three reasons.
4. "Fertilisation is not an obligatory event for fruit production in certain plants".Explain the statement.
5. List the changes observed in angiosperm flower subsequent to pollination and fertilisation.
6. Suggest a possible explanation why the seeds in pea pod are arranged in a row,whereas those in tomato are scattered in the juicy pulp.
7. Justify the statement 'Vegetative reproduction is also a type of asexual reproduction'.

8. Define
   (a) Juvenile phase.
   (b) Reproductive phase.
9. Distinguish between asexual and sexual reproduction. Why is vegetative reproduction also considered as a type of asexual reproduction?
10. Identify each part in a flowering plant and write whether it is haploid (n) or diploid (2n).
    (a) Ovary —— (b) Anther ——
    (c) Egg —— (d) Pollen ——
    (e) Male gamete ——————
    (f) Zygote ——————
11. Give a brief account on the phases of the life cycle of an angiosperm plant.

LONG ANSWER TYPE QUESTIONS

1. Enumerate the differences between asexual and sexual reproduction. Describe the types of asexual reproduction exhibited by unicellular organisms.
2. Although sexual reproduction is long drawn, energy-intensive complex form of reproduction, many groups of organisms in kingdom plantae prefer this mode of reproduction. Give atleast three reasons for this.
3. Describe the post-fertilisation changes in a flower.

EXERCISES

1. Why is reproduction essential for organisms?
2. Which is a better mode of reproduction sexual or asexual? Why?
3. Why is the offspring formed by asexual reproduction referred to as clone?
4. How does the progeny formed from asexual reproduction differ from those formed by sexual reproduction?
5. What is vegetative propagation? Give two suitable examples.
6. Higher organisms have resorted to sexual reproduction in spite of its complexity. Why?
7. Explain why meiosis and gametogenesis are always interlinked?
8. Define external fertilisation. Mention its disadvantages.
9. Differentiate between a zoospore and a zygote.

Activity

10. Examine a few flowers of any cucurbit plant and try to identify the staminate and pistillate flowers. Do you know any other plant that bears unisexual flowers?
11. What is a bisexual flower? Collect five bisexual flowers from your neighbourhood and with the help of your teacher find out their common and scientific names.

FIGURE 6.1 (LIFE SPANS) ANSWERS

a. Banyan tree: 300+ years
b. Wolffia: 2 weeks (smallest angiosperm)
c. Pinus : 300 + years
d. Carrot : 1 year
e. Banana : About 2 years
f. Rice : 3 - 7 months
g. Rose Plant: 5+ years

CHAPTER 7

SEXUAL REPRODUCTION IN FLOWERING PLANTS

A look at the diversity of structures of the inflorescences, flowers and floral parts, presented in the earlier chapters shows an amazing range of adaptations to ensure formation of the end products of sexual reproduction, the fruits and seeds. To a botanist, flowers are morphological and embryological marvels and the sites of sexual reproduction. *Have you heard of floriculture – what does it refer to?* Figure 7.1 will help you recall the parts of a typical flower. Can you name the parts in a flower in which the two most important units of sexual reproduction develop? In this chapter, let us understand the nature and development of the structures and the processes associated with sexual reproduction in angiosperms; this branch of botany is called **Embryology**.

7.1 PRE-FERTILISATION STRUCTURES AND EVENTS

Much before the actual flower is seen on a plant, the decision that the plant is going to flower has taken place. Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium. Inflorescences are formed which bear the floral buds and then the flowers. In the flower the

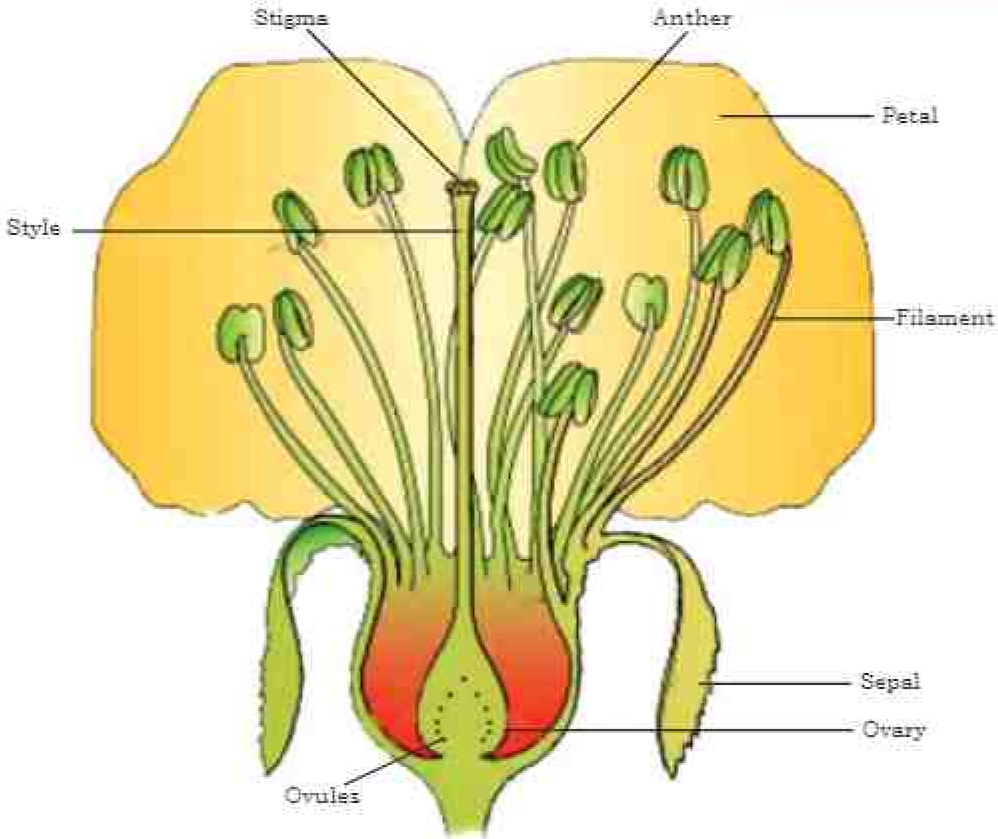


Figure 7.1 Diagrammatic representation of L.S of a flower

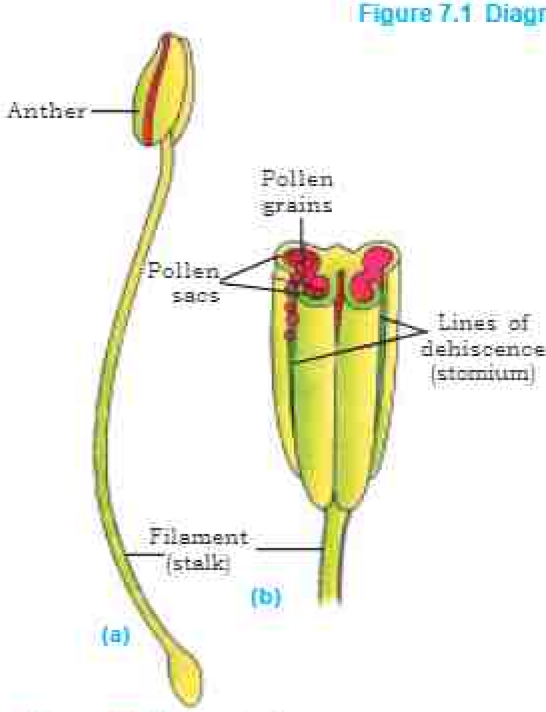


Figure 7.2 (a) A typical stamen (b) three-dimensional cut section of an anther

male and female reproductive structures, the androecium and the gynoecium, differentiate and develop. You would recollect that the androecium consists of a whorl of stamens representing the male reproductive organs and the gynoecium represents the female reproductive organ.

7.1.1 Stamen, Microsporangium and Pollen Grain

Figure 7.2 (a) shows the two parts of a typical stamen – the long and slender stalk called the filament, and the terminal generally bilobed structure called the anther. The proximal end of the filament is attached to the thalamus or the petal of the flower. The number and length of stamens are variable in flowers of different species. If you were to collect a stamen each from ten flowers (each from different

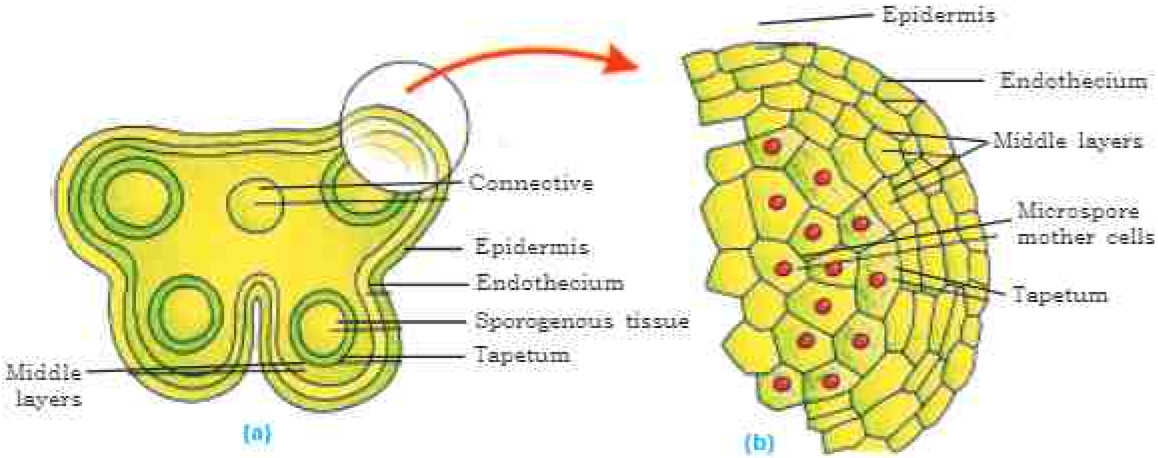


Figure 7.3 (a) Transverse section of a young anther
(b) Enlarged view of one microsporangium showing wall layers

species) and arrange them on a slide, you would be able to appreciate the large variation in size seen in nature. Careful observation of each stamen under a dissecting microscope and making neat diagrams would elucidate the range in shape and attachment of anthers in different flowers.

A typical angiosperm anther is bilobed with each lobe having two theca(sac), i.e., they are dithecous (Figure 7.2 b). Often a longitudinal groove runs lengthwise separating the theca. The anther of ***Hibiscus*** is single lobed, and it is known as **monothecous**. Let us understand the various types of tissues and their organisation in the transverse section of an anther (Figure 7.3 a). The bilobed nature of an anther is very distinct in the transverse section of the anther. The anther is a four-sided (tetragonal) structure consisting of four microsporangia located at the corners, two

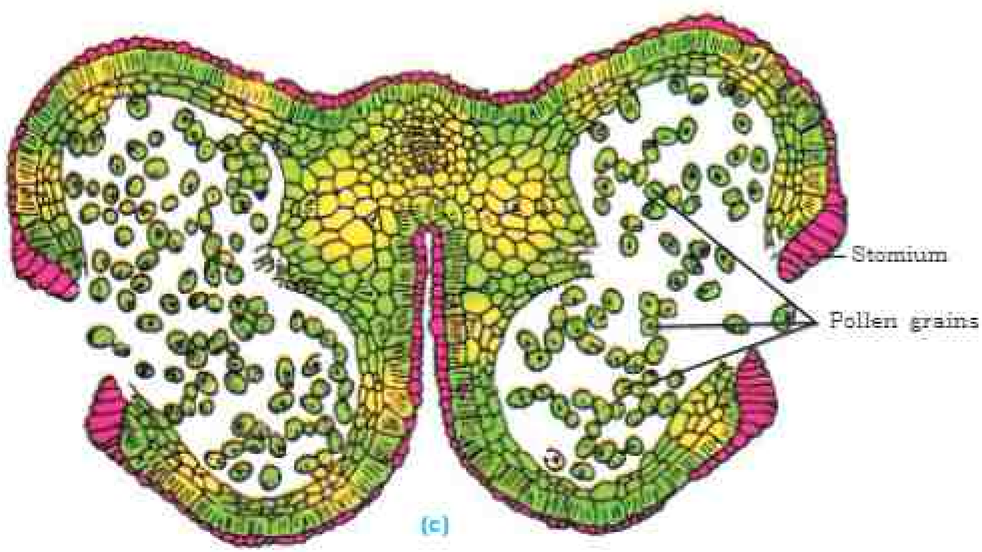


Figure 7.3 (c) A mature dehisced anther

in each lobe. The microsporangia develop further and become pollen sacs. They extend longitudinally all through the length of an anther and are packed with pollen grains.

Structure of microsporangium

In a transverse section, a typical microsporangium appears near circular in outline. It is generally surrounded by four wall layers (Figure 7.3 b)– the **epidermis**, **endothecium**, **middle layers** and the **tapetum**. The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen. The epidermis is one celled thick, the cells present between the pollen sacs are thin walled and this region is called as **stomium**, which is useful for the dehiscence of pollen sacs. The endothecium is below the epidermis and expands radially with fibrous thickenings; at maturity these cells lose water and contract and help in the dehiscence of pollen sacs. The innermost wall layer is the **tapetum**. It nourishes the developing pollen grains. Cells of the tapetum possess dense cytoplasm and generally have more than one nucleus. *Can you think of how tapetal cells could become bi-nucleate?*

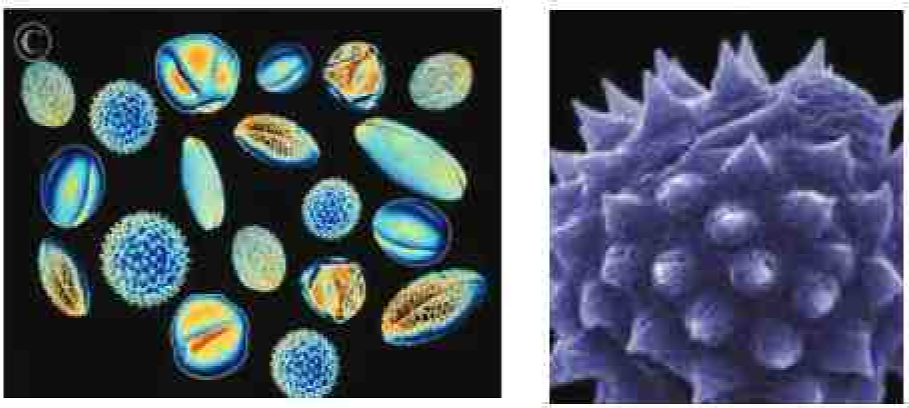


Figure 7.4 Scanning elecron micrographs of a few pollen grains

When the anther is young, a group of compactly arranged homogenous cells called the sporogenous tissue occupies the centre of each microsporangium.

Microsporogenesis : As the anther develops, the cells of the sporogenous tissue undergo meiotic divisions to form microspore tetrads. This process is known as microsporogenisis. *What would be the ploidy of the cells of the tetrad?*

As each cell of the sporogenous tissue is capable of giving rise to a microspore tetrad, each one is a potential pollen or microspore mother cell (PMC). The process of formation of microspores from a pollen mother cell through meiosis is called microsporogenesis. The microspores, as they are formed, are arranged in a cluster of four cells– the microspore tetrad (Figure 7.5 a). As the anthers mature and dehydrate, the microspores dissociate from each other and develop into pollen grains (Figure 7.3 b). Inside each microsporangium several thousands of microspores or pollen grains are formed that are released with the dehiscence of anther (Figure 7.3 c).

Pollen grain: The pollen grains represent the male gametophytes. If you touch the opened anthers of *Hibiscus* or any other flower you would find deposition of yellowish powdery pollen grains on your fingers. Sprinkle these grains on a drop of water taken on a glass slide and observe under a microscope. You will really be amazed at the variety of architecture – sizes, shapes, colours, designs – seen on the pollen grains from different species (Figure 7.4).

Pollen grains are generally spherical measuring about 25-50 micrometers in diameter. It has a prominent two-layered wall. The hard outer layer called the **exine** is made up of **sporopollenin** which is one of the most resistant organic material known. It can withstand high temperatures and strong acids and alkali. No enzyme that degrades sporopollenin is so far known. Pollen grain exine has prominent apertures called germ pores where sporopollenin is absent. Pollen grains are well preserved as fossils because of the presence of sporopollenin. The exine exhibits a fascinating array of patterns and designs. *Why do you think the exine should be hard? What is the function of germ pore(aperture)?*

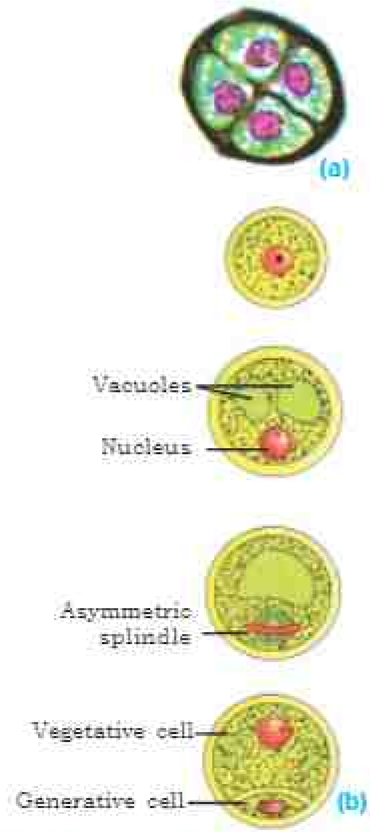


Figure 7.5 (a) Enlarged view of a pollen grain tetrad. (b) stages of a microspore maturing into a pollen grain

The inner wall of the pollen grain is called the **intine**. It is a thin and continuous layer made up of cellulose and pectin. The cytoplasm of pollen grain is surrounded by a plasma membrane. When the pollen grain is mature it contains two cells, the vegetative cell and generative cell (Figure 7.5 (b). The vegetative cell is bigger, has abundant food reserve and a large irregularly shaped nucleus. The generative cell is small and floats in the cytoplasm of the vegetative cell. It is spindle shaped with dense cytoplasm and a nucleus. In over 60 per cent of angiosperms, pollen grains are shed at this 2-celled stage [Figure 7.6]. In the remaining species, the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed (3-celled stage).

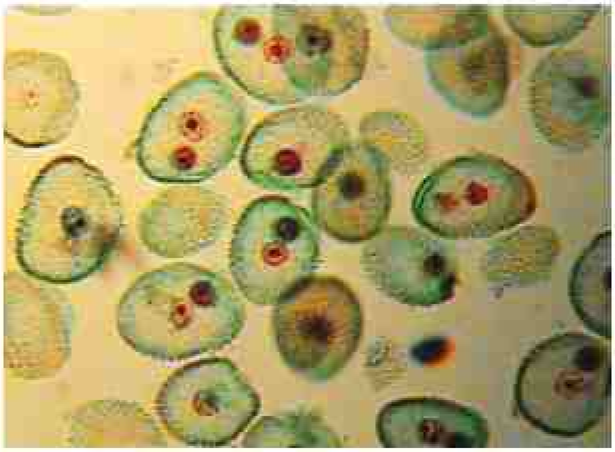


Figure 7.6 2-celled stage of pollen grains

Pollen grains of many species cause severe allergies and bronchial afflictions in some people often leading to chronic respiratory disorders– asthma, bronchitis, etc. It may be mentioned that *Parthenium* or carrot grass that came into India as a seed contaminant with imported wheat, has become ubiquitous in occurrence and causes pollen allergy.

Figure 7.7 Pollen Products

Pollen grains are rich in nutrients. It has become a fashion in recent years to use pollen tablets as food supplements. In western countries, a large number of pollen products in the form of tablets and syrups are available in the market. Pollen consumption has been claimed to increase the performance of athletes and race horses (Figure 7.7).

When once they are shed, pollen grains have to land on the stigma before they lose viability if they have to bring about fertilisation. How long do you think the pollen grains retain viability? The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity. In some cereals such as rice and wheat, pollen grains lose viability within 30 minutes of their release, and in some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for months. It is possible to store pollen grains of a large number of species for years in liquid nitrogen (-196°C). Such stored pollen can be used as **pollen banks**, similar to **seed banks**, in crop breeding programmes.

7.1.2 The Pistil, Megasporangium (ovule) and Embryo sac

The gynoecium represents the female reproductive part of the flower. The gynoecium may consist of a single pistil (**monocarpellary**) or may have more than one pistil (**multicarpellary**). When there are more than one, the pistils may be fused together (**syncarpous** e.g. *Hibiscus, Papaver*) (Figure 7.8 a, b) or may be free (**apocarpous** e.g., *Annona, Michelia*) (Figure 7.8 c). Each pistil has three parts (Figure 7.8 a), the stigma, style and ovary. The stigma serves as a landing platform for pollen grains. The style is the elongated slender part beneath the stigma. The basal bulged part of the pistil is the ovary. Inside the ovary is the ovarian cavity (locule). The placenta is located inside the ovarian cavity. Recall the definition and types of placentation

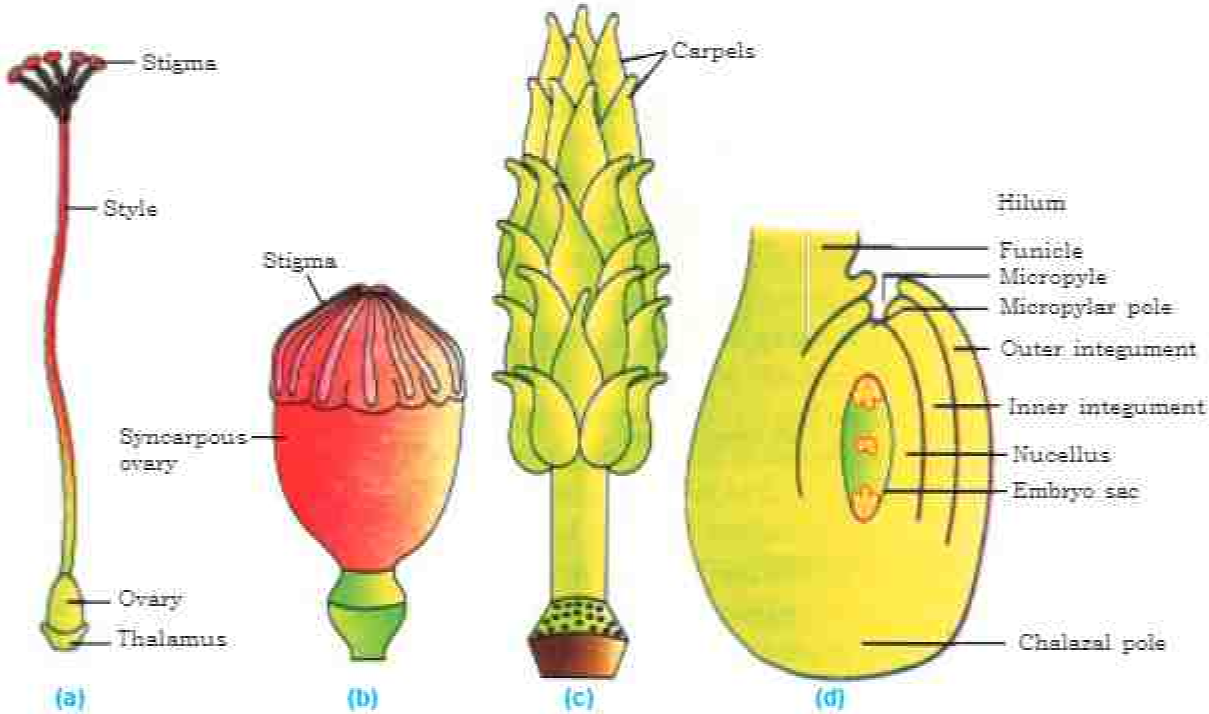


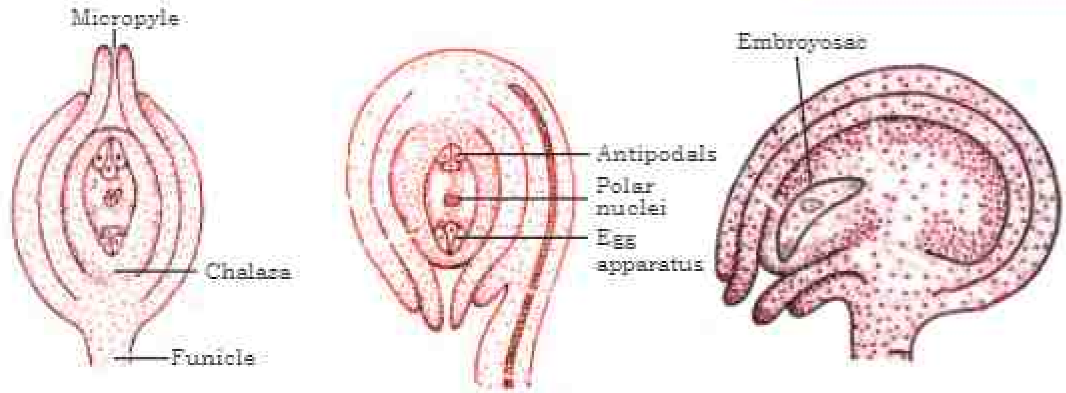
Figure 7.7 (a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed) (b) Multicarpellary, syncarpous pistil of *Papaver* (c) A multicarpellary, apocarpous gynoecium of *Michelia* (d) A diagrammatic view of typical anatropous ovule

that you studied in the previous chapter. Arising from the placenta are the megasporangia, commonly called ovules. The number of ovules in an ovary may be one (wheat, paddy, sunflower) to many (papaya, water melon, orchids).

The Megasporangium (Ovule)

Let us familiarise ourselves with the structure of a typical angiosperm ovule (Figure 7.8 (d). The ovule is a small structure attached to the placenta by means of a stalk called funicle. The body of the ovule fuses with funicle in the region called hilum. Thus, hilum represents the junction between ovule and funicle. Each ovule has one or two protective envelopes called integuments. Integuments encircle the ovule except at the tip where a small opening called the micropyle is organised. Opposite the micropylar end is the chalaza representing the basal part of the ovule.

Enclosed within the integuments is a mass of cells called the nucellus. In *Loranthus* the ovule is not covered by integuments. *Helianthus* and *Datura* ovules are covered by a single integument. In monocots and polypetalous members, the integuments are two. Cells of the nucellus have abundant reserve food materials.



(a) Orthotropous (b) Anatropous (c) Campylotropous

Figure 7.9 Types of Ovules

Located in the nucellus is the embryo sac or female gametophyte. An ovule generally has a single embryo sac formed from a megaspore through reduction division. In *Polygonum* the micropyle, chalaza and funiculus are on the same vertical line. This straight ovule is known as **Orthotropous** ovule (Figure 7.9 (a). The ovules of Sunflower family are inverted and the micropyle lies close to funiculus as a result of 180° curvature alongside of the funiculus; such ovules are called **anatropous** ovules (Figure 7.9 b). In bean family, the body of the ovule is placed at right angles to the funiculus. Body of the ovule bends in such a way that micropyle comes towards the funiculus and the embryosac is slightly curved; these ovules are called **campylotropous** ovules (Figure 7.9 c).

Megasporogenesis: The process of formation of megaspores from the megaspore mother cell is called megasporogenesis. Ovules generally differentiate a single megaspore mother cell (MMC) in the micropylar region of the nucellus. It is a large cell containing dense cytoplasm and a prominent nucleus. The MMC undergoes meiotic division. *What is the importance of the MMC undergoing meiosis?* Meiosis results in the production of four megaspores (Figure 7.10 a).

Female gametophyte: In a majority of flowering plants, one of the megaspores is functional while the other three degenerate. Only the functional megaspore acts as a mothercell for the development of **female gametophyte (embryo sac)**. This method of embryo sac formation from a single megaspore is termed **monosporic** development. *What will be the ploidy of the cells of the nucellus, MMC, the functional megaspore and female gametophyte?*

Let us study the formation of the embryo sac in a little more detail. (Figure 7.10 b, c). The nucleus of the functional megaspore divides mitotically to form two nuclei which move to the opposite poles, forming the 2-nucleate embryo sac. Two more sequential mitotic nuclear divisions result in the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac. It is of interest to note that these mitotic divisions are strictly free nuclear, that is, nuclear divisions are not followed immediately by cell wall formation. After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical female gametophyte or embryo sac. Observe the distribution of cells inside the embryo sac (Figure 7.10 b, c). Six of the eight nuclei are surrounded by cell walls and organised into cells; the remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large central cell.

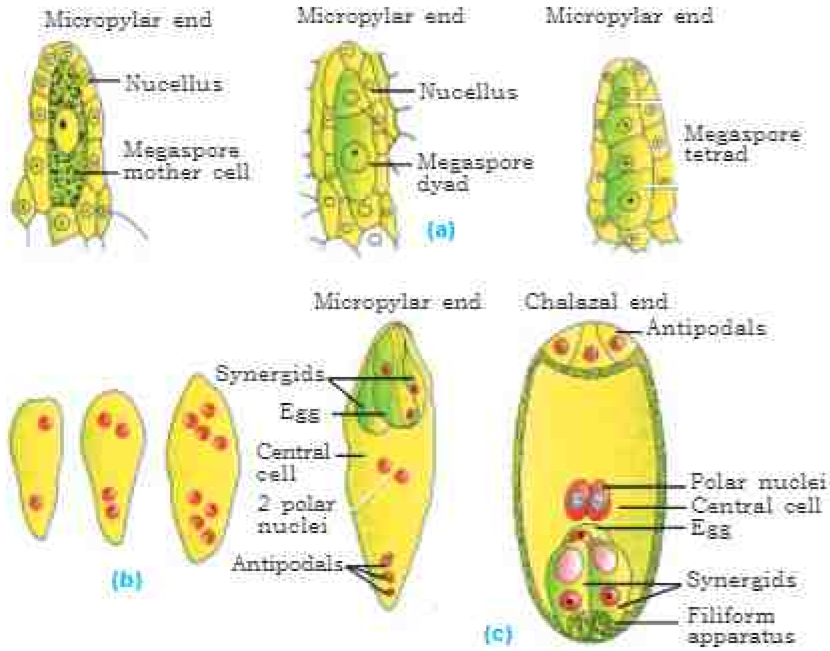
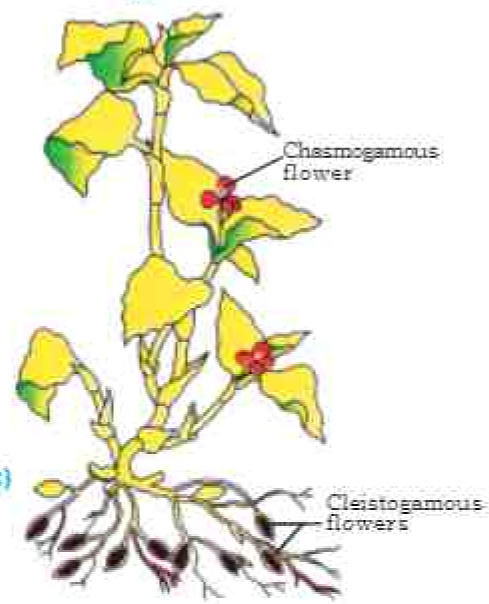


Figure 7. 10 (a) Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores
(b) 2, 4 and 8-nucleate stages of embryo sac and a mature embryo sac
(c) A diagrammatic representation of the mature embryo sac.

There is a characteristic distribution of the cells within the embryo sac. Three cells are grouped together at the micropylar end and constitute the **egg apparatus**. The egg apparatus, in turn, consists of **two synergids** and **one egg cell**. The synergids have special cellular thickenings at the micropylar tip called **filiform apparatus**, which play an important role in guiding the pollen tubes into the synergid. Three cells are at the chalazal end and are called the **antipodals**. The large central cell, as mentioned earlier, has **two polar nuclei**. Thus, a typical angiosperm embryo sac, at maturity, though **8-nucleate is 7-celled**.

(a)

(b)



(c)

Figure 7.11 (a) Self-pollinated flowers
(b) Cross pollinated flowers
(c) Cleistogamous flowers

7.2 POLLINATION

In the preceding sections you have learnt that the male and female gametes in flowering plants are produced in the pollen grain and embryo sac, respectively. As both types of gametes are non-motile, they have to be brought together for fertilisation to occur. How is this achieved?

Pollination is the mechanism to achieve this objective. Transfer of pollen grains (shed from the anther) to the stigma of a pistil is termed pollination. Flowering plants have evolved an amazing array of adaptations to achieve pollination. They make use of external agents to achieve pollination. *Can you list the possible external agents?*

Kinds of Pollination : Depending on the source of pollen, pollination can be divided into three types.

(i) Autogamy

In this type, pollination is achieved within the same flower. Transfer of pollen grains from the anther to the stigma of the same flower (selfing) (Figure 7.11(a). In a normal flower which opens and exposes the anthers and the stigma, complete autogamy is rather rare. Autogamy in such flowers requires synchrony in pollen release and stigma receptivity and also, the anthers and the stigma should lie close to each other so that self-pollination can occur. Some plants such as *Viola* (common pansy), *Oxalis*, and *Commelina* produce two types of flowers – **chasmogamous** flowers which open and are similar to flowers of other species with exposed anthers and stigma, and **cleistogamous** flowers which do not open at all (Figure 7. 11 c). In such flowers, the anthers and stigma lie close to each other. When anthers dehisce in the flower buds, pollen grains come in contact with the stigma to effect pollination. Thus, cleistogamous flowers are invariably autogamous as there is no chance of cross-pollen landing on the stigma. Cleistogamous flowers produce assured seed-set even in the absence of pollinators.

Do you think that cleistogamy is advantageous or disadvantageous to the plant? Why?

(ii) Geitonogamy – It is the transfer of pollen grains from the anther to the stigma of another flower of the same plant. Although geitonogamy is functionally cross-pollination involving a pollinating agent, genetically it is similar to autogamy, since the pollen grains come from the same plant.

(iii) Xenogamy- It involves transfer of pollen grains from the flower of one plant to the stigma of another plant. This is the only type of pollination which brings genetically different types of pollen grains to the stigma (Figure 7. 11 b).

7.2.1 Agents of Pollination

Plants use two abiotic (wind and water) and one biotic (animals) agents to achieve pollination. Majority of plants use biotic agents for pollination. Only a small proportion of plants use abiotic agents. Pollen grains coming in contact with the stigma is a chance factor in both wind and water pollination. To compensate for this uncertainties and associated loss of pollen grains, the flowers produce enormous amount of pollen when compared to the number of ovules available for pollination. Pollination by wind **(anemophily)** is more common amongst abiotic pollinations. Wind pollination also requires that the pollen grains are light and non-sticky so that they can be transported in wind currents. They often possess well-exposed stamens so that the pollen is easily dispersed into wind currents, (Figure 7.12 a) and large often-feathery stigma to easily trap air-borne pollen grains. Wind pollinated flowers often have a single ovule in each ovary and numerous flowers packed into an inflorescence; a familiar example is the corn cob – the bunch of silky hairs you see are nothing but the stigma and style which wave in the wind to trap pollen grains. Wind-pollination is quite common in grasses.

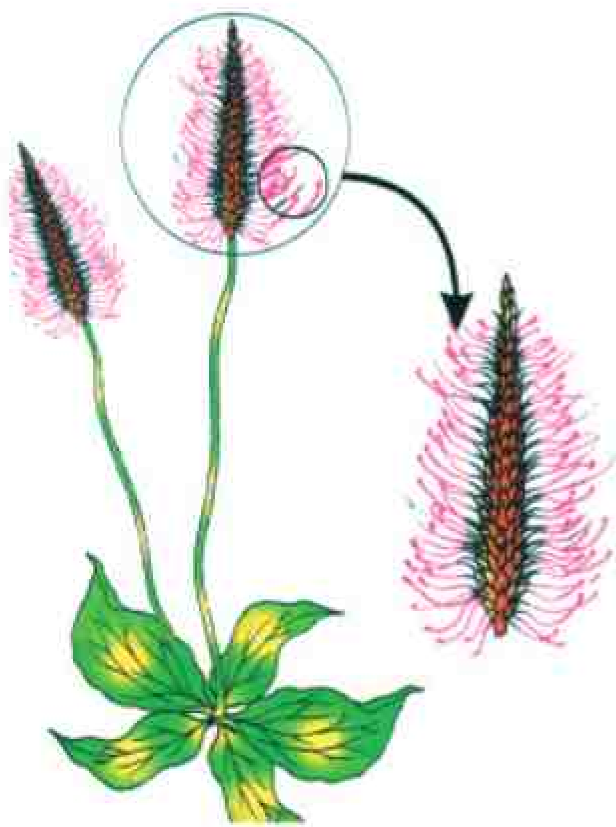


Figure 7.12 (a) A wind pollinated plant showing compact inflorescence and well exposed stamens

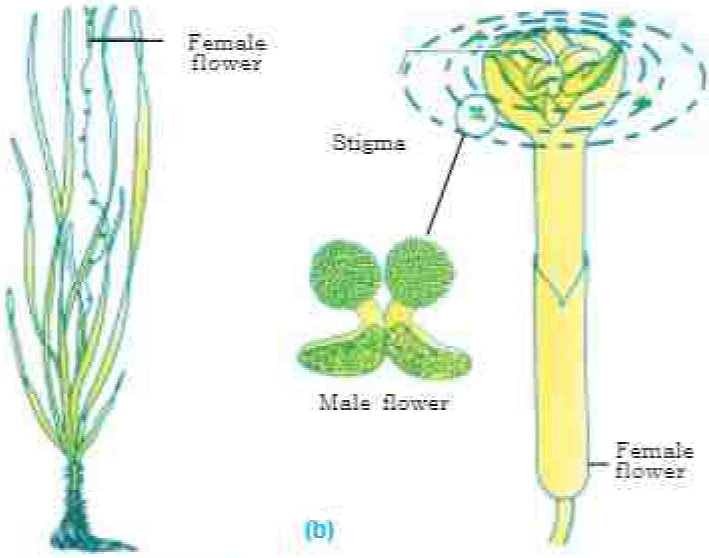


Figure 7.12 (b) Pollination by water in *Vallisneria*

Pollination by water (**hydrophily**) is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons. As against this, you would recall that water is a regular mode of transport for the male gametes among the lower plant groups such as algae, bryophytes and pteridophytes. It is believed, particularly for some bryophytes and pteridophytes, that their distribution is limited because of the need for water for the transport of male gametes and fertilisation. Some examples of water pollinated plants are *Vallisneria* and *Hydrilla* which grow in fresh water and several marine sea-grasses such as *Zostera*. Not all aquatic plants use water for pollination. In a majority of aquatic plants such as water hyacinth and water lily, the flowers emerge above the level of water and are pollinated by insects or wind as in most of the land plants. In *Vallisneria*, the female flowers reach the surface of water by the long stalk and the male flowers are released on to the surface of water. They are carried passively by water currents (Figure 7.12 b); some of them eventually reach the female flowers and the stigma (**epihydrophily**).

In another group of water pollinated plants such as seagrasses (Eg. *Zostera),* female flowers remain submerged in water and the pollen grains are released inside the water. Pollen grains in many such species are long, ribbon like and they are carried passively inside the water; some of them reach the stigma and achieve pollination (**hypohydrophily**). In most of the water-pollinated species, pollen grains are protected from wetting by a mucilaginous covering. Both wind and water pollinated flowers are not very colourful and do not produce nectar. *What would be the reason for this?*

Figure 7.12 (c) Insect pollination

Majority of flowering plants use a range of animals as pollinating agents (**zoophily**). Bees, butterflies, flies, beetles, wasps, ants, moths (**entomophily**-pollination by insects), (Figure 7.12 c) sunbirds and humming birds, (**ornithophily**-pollination by birds) (Figure 7.12 d) and bats (**chiropterophily**) are the common pollinating agents. Among the animals, insects, particularly bees are the dominant biotic pollinating agents. Even larger animals such as some squirrels (**therophily**) primates (lemurs), arboreal (tree-dwelling) rodents, or even reptiles (snakes-**ophiophily**; Gecko lizard and garden lizard) have also been reported as pollinators in some species.


Figure 7.12 (d) Bird pollination

Often flowers of animal - pollinated plants are specifically adapted for a particular species of animal. Majority of insect-pollinated flowers are large, colourful, fragrant and rich in nectar. When the flowers are small, a number of flowers are clustered into an inflorescence to make them conspicuous. Animals are attracted to flowers by colour and/or fragrance. The flowers pollinated by flies and beetles secrete foul odours to attract these animals. To sustain animal visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are the usual floral rewards. For harvesting the reward(s) from the flower, the animal visitor comes in contact with the anthers and the stigma. The body of the animal gets a coating of pollen grains, which are generally sticky in animal-pollinated flowers. When the animal carrying pollen on its body comes in contact with the stigma, it brings about pollination.

In some species, floral rewards are in providing safe places to lay eggs; an example is that of the inflorescence of *Amorphophallus* (the inflorescence is about 6 feet in height). A similar relationship exists between a species of moth and the plant *Yucca* where both species – the moth and the plant – cannot complete their life cycles without each other. The moth *(Tegeticula yuccasella)* deposits its eggs in the locule of the ovary and the flower in turn, gets pollinated by the moth. The larvae of the moth come out of the eggs as the seeds start developing.

Why don't you observe some flowers of the following plants (or any others available to you): Cucumber, Mango, Peepal, Coriander, Papaya, Onion, *Lobia*, Cotton, Tobacco, Rose, Lemon, *Eucalyptus*, Banana? Try to find out which animals visit them and whether they could be pollinators. You'll have to patiently observe the flowers over a few days and at different times of the day. You could also try to see whether there is any correlation in the characteristics of a flower to the animal that visits it. Carefully observe if any of the visitors come in contact with the anthers and the stigma as only such visitors can bring about pollination. Many insects may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred to as pollen/nectar robbers. You may or may not be able to identify the pollinators, but you will surely enjoy your efforts!

Figure 7.13 (a) Herkogamy in Hibiscus

Figure 7.13 (b) Heterostyly

Figure 7.14 Pollen grains germinating on the stigma

7.2.2 Outbreeding Devices

Majority of flowering plants produce hermaphrodite flowers and pollen grains are likely to come in contact with the stigma of the same flower. Continued self-pollination results in inbreeding depression. Flowering plants have developed many **devices or adaptations** or **contrivances** to discourage self-pollination and to encourage cross-pollination. In some species, pollen release and stigma receptivity are not synchronised (**dichogamy**). Either the pollen is released before the stigma becomes receptive (**protandry**, e.g., Sunflower) or stigma becomes receptive much before the release of pollen (**protogyny** e.g., *Datura, Solanum)*. In some other species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower (**herkogamy**, e.g., *Hibiscus* (Figure 7.13 a), *Gloriosa*. Both these devices prevent autogamy. The third device to prevent inbreeding is the styles of the flowers of the same species are in different heights (**heterostyly**) (Figure 7.13 b). The fourth device to prevent inbreeding is **self sterility (self-incompatibility)** (eg. *Abutilon)*. This is a genetic mechanism which prevents self-pollen from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil. Another device to prevent self-pollination is the production of unisexual flowers (**dicliny**). If both male and female flowers are present on the same plant such as castor and maize (**monoecious**), it prevents autogamy but not geitonogamy. In several species such as Papaya, male and female flowers are present on different plants, i.e., each plant is either male or female (**dioecious**). This condition prevents both autogamy and geitonogamy.

7.3 Pollen-pistil Interaction

Pollination does not guarantee the transfer of the right type of pollen (compatible pollen of the same species as the stigma). Often, pollen of the wrong type, either from other species or from the same plant also land on the stigma. The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible). If it is of the right type, the pistil accepts the pollen and promotes post-pollination events that lead to fertilisation. If the pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style. The ability of the pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous dialogue between pollen grain and the pistil. This dialogue is mediated by chemical components of the pollen interacting with those of the pistil. It is only in recent years that botanists have been able to identify some of the pollen and pistil components and the interactions leading to the recognition, followed by acceptance or rejection.

As mentioned earlier, following compatible pollination, the pollen grain germinates on the stigma (Figure 7.14) to produce a pollen tube through one of the germ pores (Figure 7.16 a). The contents of the pollen grain move into the pollen tube. Pollen tube grows through the tissues of the stigma and style and reaches the ovary. You would recall that in some plants, pollen grains are shed at two-celled condition (a vegetative cell and a generative cell). In such plants, the generative cell divides and forms the two male gametes during the growth of pollen tube in the stigma. In plants which shed pollen in the three-celled condition, pollen tubes carry the two male gametes from the beginning. Pollen tube, travels through the style and reaches the ovary. The pollen tube after reaching the ovary enters the ovule through the micropyle (**porogamy**) (Figure 7. 15 a) and then enters one of the synergids through the filiform apparatus (Figure 7.16 b, c). The pollen tube may enter the ovule through chalaza (**chalazogamy**) (Figure 7.15 b) or through the integuments (**mesogamy**) (Figure 7.15 c) . Many recent studies have shown that filiform apparatus present at the micropylar part of the synergids guides the entry of pollen tube. All these events–from pollen deposition on the stigma until pollen tubes enter the ovule–are together referred to as **pollen-pistil interaction**. As pointed out earlier, pollen-pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the

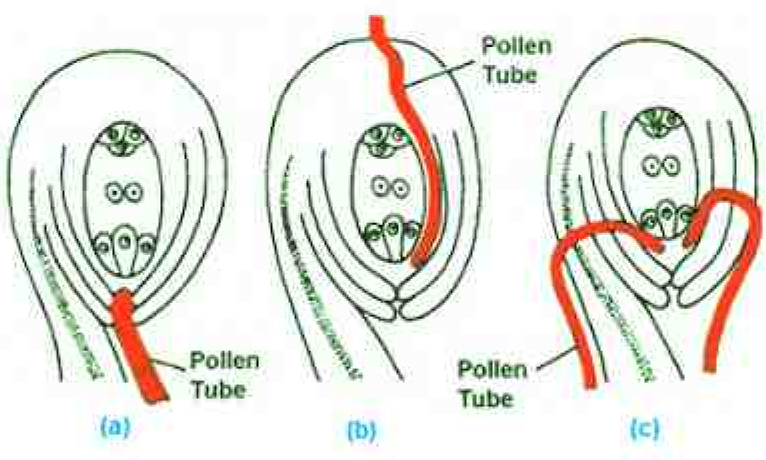


Figure 7.15 (a) Entry of Pollen tube through Micropyle
(b) Entry of Pollen tube through Chalaza
(c) Entry of Pollen tube through Integuments

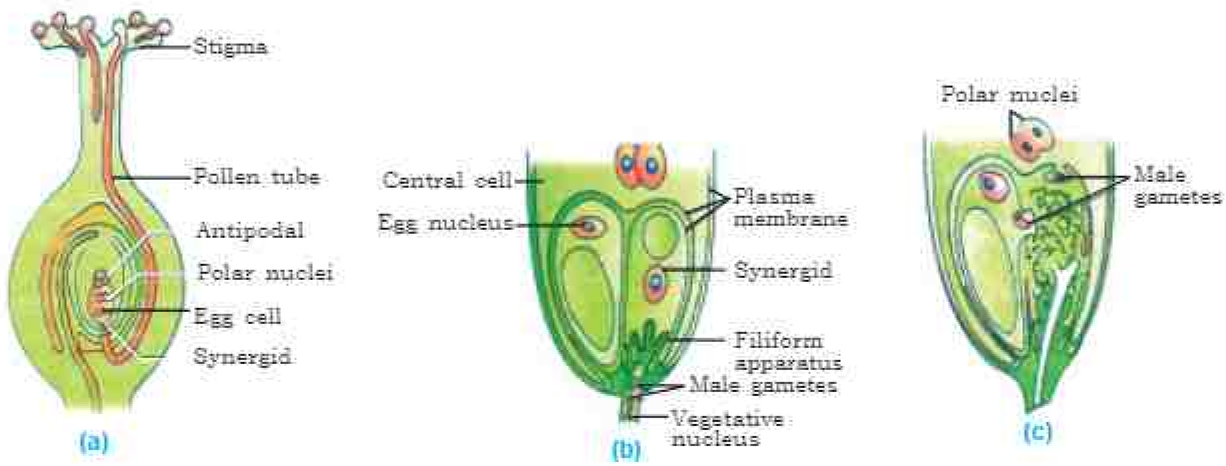


Figure 7.16 (a) Pollen grains germinating on the stigma
(b) Enlarged view of an egg apperatus showing entry of pollen tube into a synergid
(c) Discharge of male gametes

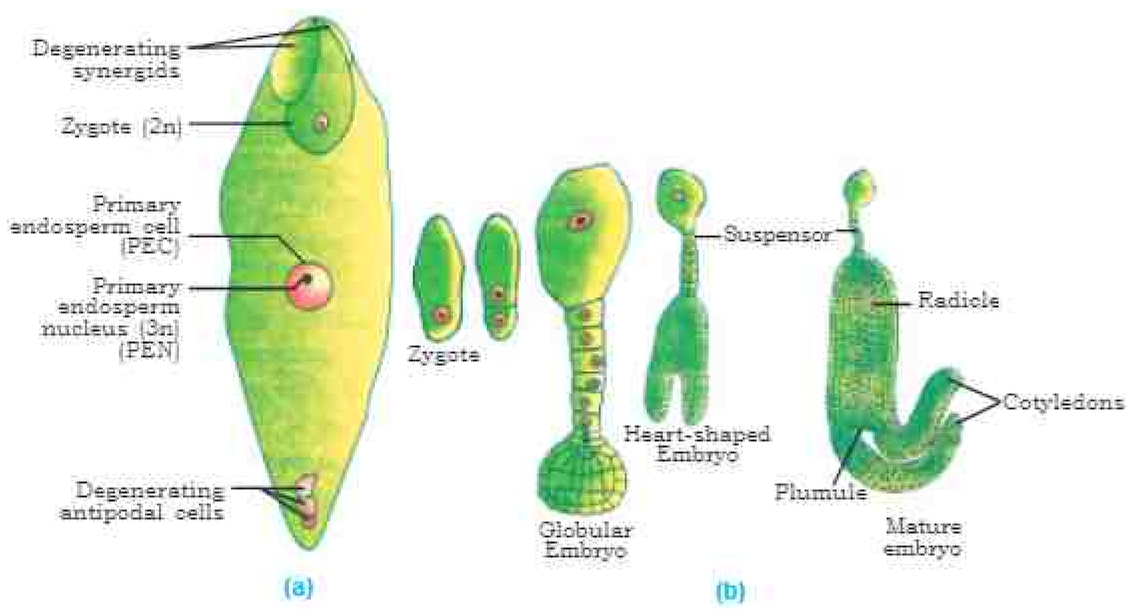


Figure 7.17 (a) Fertilised embryo sac showing zygote and primary Endosperm Nucleus (PEN)
(b) Stages in embryo development in a dicot

pollen. The knowledge gained in this area would help the plant breeder in manipulating pollen-pistil interaction, even in incompatible pollinations, to get desired hybrids.

You can easily study pollen germination by dusting some pollen from flowers such as pea, chickpea, *Crotalaria*, balsam and *Vinca* on a glass slide containing a drop of sugar solution (about 10 per cent). After about 15–30 minutes, observe the slide under the low power lens of the microscope. You are likely to see pollen tubes coming out of the pollen grains.

As you shall learn in the coming chapters on plant breeding, a breeder is interested in crossing different species and often genera to combine desirable characters to produce commercially 'superior' varieties.

7.3.1 Artificial Hybridisation

It is one of the major approaches of crop improvement programme. In such crossing experiments it is important to make sure that only the desired pollen grains are used for pollination and the stigma is protected from contamination (from unwanted pollen). This is achieved by **emasculation** and **bagging** techniques.

If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces using a pair of forceps is necessary. This step is referred to as **emasculation**. Emasculated flowers have to be covered with a bag of suitable size, generally made up of butter paper, to prevent contamination of its stigma with unwanted pollen. This process is called **bagging**. When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are **rebagged**, and the fruits allowed to develop.

If the female parent produces unisexual flowers, there is no need for emasculation. The female flower buds are bagged before the flowers open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

7.4 Double Fertilisation

After entering one of the synergids, the pollen tube bursts and releases the two male gametes into the cytoplasm of the synergid. One of the male gametes moves towards the egg cell and the nucleus of the male cell fuses with its nucleus thus completing the **syngamy** or fertilisation. This results in the formation of a diploid cell, the **zygote**. The other male gamete moves towards the two polar nuclei located in the central cell and fuses with them to produce a triploid **primary endosperm**

nucleus (PEN) (Figure 7.17 a). As this involves the fusion of three haploid nuclei, it is termed **triple fusion**. Since two types of fusions, syngamy and triple fusion, take place in an embryosac, the phenomenon is termed **double fertilisation,** an event unique to flowering plants. The central cell after triple fusion becomes the **primary endosperm cell** (PEC) and develops into the **endosperm** while the zygote develops into an **embryo** (Figure 7.17 b).

7.5 Post-fertilisation: Structures And Events

Following double fertilisation, events of endosperm and embryo development, maturation of ovule(s) into seed(s) and ovary into fruit, are collectively termed **post-fertilisation events**. The accessory organs, stamens and style wither and fall off.

7.5.1 Endosperm

Endosperm development precedes embryo development. *Why?* The primary endosperm cell divides repeatedly and forms a triploid endosperm tissue. The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo. In the most common type of endosperm development, the PEN undergoes successive nuclear divisions to give rise to free nuclei. This stage of endosperm development is called free-nuclear endosperm. Subsequently cell wall formation occurs and the endosperm becomes cellular. The number of free nuclei formed before cellularisation varies greatly. The coconut water from tender coconut that you are familiar with, is nothing but free - nuclear endosperm (made up of thousands of nuclei) and the surrounding white kernel is the cellular endosperm.

Endosperm may either be completely consumed by the developing embryo (e.g., pea, groundnut, beans) before seed maturation (such seeds are described as **non-endospermic seeds**) or it may persist in the mature seed (**endospermic** e.g., castor and coconut) and be used up during seed germination . *Split open some seeds of castor, peas, beans, groundnut, and fruit of coconut and look for the endosperm in each case. Find out whether the endosperm is persistent in cereals – wheat, rice and maize.*

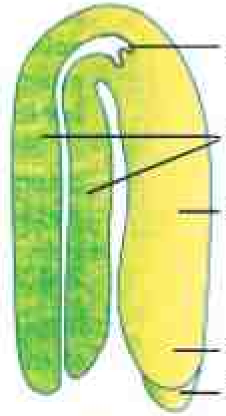
7.5.2 Embryo

Embryo develops at the micropylar end of the embryo sac where the zygote is situated. Most zygotes divide only after certain amount of endosperm is formed. This is an adaptation to provide assured nutrition to the developing embryo. Though the seeds differ greatly, the early stages of embryo development (**embryogeny**) are similar in both monocotyledons and dicotyledons. Figure 7.17 (b) depicts the stages of embryogeny in a dicotyledonous embryo. The zygote gives rise to the **proembryo** and subsequently to the **globular, heart-shaped and mature embryo**.

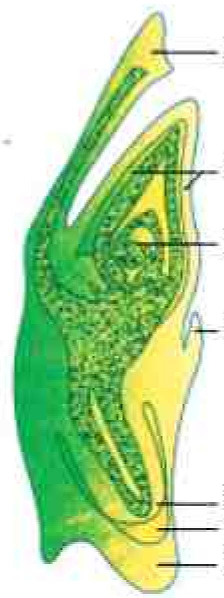
A typical dicotyledonous embryo (Figure 7.18 a) consists of an **embryonal axis** and two **cotyledons**. The cotyledons are often fleshy and full of reserve food material in dicots. The portion of embryonal axis above the level of cotyledons is the **epicotyl**, which terminates with the **plumule or stem tip**(first apical bud of shoot). The cylindrical portion below the level of cotyledons is **hypocotyl** that terminates at its lower end in the **radicle** or **root tip**. The root tip is covered with a **root cap**.

Embryos of monocotyledons (Figure 7.18 b) possess only one cotyledon. In the grass family, the cotyledon is called **scutellum** that is situated towards one side (lateral) of the embryonal axis. At its lower end, the embryonal axis has the radical and root cap is enclosed in an undifferentiated sheath called **coleorhiza**. The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl. Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the **coleoptile**. The outer covering of the endosperm separates the embryo by a proteinaceous layer called aleurone layer.

Occasionally, in some seeds such as black pepper and beet, remnants of nucellus are also persistent. This residual, persistent nucellus is the **perisperm**.



(a)



(b)

Figure 7.18 (a) A typical dicot embryo (b) L.S of an embryo of grass (Monocot)

7.5.3 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 7.19). In some seeds such as castor, the **endosperm** formed as a result of double fertilisation, is a food storing tissue. In plants such as bean, gram and pea, the endosperm is not present in mature seeds and such seeds are called non-endospermous.

7.5.4 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 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 7.19).

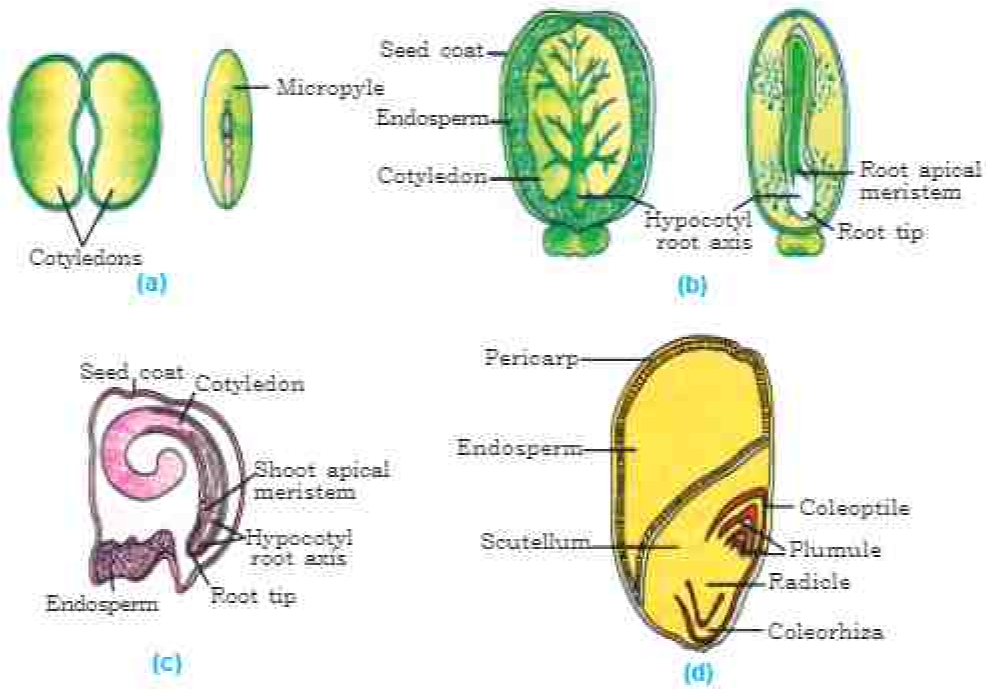


Figure 7.19 Structure of Seeds

Soak a few seeds in water (say of wheat, maize, peas, chickpeas, ground nut) overnight. Then split the seeds and observe the various parts of the embryo and the seed.

7.5.5 Significance of Fruit and Seed

Integuments of ovules harden as tough protective seed coats. The micropyle remains as a small pore in the seed coat. This facilitates entry of oxygen and water into the seed during germination. As the seed matures, its water content is reduced and seeds become relatively dry (10-15 per cent moisture by mass). The general metabolic activity of the embryo slows down. The embryo may enter a state of inactivity called **dormancy**, or if favourable conditions are available (adequate moisture, oxygen and suitable temperature), they germinate.

Many fruits have evolved mechanisms for **dispersal of seeds**. A fruit is an adaptation for dispersing seeds e.g., coconuts float, martynia (Tiger claw plant) catch onto animal fur; seeds of Guava and Figs are eaten by birds are not digestible but the hard seed coat is partly softened. The fruits attract the animals by providing food for the dispersal of the seeds.

Is there any relationship between number of ovules in an ovary and the number of seeds present in a fruit?

There is wide variation in the size of the mature seeds eg. in Orchids the seed is microscopic and the seeds are produced in more numbers, each seed measures 85 micrometers and weighs 0.81 micrograms, where as the largest seed can be seen in Lodecia maldivica, the double coconut (Fig 7.20) which measures 30 cm long, nearly 90 cm in circumference and weigh 18 kg.


Figure 7.20 Double Coconut

Seeds offer several advantages to angiosperms. Firstly, since reproductive processes such as pollination and fertilisation are independent of water, seed formation is more dependable. Also seeds have better adaptive strategies for dispersal to new habitats and help the species to colonise in other areas. As they have sufficient food reserves, young seedlings are nourished until they are capable of photosynthesis on their own. The hard seed coat provides protection to the young embryo. Being products of sexual reproduction, they generate new genetic combinations leading to variations.

Seed is the basis of our agriculture. Dehydration and dormancy of mature seeds are crucial for storage of seeds which can be used as food through out the year and also to raise crop in the next season. Can you imagine agriculture in the absence of seeds, or in the presence of seeds which germinate straight away soon after formation and cannot be stored?

How long do the seeds remain alive after they are dispersed? This period again varies greatly. In a few species, the seeds lose viability within a few months. Seeds of a large number of species live for several years. Some seeds can remain alive for hundreds of years. There are several records of very old yet viable seeds. The oldest is that of a lupine, *Lupinus arcticus* excavated from Arctic Tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy.

A recent record of 2000 years old viable seed is of the date palm, *Phoenix dactylifera* discovered during the archeological excavation at King Herod's palace near the Dead Sea.

After completing a brief account of sexual reproduction of flowering plants, it would be worth attempting to comprehend the enormous reproductive capacity of some flowering plants by asking the following questions:

How many eggs are present in an embryo sac?

How many embryo sacs are present in an ovule?

How many ovules are present in an ovary?

How many ovaries are present in a typical flower?

How many flowers are present on a tree? And so on...

Can you think of some plants in which fruits contain very large number of seeds? Orchid fruits are one such category and each fruit contain thousands of tiny seeds. Similar is the case in fruits of some parasitic species such as *Orobanche* and *Striga*. Have you seen a tiny seed of *Ficus*? How large is the tree of *Ficus* developed from that tiny seed. How many billions of seeds does each *Ficus* tree produce? Can you imagine any other example in which such a tiny structure can produce such a large biomass over the years?

7.6 Apomixis, Parthenocarpy and Polyembryony

Although seeds, in general, are the products of fertilisation, a few flowering plants such as some species of Asteraceae and grasses, have evolved a special mechanism, to produce seeds without fertilisation, called **apomixis**.

The fruit production without fertilisation of the ovary is called **parthenocarpy** and these fruits do not possess seeds, e.g., Grapes, Banana. Parthenocarpy may be natural or induced. This phenomenon is applied for the commercial production of seedless fruits.

Apomixis is a form of asexual reproduction that mimics sexual reproduction. Can they be called clones? There are several ways of development of apomictic seeds. In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilisation. It is an assured reproduction in the absence of pollinators, such as in extreme environments.

More often, as in many *Citrus* and mango varieties, some of the nucellar cells surrounding the embryo sac start dividing, protrude into the embryo sac and develop into the embryos. In such species each ovule contains many embryos. Occurrence of more than one embryo in a seed is referred to as **polyembryony**.

Take out some seeds of orange and squeeze them. Observe the many embryos of different sizes and shapes from each seed. Count the number of embryos in each seed. What would be the genetic nature of apomictic embryos? Can they be called clones?

Hybrid varieties of several of our food and vegetable crops are being extensively cultivated. Cultivation of hybrids has tremendously increased productivity. One of the problems of hybrids is that hybrid seeds have to be produced every year. If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters. Production of hybrid seeds is costly and hence the cost of hybrid seeds becomes too expensive for the farmers. If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. Then the farmers can keep on using the hybrid seeds to raise new crop year after year and he does not have to buy hybrid seeds every year. Because of the importance of apomixis in hybrid seed industry, active research is going on in many laboratories around the world to understand the genetics of apomixis and to transfer apomictic genes into hybrid varieties.

SUMMARY

Flowers are the seat of sexual reproduction in angiosperms. In the flower, androecium consisting of stamens represents the male reproductive organs and gynoecium consisting of pistils represents the female reproductive organs.

A typical anther is bilobed, dithecous and tetrasporangiate. Pollen grains develop inside the microsporangia. Four wall layers, the epidermis, endothecium, middle layers and the tapetum surround the microsporangium. Cells of the sporogenous tissue lying in the centre of the microsporangium, undergo meiosis (microsporogenesis) to form tetrads of microspores. Individual microspores mature into pollen grains. Pollen grains represents the male gametophytic generation. The pollen grains have a two-layered wall, the outer exine and inner intine. The exine is made up of sporopollenin and has germ pores. Pollen grains may have two-celled (a vegetative cell and generative cell) or three cells (a vegetative cell and two male gametes) at the time of shedding.

The pistil has three parts – the stigma, style and the ovary. Ovules are present in the ovary. The ovules have a stalk called funicle, protective integument(s), and an opening called micropyle. The central tissue is the nucellus in which the archesporium differentiates. A cell of the archesporium, the megaspore mother cell divides meiotically and one of the megaspores forms the embryo sac (the female gametophyte). The mature embryo sac is 7-celled and 8-nucleate. At the micropylar end is the egg apparatus consisting of two synergids and an egg cell. At the chalazal end are three antipodals. At the centre is a large central cell with two polar nuclei.

Pollination is the mechanism to transfer pollen grains from the anther to the stigma. Pollinating agents are either abiotic (wind and water) or biotic (animals).

Pollen-pistil interaction involves all events from the landing of pollen grains on the stigma until the pollen tube enters the embryo sac (when the pollen is compatible) or pollen inhibition (when the pollen is incompatible). Following compatible pollination, pollen grain germinates on the stigma and the resulting pollen tube grows through the style, enters the ovule and finally discharges two male gametes in one of the synergids. Angiosperms exhibit double fertilisation because two fusion events occur in each embryo sac, namely syngamy and triple fusion. The products of these fusions are respectively, the diploid zygote and the triploid primary endosperm nucleus (in the primary endosperm cell). Zygote develops into the embryo and the primary endosperm cell forms the endosperm tissue. Formation of endosperm always precedes development of the embryo. The developing embryo passes through different stages such as the proembryo, globular and heart-shaped stages before maturation. Mature dicotyledonous embryo has two cotyledons and an embryonal axis with epicotyl and hypocotyl. Embryos of monocotyledons have a single cotyledon. After fertilisation, ovary develops into fruit and ovules develop into seeds.

A phenomenon called apomixis is found in some angiosperms, particularly in grasses. It results in the formation of seeds without fertilisation. Apomicts have several advantages in horticulture and agriculture. Some angiosperms produce more than one embryo in their seed. This phenomenon is called polyembryony.

GLOSSARY

Allogamy: Transfer of pollengrains from one flower to another

Anemophily: Pollination by wind.

Autogamy: Transfer of pollen grains within the same flower

Antipodals: Three cells present in the embryosac towards chalaza.

Apomixis: Production of seeds without fertilisation.

Chasmogamy: Pollination occurring in an opened flower.

Chiropterophily: Pollination by bats.

Cleistogamy: Pollination occurring in a closed flower.

Clone: Morphologically and genetically similar individual produced through means other than sexual reproduction.

Chalaza: Basal portion of the nucellus in the ovule from which the integuments appear.

Chalazogamy: Entry of pollen tube into embryosac through chalaza of the ovule.

Coleorhiza: Undifferentiated sheath of embryonal axis enclosing radicle and root cap.

Coleoptile: Hollow foliar structure of epicotyl, that encloses plumule.

Dichogamy: Ripening of anthers and stigma in a flower at different times

Dioecious: Male and female flowers on different plants

Doublefertilization: Two fusion processes (a) one male gamete + egg cell (b) second male gamete+ secondary nucleus; characteristic feature of angiosperms.

Entomophily: Pollination by insects

Egg apparatus: Three cells present in the embryosac towards micropyle.

Egg cell: Female gamete cell hanging in embryosac in between synergids.

Embryo: Miniature plant consisting of axis (plumule, radical) and cotyledons enclosed in the seed coat.

Embryology: Branch of science which deals with development and formation of gametes, process of fertilisation and development of embryo.

Embryosac: Female gametophyte containing egg apparatus, secondary/ polar nuclei and antipodals ; in angiosperms mostly 7 celled (8-nucleate).

Endosperm: Nutritive tissue for the developing embryo; in angiosperms it is a triploid tissue.

Endothecium: The layer below the epidermis in anther wall with fibrous bands on tangential walls, which help in dehiscence of anther.

Fertilization: Fusion of male gamete with the egg cell.

Floriculture: Cultivation of flower yielding plants.

Funicle: Stalk of the ovule.

Gametophyte: Plant body with haploid cells producing gametes.

Geitonogamy : Transfer of pollen grains from one flower to another of the same plant.

Herkogamy: Anthers and stigma at different heights or in different directions.

Heterogametes: Two morphologically distinct gametes (male and female).

Homogamy: Anthers and stigma of a flower ripen at the same time.

Hydrophily: Pollination by water.

Integuments: Multicellular coats Protecting the nucellus in the ovule.

Isogametes (Homogametes): Two Gametes are similar in structure and function.

Juvenile Phase: The stage of growth and maturity.

Malacophily: Pollination by snails

Monoecious: Male and female flowers on the same plant.

Megaspore: Haploid cell, developing into female gametophyte or embryosac.

Mesogamy: Entry of pollen tube through base of ovule or through funicle or integuments.

Micropyle: An opening into the ovule where integuments do not enclose the nucellus.

Microspore: Pollen grain developing into male gametophyte (3-celled.)

Nucellus: Mass of thin walled parenchymatous tissue inside the ovule.

Ornithophily: Pollination by birds.

Ovule: Megasporangium in flowering plants.

Pericarp: The outer wall of a fruit .

Perisperm: The persistent residual nucellus.

Pollen Bank: It is a collection of pollen grains in viable state of posterity. Pollen banks are important, as it can made available pollen for breeding experiments, and for raising haploid plants.

Pollen/ Nectar robbers: Insects which consume pollen or nectar without helping in pollination.

Pollination: Transfer of pollen grains from anther to stigma.

Pollinators: Agents which help in pollination.

Protandry : Ripening of anthers earlier than stigmas of same flower.

Protogyny : Ripening of stigma earlier than anthers of same flower.

Plumule: Apex of epicotyl region of the axis of embryo which develops into shoot system.

Polyembryony: Development of more than one embryo, in the same seed.

Porogamy: Entry of pollen tube through the micropylar end ofthe ovule.

Primary Endosperm Nucleus: Triploid nucleus formed by the union of second male gamete and fusion product of two polar nuclei.

Radicle: Lower portion of hypocotyl region of the axis of embryo which develops into root system.

Raphe: Part of funicle in an inverted ovule, which remain attached beyond hilum along side of the body of ovule.

Scutellum: Cotyledon of Monocots (Grass Family).

Secondary Nucleus: Fusion product of two polar nuclei.

Seed bank: It is a collection of seeds in a viable state of posterity. It is one of the most efficient methods of *ex-situ* conservation for sexually reproducing species.

Self sterility: Inability of pollen grains to germinate on stigma of the same flower.

Sporophyte : Plant body with diploid cells producing haploid spores by meiosis in spore mother cells.

Synergids : Two cells present on either side of egg in egg apparatus.

Syngamy: Fusion of male gamete and egg cell in angiosperms (primary fertilisation)

Tapetum: Inner most wall layer of anther nourishing the developing microspores.

Triple Fusion: Fusion of second male gamete and fusion product of two polar nuclei (secondary fertilisation).

Vivipary: The seeds germinate while they are still attached to the mother plant.

Xenogamy: Transfer of pollen grains from one plant to another of the same species.

Zoophily: Pollination by animals.

Zygote: Diploid cell formed by the fusion of male and female gametes.

VERY SHORT ANSWER TYPE QUESTIONS

1. Name the component cells of the 'egg apparatus' in an embryo sac.
2. Name the part of gynoecium that determines the compatible nature of pollen grain.
3. Name the common functions that cotyledons and nucellus perform.
4. Name the parts of pistil which develop into fruit and seeds.
5. In case of ployembryony, if an embryo develops from the synergid and another from the nucellus which is haploid and which is diploid ?
6. Can an unfertilised, apomictic embryo sac give rise to a diploid embryo ? If yes, then how ?
7. Which are the three cells found in a pollen grain when it is shed at the three celled stage ?
8. What is self-incompatibility ?
9. Name the type of pollination in self-incompatible plants.
10. Draw the diagram of a mature embryo sac and show its 8-nucleate, 7-celled nature. Show the following parts : antipodals, synergids, egg, central cell, polar nuclei.
11. Which is the triploid tissue in a fertilized ovule ? How is the triploid condition achieved ?
12. Are pollination and fertilisation necessary in apomixis? Give reasons.
13. How is pollination carried out in water plants ?
14. What is the function of the two male gametes produced by each pollen grain in angiosperms.
15. Name the parts of an angiosperm flower in which development of male and female gametophyte take place.
16. What is meant by monosporic development of female gametophyte?
17. Mention two strategies evolved to prevent self-pollination in flowers.
18. Why do you think the zygote is dormant for some time in a fertilized ovule ?
19. If one can induce parthenocarpy through the application of growth substances,which fruits would you select to induce parthenocarpy and why ?
20. Explain the role of tapetum in the formation of pollen grain wall.

SHORT ANSWER TYPE QUESTIONS

1. List three strategies that a bisexual chasmogamous flower can evolve to prevent self pollination (autogamy).
2. Given below are the events that are observed in an artificial hybridization programme. Arrange them in the correct sequential order in which they are followed in the hybridization programme.
   a) Re-bagging
   (b) Selection of parents
   (c) Bagging
   (d) Dusting the pollen on stigma
   (e) Emasculation
   (f) Collection of pollen from male
3. Vivipary automatically limits the number of offsprings in a litter. How?
4. Does self incompatibility impose any restrictions on autogamy ? Give reasons and suggest the method of pollination in such plants.
5. What is polyembryony and how can it be commercially exploited ?

6. Are parthenocarpy and apomixis different phenomena ? Discuss their benefits.
7. Why does the zygote begin to divide only after the division of Primary endosperm cell (PEC)?
8. The generative cell of two-celled pollen divides in the pollen tube but not in a three-celled pollen. Give reasons.
9. Discuss the various types of pollen tube entry into ovary with the help of diagrams.
10. Differentiate between micro-sporogenesis and megasporogenesis. Which type of cell division occurs during these events? Name the structures formed at the end of these two events.
11. What is bagging technique? How is it useful in a plant breeding programme?
12. What is triple fusion? Where and how does it take place? Name the nuclei involved in triple fusion.
13. Diffrentiate between
    a) Hypocotyl and Epicotyl
    b) Coleoptile and Coleorhiza
    c) Integument and testa
    d) Perisperm and Pericarp
14. What is meant by emasculation? When and why does a plant breeder employ this technique?
15. What is apomixis? What is its importance?

LONG ANSWER TYPE QUESTIONS

1. Starting with the zygote, draw the diagrams of the different stages of embryo development in a dicot.
2. What are the possible types of pollinations in chasmogamous flowers? Give reasons.
3. With a neat, labeled diagram, describe the parts of a mature angiosperm embryo sac. Mention the role of synergids.
4. Draw the diagram of a microsporangium and label its wall layers. Write briefly about the wall layers.
5. Embryo sacs of some apomictic species appear normal but contain diploid cells. Suggest a suitable explanation for the condition.
6. Describe the process of Fertilization in angiosperms.

Activity :

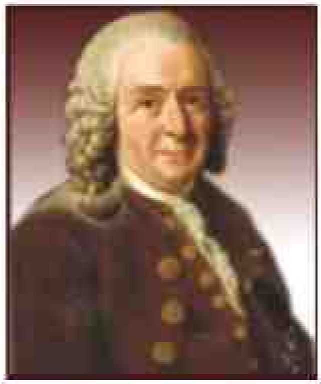
1. Collect pollen grains of different plants, germinate and observe under microscope.
2. Observe how different insects visit different plants and cross pollinate flowers.

UNIT IV

PLANT SYSTEMATICS

CHAPTER 8
Taxonomy of Angiosperms

In the earlier units we considered the great diversity of plant kingdom. The diversity of plant life in all its aspects is the raw material of taxonomic botany. The taxonomist collecting plants from the natural vegetation like forests and observing the breeding systems, the botanist working in the laboratory on embryology and anatomy, the cytogeneticist studying chromosomes and the phytochemist reaching for molecular details in his quest for knowledge- all contribute to the growth and progress of plant taxonomy. The taxonomic study or approach with due emphasis on phylogeny is regarded as Plant Systematics. Probably no other branch of botany needs such varied interests.


Carl Linnaeus
(1707-78)

Carl Linnaeus: It is Carl Linnaeus [1707-78], a Swedish pastor, physician and a botanist who has the honour of being hailed as the "Father of Taxonomy". In 1753 after experimenting with a number of approaches, he refined and standardised a binomial naming system. He also established a classification system, which was simple enough to allow most people to key out a plant much as we do today. It was called an artificial system because it relied on a very few features of the flower, primarily the number of stamens and pistils, as the primary basis for division.

CHAPTER 8

TAXONOMY OF ANGIOSPERMS

As we walk through different areas of vegetation *viz.*, natural forests, botanical gardens, shrub jungles etc., we observe large number of plants exhibiting variability in their size as well as in their vegetative and reproductive morphological characters. It is not easy to study, understand and record all such heterogeneous group of plants individually, but yet possible using specific approach. This approach is **taxonomy**. The term Taxonomy was coined by A.P.de Candolle in 1813. So far several thousands of Angiosperms are already known to us and many more are still being discovered and recorded. Taxonomy purely based on the description of morphological characteristics, is called **'Alpha Taxonomy'**. In recent times, we have advanced to **'Omega Taxonomy'** in which information from other sources, *viz.*, Embryology, Cytology, Palynology, Phytochemistry, Serology etc. also form criteria apart from morphological features. Taxonomy includes four basic components *viz.*, characterization, identification, nomenclature and classification. You have learnt about the basic aspects of identification and nomenclature in Chapter-1 and about detailed morphological characteristics of flowering plants in Chapter-5. In the following pages of this chapter, classification, semi-technical description of a typical flowering plant and of selected families are dealt with.

8.1 Systems, Types of Classification

Classification of plants refers to grouping plants based on their structural similarities and inter relationships. The earlier classifications of plants were based on their economic uses. e.g. Cereals, medicinal plants, fibre- yielding plants, oil-yielding plants etc., or on gross structural resemblances, e.g., herbs, shrubs, trees, climbers etc. These classifications were incomplete and fragmentary as plants that did not fit into such classifications or of no apparent economic value were usually ignored. So, different systems or classifications have developed gradually over the period and in tune with the advances that have taken place in other branches of Botany as well as in allied sciences. Based on the criteria followed for classification, all the systems proposed from the beginning are grouped under three types, *viz.* **artificial, natural** and **phylogenetic**.

Artificial system is the earliest system of plant classification based only on gross superficial morphological characters such as habit, colour, number and shape of leaves etc. In this system only one or a few characters were selected arbitrarily and plants were arranged into groups according to such characters. As a result, closely related plants were often placed in different groups, while unrelated plants were placed in the same group because of the presence or absence of a particular character. This system did not indicate the natural relationship that exists among the individuals forming a group. Nevertheless identification of an unknown plant was rendered easier by this system.

Theophrastus (370 to 285 BC) classified plants into 3 groups based on their habit as (i) herbs (ii) shrubs and (iii) trees in his book '**Historia Plantarum**' and **Linnaeus** (1754) classified plants into 24 groups on the basis of number, length and union of stamens and of carpels (sexual characters) in his book "**Species Plantarum**", these are examples of **artificial systems** of classification. They gave equal importance to vegetative and sexual characterestics. This is not acceptable since we know now that often the vegetative characters are not stable as they get affected more easily by environment.

In **Natural System** of classification, all the important, mostly morphological, characters were taken into consideration and plants were classified accordingly. Thus plants were first classified into few big groups. These were further divided and subdivided into smaller and smaller groups until the smallest division/taxon (**species**) is reached. Usually, the floral characters were given greater importance since they are more conserved and do not change due to the effect of environment. However, characters of evolutionary importance were not considered. Despite this draw back, Natural System still provides an easy means of the identification of plants.

Bentham & Hooker's (1862-1893) system of classification of plants as proposed in their book **"Genera Plantarum"** is a **Natural System** of Classification.

Bentham and Hooker divided the flowering plants into three classes namely **Dicotyledonae, Gymnospermae** and **Monocotyledonae.** Dicotyledonae was divided into three subclasses namely Polypetalae, Gamopetalae and Monochlamydae. Polypetalae was divided into three series namely Thalamiflorae (with 6 cohorts or orders), Disciflorae (with 4 cohorts) and Calyciflorae (with 5 cohorts). Gamopetalae was divided into three series viz. Inferae (with 3 cohorts), Heteromerae (with 3 cohorts) and Bicarpellatae (with 4 cohorts). Monochlamydae was divided into eight series (not divided into cohorts). Monocotyledonae was divided into seven series (not divided into cohorts). The cohorts were further divided into natural orders. Thus they grouped the flowering plants into 202 natural orders now called as families. Of these 165 natural orders belong to Dicotyledonae, 3 to Gymnospermae and 34 belong to Monocotyledonae.

Phylogenetic System: The classifications of post-Darwinian period considered evolutionary trends in plants and so they are considered as phylogenetic systems. In a phylogenetic system, primitive and advanced characters are recognized. Evolution may be progressive or retrogressive. While considering the status of a taxon, a comprehensive picture of all the characters is taken in to account. The system proposed by Engler and Prantl in their book **"Die Naturlichen Planzenfamilien"** (1887-1893) and by J.Hutchinson (1954) in his book **"Families of Flowering Plants"** are examples for phylogenetic system. The latest phylogenetic classfication is **APG (Angiospermic Phylogenetic Group) system.**

Other Types

Numerical taxonomy uses mathematical methods to evaluate observable differences and similarities between taxonomic groups. Numerical taxonomy which is now easily carried out using the computers is based on all observable characterestics. In this process, number and codes are assigned to all the characters and the data are then processed. Each character is given equal importance and at the same time hundreds of characters can be considered.

Cytotaxonomy: A branch of taxonomy that uses the cytological characters like chromosome number, structure in solving taxonomic problems.

Chemotaxonomy: A branch of taxonomy that uses the phytochemical data to solve the problems of taxonomy.

Figure 8.1 Floral diagram with floral formula

$Ebr\ Ebrl \oplus ⚥ K_{2+2} C_{4} A_{2+4} G_{(2)}$

8.2 Semi-technical Description of a Typical Flowering Plant

Description of various morphological features of a flowering plant presented in Unit 2 forms the basis for characterization, identification and classification of plants. A brief technical description based on these in scientific language is presented now in a proper sequence.

The plant is described beginning with its habit, habitat, vegetative characters (roots, stem and leaves) and then floral characters (inflorescence, flower and its parts) followed by fruit. After describing various parts of a plant, a floral diagram and a floral formula are presented. The floral formula is represented by some symbols of floral parts. In the floral formula, **Br** stands for bracteate, **Ebr** for ebracteate (bracts absent); **Brl** stands for bracteolate, **Ebrl** for ebracteolate (bracteoles absent); ⊕stands for actinomorphic, % for zygomorphic; ♂ for male, for female, for bisexual flower; **K** stands for calyx, **C** for corolla, **P** for perianth, **A** for androecium and **G** for Gynoecium; **G** stands for superior ovary and $\bar{G}$ for inferior ovary. **Floral formula** also indicates the number of free or united (within brackets) members of the corresponding whorl as subscript of the respective symbol. It also shows cohesion (union among similar members) and adhesion (union between dissimilar members).

A **floral diagram** provides information about the number of parts of a flower, their arrangement and the relation they have with one another (Figure 8.1). The mother axis represents the posterior side of the flower and is indicated as a dot or a circle at 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 represented by a diagram of T.S. of ovary . The bract represents the anterior side of the flower and is indicated at the bottom of the floral diagram. The floral diagram and floral formula shown in Figure 8.1 represent those of the mustard plant (Family: Brassicaceae).

8.3 Description of Some Important Families

8. 3.1 Fabaceae

This family was earlier called as Papilionoideae, a sub-family of Leguminosae in Bentham and Hooker's system of classification. Plants of this family are distributed all over the world, mostly tropical and subtropical, in mesophytic habitat. It comprises about 8500 species under 450 genera. Some important plants among these include: *Arachis hypogaea* (groundnut), *Cajanus cajan* (Red gram, pigeon pea), *Cicer aritetinum* (Bengal gram, chickpea), *Crotalaria juncea* (Sun hemp), *Dolichos lablab* (Bean), *Dalbergia latifolia* (Indian rosewood), *Glycine max* (Soybean), *Derris indica* (Kanuga, Petro plant), *Phaseolus mungo* (Black gram), *Phaseolus aureus* (Green gram), *Pisum sativum* (Garden pea), *Lathyrus satius* (Wild pea), *Pterocarpus santalinus* (Red sander), *Trigonella foenum-graecum*(Fenugreek). Figure 8.2 shows characteristics of garden pea (*Pisum sativum*) plant as a typical representative of this family.

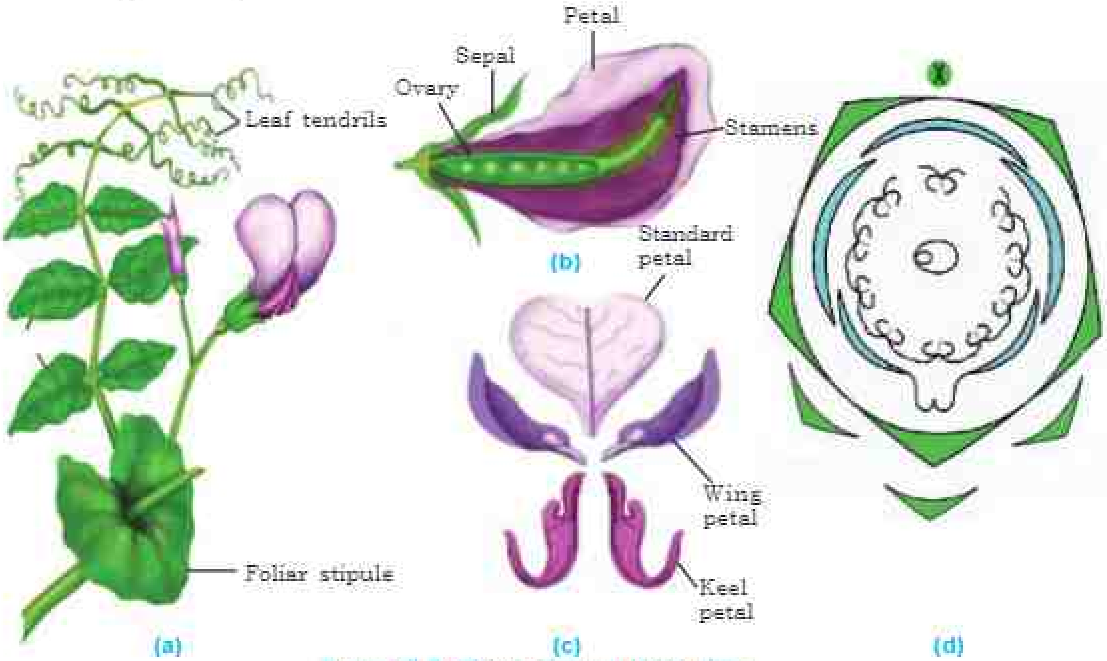


Figure 8.2 *Pisum sativum* (pea) plant

(a) Flowering twig (b) L.S of Flower (c) Papilionaceous corolla (d) Floral diagram

Floral Formula: Br Brl % ⚥ $K_{(5)}\ C_{1+2+(2)}\ A_{(9)+1}\ \overline{G}_1$

Vegetative Characters

Habit: Majority herbs, some are shrubs, trees, weak stemmed twiners or tendril climbers.

Root system: Tap root system, **nodular roots** (containing *Rhizobia*-the nitrogen fixing bacteria)

Stem: Aerial, prostrate or erect, herbaceous or woody climbers.

Leaves: Cauline, alternate, stipulate, base pulvinate, petiolate, simple or pinnately compound leaf; venation reticulate.

Floral Characters

Inflorescence: Mostly a raceme

Flower: Bracteate, bracteolate or ebracteolate, pedicillate, zygomorphic, complete, bisexual, pentamerous, perigynous, cup-shaped thalamus.

Calyx: Sepals five, gamosepalous; imbricate aestivation, odd sepal anterior.

Corolla: Petals five, polypetalous, papilionaceous consisting of a large posterior petal (standard), two laterals (wings), two anterior fused petals (keel) enclosing the stamens and pistil, vexillary/descendingly imbricate aestivation.

Androecium: Stamens ten, diadelphous [(9)+1]as in *Pisum* or monadelphous as in *Arachis*, *Crotalaria*, anthers dithecous

Gynoecium: Monocarpellary unilocular half-superior ovary with many ovules on marginal placentation; style single, long, terminal; stigma simple.

Pollination: Flowers are protandrous, usually entomophilous-cross pollination with 'Piston mechanism'; self pollination in *Pisum* and *Lathyrus*.

Fruit: Mostly legume or pod; geocarpic, indehiscent in *Arachis*.

Seed: One to many, non-endospermic, two cotyledons which store mostly proteins but also oil in *Arachis*.

Economic importance

Many plants belonging to the family are good sources of proteins (pulses like redgram, blackgram), edible oils (soyabean, groundnut), vegetables (Pods of bean, soyabean; seeds of garden pea, groundnut; leaves of Menthi), timber (Red sanders, Indian rose wood) and fiber (sunhemp). Other commercially important products obtained are *viz.*, blue dye (*Indigofera tinctoria*), yellow dye (*Butea monosperma*, commonly called flame of the forest); medicine (*Derris indica*); fodder (*Crotalaria, Phaseolus*) or green manure (*Sesbania, Tephrosia*).

8.3.2 Solanaceae

It is commonly called as the 'potato family' and includes about 2200 species belonging to 85 genera. Members of this family are widely distributed in mesophytic habitat of tropics, subtropics and even temperate zones. Some important plants of this family are *Atropa belladonna* (Belladona), *Capsicum frutescens* (Chilli), *Cestrum nocturnum* (Night queen), *Datura metel* (Thorn apple), *Lycopersicon esculentum* (Tomato), *Nicotiana tabacum* (Tobacco), *Petunia alba* (Petunia), *Solanum melongena* (Brinjal), *Solanum tuberosum* (Potato), *Withania somnifera* (Aswagandha) etc. Figure 8.3 shows characteristics of this family as represented by *Solanum nigrum* (Makoi, kamanchi) plant.

Vegetative Characters

Habit: Plants mostly herbs, some shrubs (*Cestrum*).

Root system: Tap root

Stem: Aerial, erect, herbaceous or rarely woody, cylindrical, solid or hollow, hairy or glabrous, underground stem tuber in Potato. **Bi-collateral vascular bundles** are common.

Leaves: Cauline, alternate phyllotaxy, exstipulate, petiolate, petiole adnate to the stem, simple or rarely pinnately compound leaf, reticulate venation.

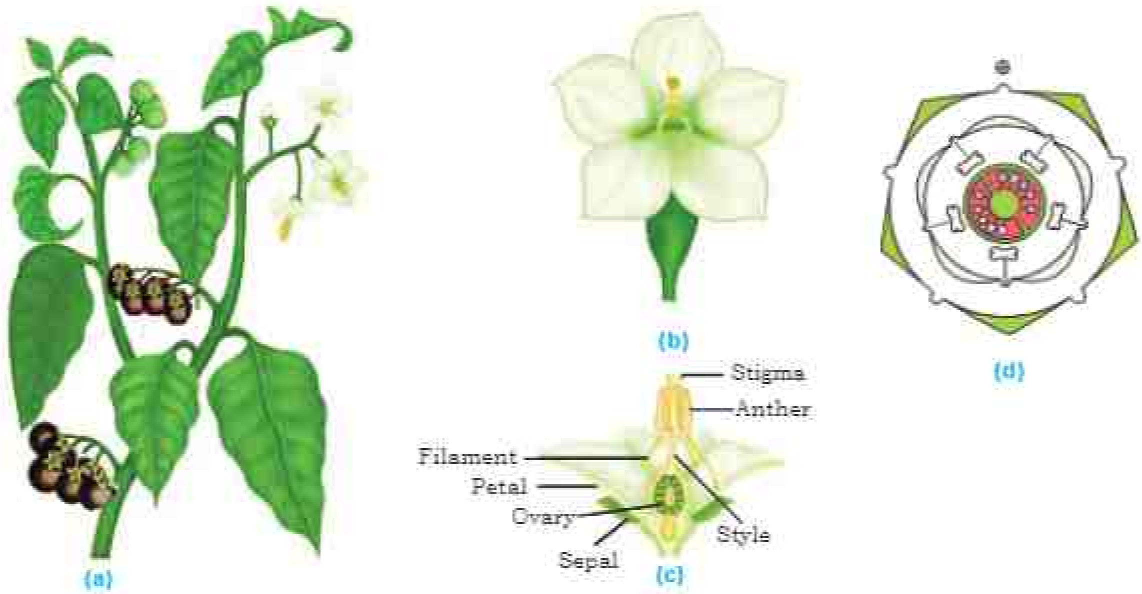


Figure 8.3 *Solanum nigrum* (makoi) plant
(a) Flowering twig (b) Flower (c) L.S. of flower (d) Floral diagram

Floral Formula: $Br\ Ebrl\ \oplus\ ⚥\ K_{(5)}\ \widehat{C_{(5)}\ A_5}\ G_{(2)}$

Floral Characters

Inflorescence: Cymose, axillary as in *Solanum*, terminal solitary as in *Datura*, Panicle in Tobacco.

Flower: Bracteate or ebracteate, ebractelolate, pedicillate, actinomorphic, complete, bisexual, pentamerous, hypogynous.

Calyx: Sepals five, gamosepalous, persistent in *Solanum* and *Capsicum*, valvate aestivation.

Corolla: Petals five, gamopetalous, valvate or twisted aestivation as in *Datura*.

Androecium: Stamens five, epipetalous, alternating with the petals, anthers dithecus, basifixed, introrse.

Gynoecium: Bicarpellary, syncarpous, bilocular but rarely unilocular e.g., chillies, superior ovary, placenta swollen with many ovules on axile placentation, style terminal, stigma capitate. Carpels are arranged obliquely at 45°.

Pollination: Flowers usually protandrous but protogynous in some species of *Solanum*, commonly entomophilous cross pollination.

Fruits: Berry (*Capsicum, Solanum, Lycopersicon*) or capsule (*Datura, Nicotiana*).

Seeds: Many, endospermic.

Economic Importance

Many plants belonging to this family are sources of vegetables (tomato, brinjal, potato), spice (chilli), medicine (belladonna, ashwagandha), ornamentals (*petunia*, night queen, day king) and produce chemical substances of medicinal value (Makoi or Kamanchi). An alkaloid nicotine is obtained from Tobacco and leaves are used in making cigarettes

8.3.3 Liliaceae

This family is commonly called the 'Lily family' and is a typical representative of monocotyledonous plants. Plants of this family are world wide in distribution as mesophytes (*Allium, Lilium*) as well as Xerophytes (*Asparagus, Ruscus, Aloe*). It includes about 254 genera with 4075 species. Some important plants among these are *Allium cepa* (Onion), *Allium sativum* (Garlic), *Aloe vera* (Aloe), *Asparagus racemosus* (Asparagus), *Colchicum autumnale* (Medow saffron), *Dracaena aungustifolia* (Red dragon), *Gloriosa superba* (Glory lily), *Lilium candidum* (Lily), *Smilax zeylanica* (Sarasaparilla), *Yucca gloriosa* (Spanish dagger) etc. Figure 8.4 shows characteristics of *Allium cepa* (onion) a typical representative of this family.

Vegetative characters

Habit: Mostly perennial herbs with underground stems such as bulbs, corms, rhizome; some are shrubs or trees (certain species of *Dracaena, Yucca, Aloe)* or climbers (*Gloriosa, Smilax*)

Root system: Adventitious roots; fasciculated, tuberous in *Asparagus*.

Stem: Underground, perennial, bulb (*Allium, Lilium*), corm (*Colchicum*), rhizome (*Gloriosa*); some are aerial, weak, tendril climbers (*Gloriosa, Smilax*), branches modified into cladophylls (*Ruscus, Asparagus*)

Leaves: Mostly radical (*Allium, Lilium*), or cauline (*Smilax, Gloriosa*), simple, alternate, linear, exstipulate, parallel venation or exceptionally reticulate in *Smilax*.

Floral Characters

Inflorescence: Solitary cyme or umbel or receme.

Flower: Bracteate, ebrateolate, pedicellate, complete, bisexual or exceptionally unisexual as in *Smilax* and *Ruscus*; actinomorphic, trimerous, hypogynous, homochlamydeous.

Perianth: Six tepals in two whorls (3+3), odd tepal of outer whorl is anterior in position and odd tepal of inner whorl is posterior in position, valvate aestivation

Androecium: Six stamens in two whorls (3+3), free or epiphyllous, anthers dithecus, basifixed, introrse and dehiscence longitudinal.

Gynoecium: Tricarpellary, syncarpous; ovary superior, trilocular with many ovules on axile placentation, style terminal, stigma trifid and capitate.

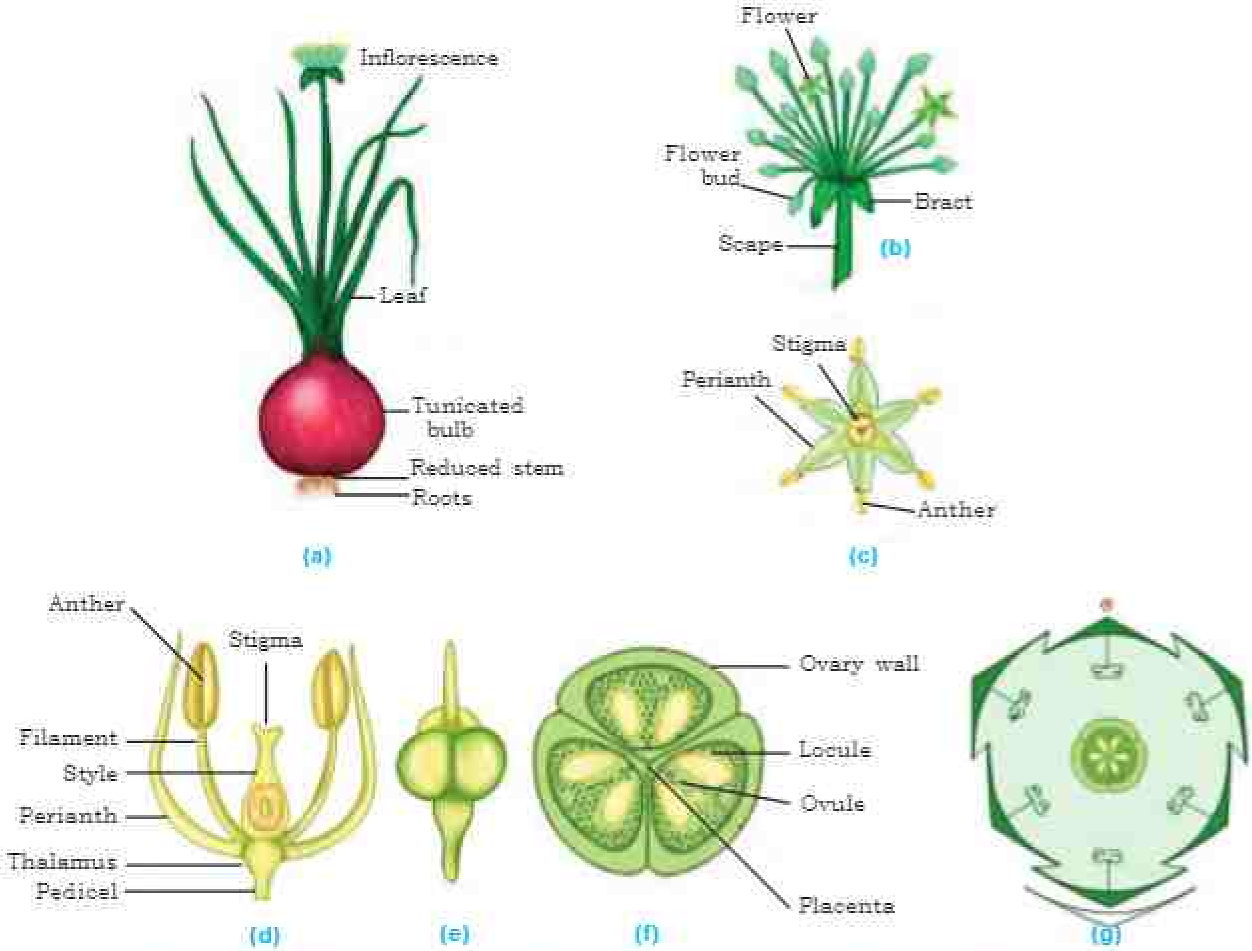


Figure 8.4 *Allium* cepa (onion) (a) Plant (b) Inflorescence (c) Flower (d) L.S of flower (e) Pistil (f) T.S of ovary (g) Floral diagram

Floral Formula: Br Ebrl $\oplus$ ⚥ $P_{\widehat{(3+3)}} A_{3+3} G_{(3)}$

Pollination: Flowers may be protandrous (*Allium*) or protogynous (*Colchicum*), entomophilous cross pollination.

Fruit: Usually capsule, rarely berry (*Asparagus*)

Seed: Endospermous, monocotyledonous, polyembryony is present in some *Allium* species.

Economic Importance

Many plants belonging to this family are good ornamentals (tulip, lilium, *Asparagus, Gloriosa*), source of medicine (*Aloe, Smilax, Gloriosa, Scilla*), vegetables (*Allium cepa, Asparagus*), spice (*Allium sativum*) and colchicine (*Colchicum autumnale*).

Summary

Plants in nature exhibit diversity in their structural characteristics. Classification of these plants into groups based on their similarities and their interrelationships is **Taxonomy**. This process has long history, started with **Carl Linnaeus** who has been hailed as '**Father of Taxonomy**'. Earlier classifications were artificial and fragmentary, based on only their economic uses and or a few morphological characteristics. Over the time, different systems of classifications namely **Natural systems** and **Phylogenetic Systems** were gradually developed in tune with advances in other branches of Botany and allied sciences. **Bentham & Hooker's System** of classification is a natural system. This system of classification is based mostly on morphological features with due emphasis on floral characters. In phylogenetic systems, evolutionary trends in plants were considered e.g., **Engler** and **Prantl**. In recent times, we have advanced to **'Omega Taxonomy'** in which information from other branches of Botany viz., cytology, embryology, palynology, and phytochemistry also form criteria in addition to morphological features. Taxonomy purely based on the description of morphological characters is called '**Alpha Taxonomy**'.

The technical description of morphological features of vegetative and floral parts including floral diagram and floral formula form the basics for taxonomic studies.

Floral formula is represented by symbols of floral parts. Floral diagram is the diagramatic representation of floral parts and their arrangement. Family **Fabaceae** of polypetalae and Dicots is represented by *Pisum sativum*, family **Solanaceae** of gamopetalae and Dicots is represented by *Solanum nigrum*, and *Allium cepa* is an example for **Liliaceae** of Monocots where described in semi-technical terms .

GLOSSARY

Actinomophic: Flowers can be divided into two symmetrical halves in any vertical plain through the axis.

Alpha taxonomy: Taxonomy purely based on the description of morphological characters.

Artificial system: A system of classification based on a few easily comparable morphological characters.

Binomial nomenclature: Providing a name with two components, the generic name and the specific epithet.

Classification: Arranging the plants to specific groups on the basis of their similarities and dissmilarities.

Complete flower: A flower with all four floral parts- calyx, corolla, androecium and gynoecium

Diadelphous: It is a condition in which stamens are fused together and form two bundles.

Flora: The actual account of habitat, distribution and systematic listing of plants of a given area.

Floral diagram: A diagram representing the number of parts of flower, the structure, arrangement, aestivation, adhesion, cohesion and position with respect to the mother axis.

Genus: A group of closely related species.

Geocarpic: The development of fruit inside the soil.

Herbarium: A collection of plant specimens that are pressed dried and preserved on sheets with collection details and stored as per classification system.

In-complete flower: One of the floral parts of the flower is absent.

Natural system: A system of classification in which plants are grouped on the basis of their natural relationships taking into consideration all possible morphological characters.

Nomenclature: Providing a correct scientific name to an identified plant.

Numerical taxonomy: A branch of taxonomy that uses mathematical methods to evaluate observable differences and similarities between taxonomic groups.

Omega taxonomy: Taxonomy based on information from other branches such as Embryology, Cytology, Phyto-chemistry, Palynology etc., in addition to morphological characters.

Piston mechanism: The insects are attracted by the standard petal. As the insect alights on the flower, the wing and keel petals get pressed down due to its weight there by exposing the stigma and stamens. The stigma which comes out first brushes against the abdomen of the insect and receives pollen already present there. As the insect leaves the flower, the essential organs return to their normal position.

Plant systematics: The study of the diversity and the history of plants and the evolutionary relationships among them.

Plant taxonomy: Deals with characterisation, identification, nomenclature and classification of plants.

Phylogenetic system: A system of classification based on genetic and evolutionary relationships among the taxa.

Taxon: Any unit used in classification. Taxa (pl) are arranged in hierarchy from kingdom to subspecies.

VERY SHORT ANSWER TYPE QUESTIONS

1. What is 'Omega Taxonomy'?
2. What is Natural system of plant classification? Name the scientists who followed it.
3. Explain the scope and significance of 'Numerical Taxonomy'.
4. What is geocarpy? Name the plant which exhibits this phenomenon.
5. Name the type of pollination mechanism found in members of Fabaceae.
6. Write the floral formula of *solanum* plant.
7. Give the technical description of ovary in *Solanum nigrum*.
8. Give the technical description of anthers of *Allium cepa*.

SHORT ANSWER TYPE QUESTIONS

1. Write a brief note on semi technical description of a typical flowering plant.
2. Describe the non-essential floral parts of plants belonging to Fabaceae.
3. Give an account of floral diagram.
4. Describe the essential floral parts of plants belonging to Lilliaceae.
5. Write a brief account on the class of Dicotyledanae of Bentham and Hooker's classification.
6. Explain floral formula
7. Give economic importance of plants belonging to Fabaceae.

LONG ANSWER TYPE QUESTIONS

1. Describe the characteristics of plants belonging to Fabaceae.
2. Write about the key characteristics of Solanaceae?
3. Give an account of the family, Liliaceae.
4. Write the characteristics of plants that are necessary for classification. Describe them in brief.
5. Describe a typical flowering plant in the taxonomic perspective.
6. Give an account of Bentham and Hooker's classification of plants.
7. What is taxonomy? Give a brief account of different types of plant classification.

UNIT V

CELL: STRUCTURE AND FUNCTIONS

Biology is the study of form, function and interrelationships of living organisms. The detailed description of their form and appearance only brought out their diversity. It is the cell theory that emphasised the unity underlying this diversity of forms, i.e., the cellular organisation of all life forms. A description of cell structure and cell growth by division is given in the chapters comprising this unit. Cell theory also created a sense of mystery around living phenomena, i.e., physiological and behavioural processes. This mystery was the requirement of integrity of cellular organisation for living phenomena to be demonstrated or observed. In studying and understanding the physiological and behavioural processes, one can take a physico-chemical approach and use cell-free systems to investigate. This approach enables us to describe the various processes in molecular terms. The approach is established by analysis of living tissues for elements and compounds. It will tell us what types of organic compounds are present in living organisms. In the next stage, one can ask the question: What are these compounds doing inside a cell? And, in what way they carry out gross physiological processes like synthesis, digestion, excretion, memory, defense, recognition, etc. In other words we answer the question, what is the molecular basis of all physiological processes? It can also explain the unusual processes that occur during any diseased condition. This physico-chemical approach to study and understand living organisms is called 'Reductionist Biology'. The concepts and techniques of physics and chemistry are applied to understand biology. In Chapter 10 of this unit, a brief description of bio-molecules is included.


G. N. Ramachandran
(1922 – 2001)

G.N. RAMACHANDRAN, an outstanding figure in the field of protein structure, was the founder of the 'Madras school' of conformational analysis of biopolymers. His discovery of the triple helical structure of collagen published in *Nature* in 1954 and his analysis of the allowed conformations of proteins through the use of the 'Ramachandran plot' rank among the most outstanding contributions in structural biology. He was born on October 8, 1922, in a small town, not far from Cochin on the southwestern coast of India. His father was a professor of mathematics at a local college and thus had considerable influence in shaping Ramachandran's interest in mathematics. After completing his school years, Ramachandran graduated in 1942 as the top-ranking student in the B.Sc. (Honors) Physics course of the University of Madras. He received a Ph.D. from Cambridge University in 1949. While at Cambridge, Ramachandran met Linus Pauling and was deeply influenced by his publications on models of the â-helix and β-sheet structures that directed his attention to solving the structure of collagen. He passed away at the age of 78, on April 7, 2001.

CHAPTER 9

CELL: THE UNIT OF LIFE

When you look around, you see both living and non-living things. You must have wondered and asked yourself – 'what is it that makes an organism living, or what is it that an inanimate thing does not have which a living thing has? The answer to this is the presence of the basic unit of life – the cell in all living organisms.

All organisms are composed of cells. Some are made up of a single Cell and these are called unicellular organisms while others, like us, composed of many cells, are called multicellular organisms.

9.1 WHAT IS A CELL?

Unicellular organisms are capable of (i) independent existence and (ii) performing the essential functions of life. Anything less than a complete structure of a cell does not ensure independent living. Hence, cell is the fundamental structural and functional unit of all living organisms.

Anton Von Leeuwenhoek first saw and described a live cell. Robert Brown later discovered the nucleus. The invention of the light microscope and its improvement leading to electron microscope made it to reveal all the structural details of the cell.

9.2 Cell Theory

In 1838, Mathias Schleiden, a German botanist, examined a large number of plants and observed that all plants are composed of different kinds of cells which form the tissues of the plant. At about the same time, Theodore Schwann (1839), a British Zoologist, studied different types of animal cells and reported that cells had a thin outer layer which is today known as the 'plasma membrane'. He also concluded, based on his studies on plant tissues, that the presence of cell wall is a unique character of the plant cells. On the basis of this, Schwann proposed the hypothesis that the bodies of animals and plants are composed of cells and products of cells.

Schleiden and Schwann together formulated the cell theory. This theory however, did not explain as to how new cells were formed. Rudolf Virchow (1855) first explained that cells divided and new cells are formed from pre-existing cells (*Omnis cellula-e cellula*). He modified the hypothesis of Schleiden and Schwann to give the cell theory a final shape. Cell theory as understood today is:

(i) all living organisms are composed of cells and products of cells.

(ii) all cells arise from pre-existing cells.

9.3 An Overview of Cell

You have earlier observed cells in an onion peel and/or human cheek cells under the microscope. Let us recollect their structure. The onion cell which is a typical plant cell, has a distinct cell wall as its outer boundary and just within it is the cell membrane. The cells of the human cheek have an outer membrane as the delimiting structure of the cell. Inside each cell is a dense membrane bound structure called nucleus. This nucleus contains the chromosomes which in turn contain the genetic material, DNA. Cells that have membrane bound nuclei are called eukaryotic whereas cells that lack a membrane bound nucleus are prokaryotic. In both prokaryotic and eukaryotic cells, a semi-fluid matrix called cytoplasm occupies the volume of the cell. The cytoplasm is the main arena of cellular activities in both the plant and animal cells. Various chemical reactions occur in it to keep the cell in the 'living state'.

Besides the nucleus, the eukaryotic cells have other membrane bound distinct structures called organelles like the endoplasmic reticulum (ER), the golgi complex, lysosomes, mitochondria, plastids (in plants), microbodies and vacuoles. The prokaryotic cells lack such membrane bound organelles.

Ribosomes are non-membrane bound organelles found in all cells – both eukaryotic as well as prokaryotic. Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles – chloroplasts (in plants) and mitochondria and on rough ER.

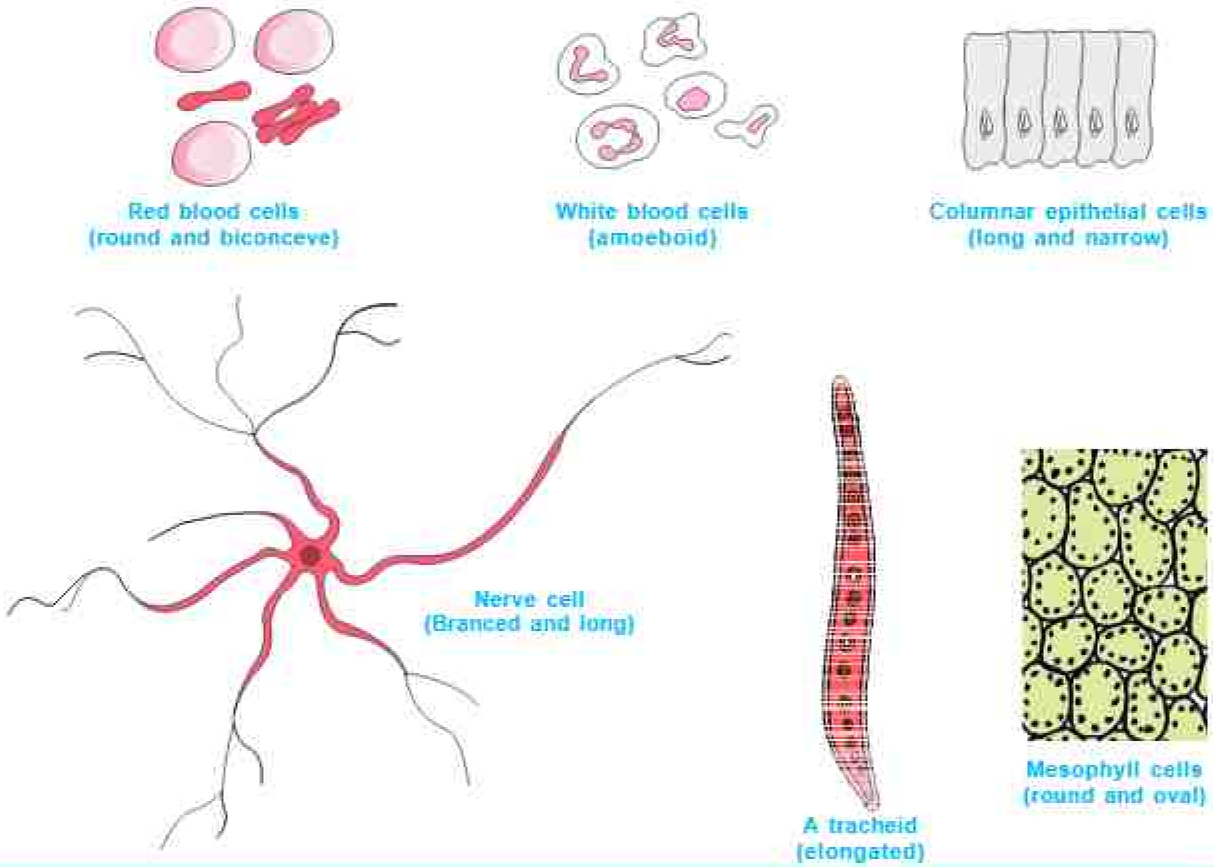


Fig 9.1 : Diagram showing different shapes of the cells

Animal cells contain another non-membrane bound organelle called centriole which helps in cell division.

Cells differ greatly in size, shape (Figure 9.1) and activities. For example, Mycoplasmas, the smallest cells, are only 0.3 μm in length while bacteria could be 3 to 5 ìm. The largest isolated single cell is the egg of an ostrich. Among multicellular organisms, human red blood cells are about 7.0 ìm in diameter. Nerve cells are some of the longest cells. Cells also vary greatly in their shape. They may be disc-like, polygonal, columnar, cuboid, thread like, or even irregular. The shape of the cell may vary with the function they perform.

9.4 Prokaryotic Cells

The prokaryotic cells are represented by bacteria, blue-green algae, mycoplasma and PPLO (Pleuro Pneumonia Like Organisms). They are generally smaller and multiply more rapidly than the eukaryotic cells (Figure 9.2). They may vary greatly in shape and size. The four basic shapes of bacteria are bacillus (rod like), coccus (spherical), vibrio (comma shaped) and spirillum (spiral).

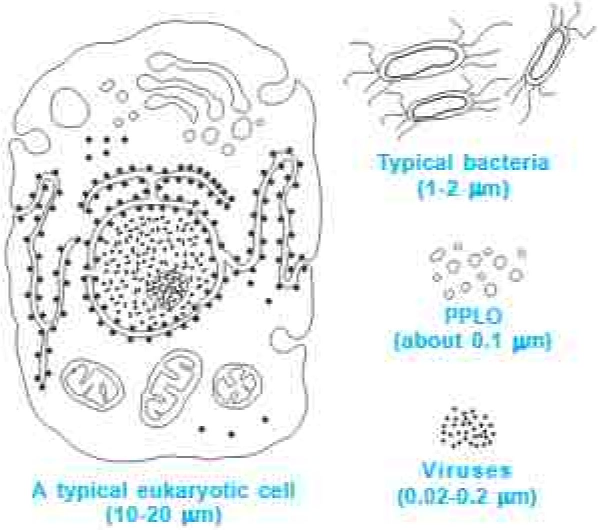


Fig 9.2 : Diagram showing comparison of eukaryotic cell with other organisms

The organisation of the prokaryotic cell is fundamentally similar even though prokaryotes exhibit a wide variety of shapes and functions. All prokaryotes have a cell wall surrounding the cell membrane. The fluid matrix filling the cell is the cytoplasm. There is no well-defined nucleus. The genetic material is basically naked, not enveloped by a nuclear membrane. In addition to the genomic DNA (the single 'chromosome'/circular DNA), many bacteria have small circular DNA outside the genomic DNA. These smaller DNAs are called plasmids. The plasmid DNA confers certain unique phenotypic characters to such bacteria. One such character is resistance to antibiotics. In higher classes you will learn that this plasmid DNA is used to monitor bacterial transformation with foreign DNA. Nuclear membrane is found in eukaryotes. No organelles, like the ones in eukaryotes, are found in prokaryotic cells except ribosomes. Prokaryotes have something unique in the form of inclusions. A specialised differentiated form of cell membrane called mesosome is the characteristic of prokaryotes. It is essentially an infolding of the cell membrane.

9.4.1 Cell Envelope and its Modifications

Most prokaryotic cells, particularly the bacterial cells, have a chemically complex cell envelope. The cell envelope consists of a tightly bound three layered structure i.e., the outermost glycocalyx followed by the cell wall and then the plasma membrane. Although each layer of the envelope performs distinct function, they act together as a single protective unit. Bacteria can be classified into two groups on the basis of the differences in the chemical composition of cell envelopes and the manner in which they respond to the staining procedure developed by Gram viz., those that take up the gram stain are **Gram positive** and the others that do not are called **Gram negative** bacteria.

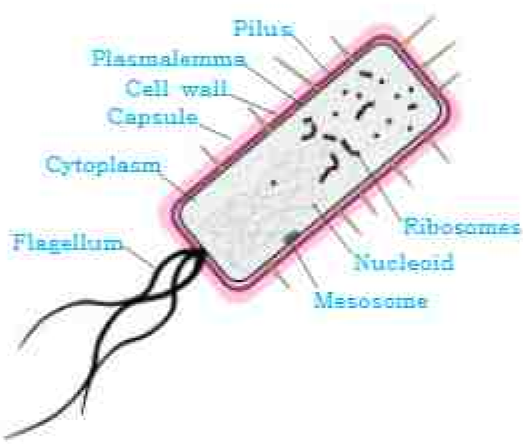


Fig 9.2 a: Typical prokaryotic cell

Glycocalyx differs in composition and thickness among different bacteria. It could be a loose sheath called the **slime layer** in some while in others it may be thick and tough, called the **capsule.** The **cell wall** determines the shape of the cell and provides a strong structural support to prevent the bacterium from bursting or collapsing (Figure 9.2 a).

The plasma membrane is semi-permeable in nature and interacts with the outside world. This membrane is structurally similar to that of the eukaryotes.

A special membranous structure is the mesosome which is formed by the extensions of plasma membrane into the cell. These extensions are in the **form of vesicles, tubules and lamellae**. They help in cell wall formation, DNA replication and its distribution to daughter cells. They also help in respiration, secretion processes, to increase the surface area of the plasma membrane (absorption of nutrients) and enzymatic content. In some prokaryotes like cyanobacteria, there are other membranous extensions into the cytoplasm called chromatophores which contain pigments.

Bacterial cells may be motile or non-motile. If motile, they have thin filamentous extensions from their cell wall called flagella. Bacteria show a range in the number and arrangement of flagella. Bacterial flagellum is composed of three parts – **filament, hook** and **basal body**. The filament is the longest portion and extends from the cell surface to the outside.

Besides flagella, Pili and Fimbriae are also surface structures of the bacteria but do not play a role in motility. The pili are elongated tubular structures made of a special protein. The fimbriae are small bristle like fibres sprouting out of the cell. In some bacteria, they are known to help attach the bacteria to rocks in streams and also to the host tissues.

9.4.2 Ribosomes and Inclusion Bodies

In prokaryotes ribosomes are associated with the plasma membrane of the cell. They are about 15 nm by 20 nm in size and are made of two subunits - 50S and 30S units which when present together form 70S prokaryotic ribosomes. Ribosomes are the sites of protein synthesis. Several ribosomes may attach to a single mRNA and form a chain called **polyribosomes** or **polysome**. The ribosomes of a polysome translate the mRNA into proteins.

Inclusion bodies: Reserve materials in prokaryotic cells are stored in the cytoplasm in the form of inclusion bodies. These are not bounded by any membrane system and lie free in the cytoplasm, e.g., phosphate granules, cyanophycean granules and glycogen granules. Gas vacuoles are found in blue green, purple and green photosynthetic bacteria.

(a)

(b)

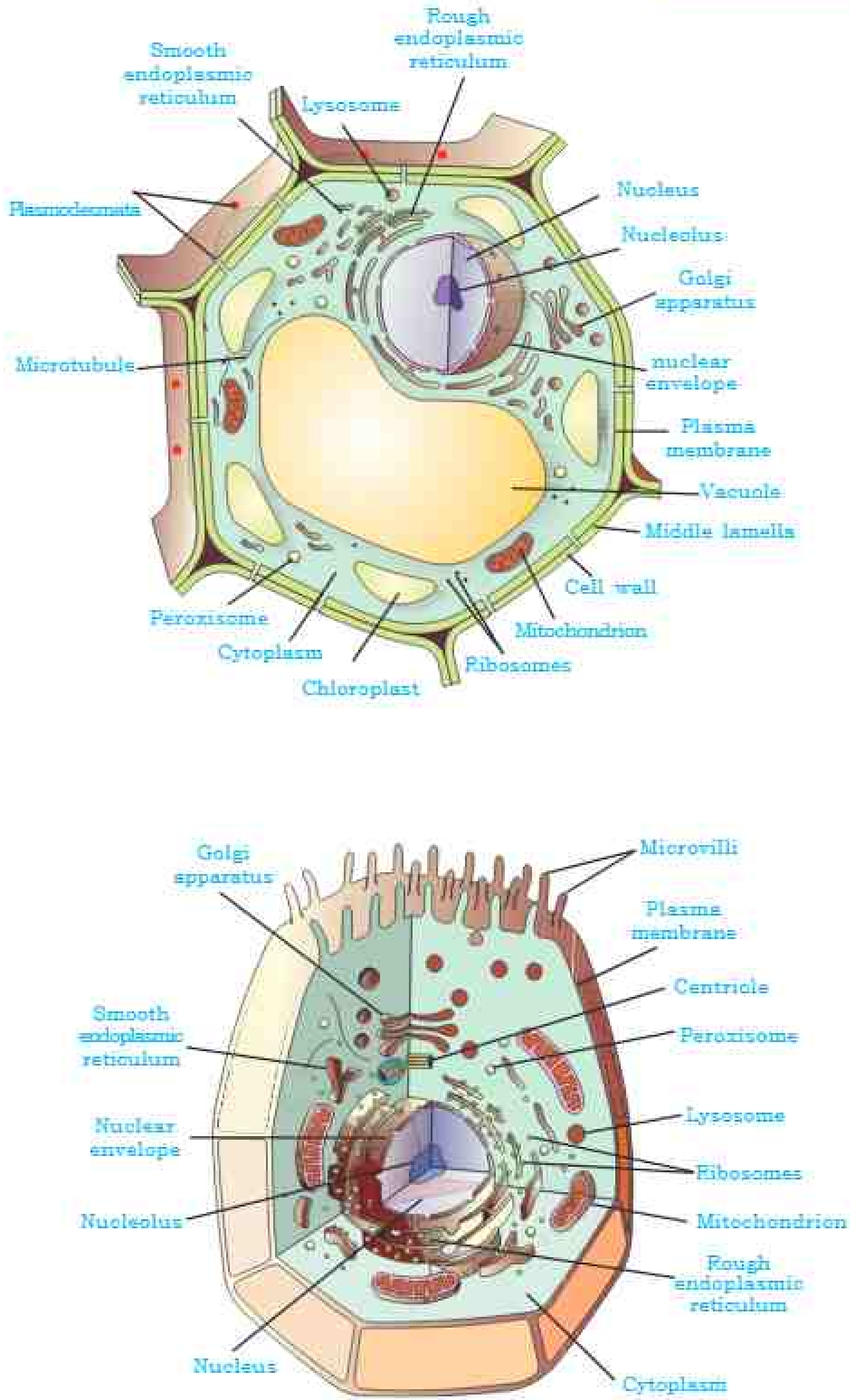


Fig 9.3 : Diagram showing (a) Plant cell (b) Animal cell

9.5 Eukaryotic Cells

The eukaryotes include all the protists, plants, animals and fungi. In eukaryotic cells there is an extensive compartmentalisation of cytoplasm through the presence of membrane bound organelles. Eukaryotic cells possess an organised nucleus with a nuclear envelope. In addition, eukaryotic cells have a variety of complex locomotory and cytoskeletal structures. Their genetic material is organised into chromosomes.

All eukaryotic cells are not identical. Plant and animal cells are different as the former possess cell walls, plastids and a large central vacuole which are absent in animal cells. On the other hand, animal cells have centrioles which are absent in almost all plant cells (Figure 9.3).

Let us now look at individual cell organelles to understand their structure and functions.

9.5.1 Cell Membrane

The detailed structure of the membrane was studied only after the advent of the electron microscope in the 1950s. Meanwhile, chemical studies on the cell membrane, especially in human red blood cells (RBCs), enabled the scientists to deduce the possible structure of plasma membrane.

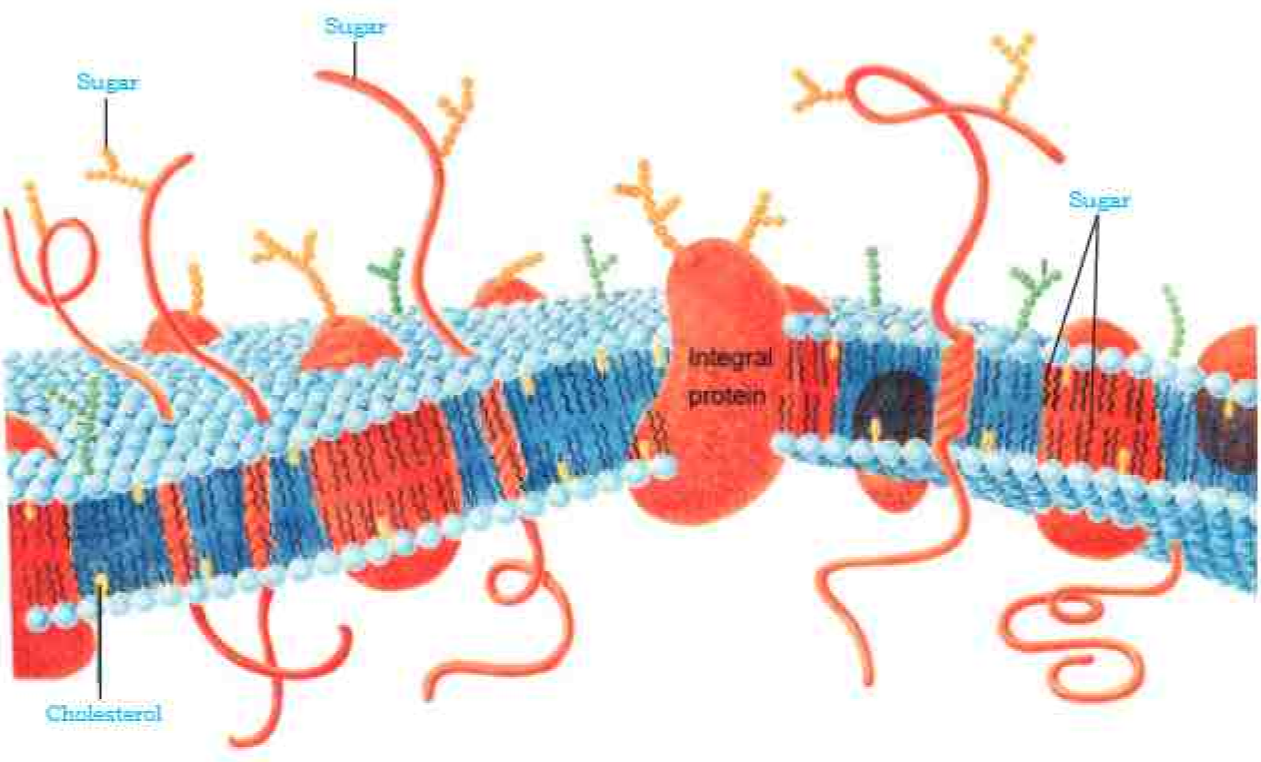


Fig 9.4 : Fluid mosaic model of plasma membrane

These studies showed that the cell membrane is composed of lipids that are arranged in a bilayer. Also, the lipids are arranged within the membrane with the polar (hydrophilic) head towards the outer sides and the hydrophobic tails towards the inner part. This ensures that the nonpolar tail of saturated hydrocarbons is protected from the aqueous environment (Figure 9.4). The lipid component of the membrane mainly consists of phosphoglycerides.

Later, biochemical investigations clearly revealed that the cell membranes also possess protein and carbohydrate. The ratio of protein and lipid varies considerably in different cell types. In human beings, the membrane of the erythrocyte has approximately 52 per cent protein and 40 per cent lipids.

Depending on the location and ease of extraction, membrane proteins can be classified as integral or peripheral. Peripheral proteins lie on the surface of membrane while the integral proteins are partially or totally buried in the membrane.

An improved model of the structure of cell membrane was proposed by Singer and Nicolson (1972) widely accepted as **fluid mosaic model** (Figure 9.4). According to this, the quasi-fluid nature of lipid enables lateral movement of proteins within the overall bilayer. This ability to move within the membrane is understood as its fluidity.

The fluid nature of the membrane is also important for cellular functions like cell growth, formation of intercellular junctions, secretion, endocytosis, cell division etc.

One of the most important functions of the plasma membrane is the transport of the molecules into and out of cells. The membrane is selectively permeable to some molecules present on either side of it. Many molecules can move briefly across the membrane without any requirement of energy and this is called the **passive transport.** Neutral solutes may move across the membrane by the process of simple diffusion along the concentration gradient, i.e., from higher concentration to the lower. Water may also move across this membrane from higher to lower concentration. Movement of water by diffusion across the membrane is called **osmosis**. As the polar molecules cannot pass through the nonpolar lipid bilayer, they require a carrier protein of the membrane to facilitate their transport across the membrane. A few ions or molecules are transported across the membrane through its carrier proteins against their concentration gradient, i.e., from lower to the higher concentration. Such a transport is an energy dependent process, in which ATP is utilised and is called **active transport,** e.g., $Na+/K+$ Pump.

9.5.2 Cell Wall

As you may recall, plant cells can be distinguished from animal cells by the presence of 'cell wall'. It was first observed by Robert Hooke (1665) in cork tissue of

Oak tree. Cell wall is a non-living rigid structure and forms an outer covering for the plasma membrane of fungi and plants. Cell wall not only gives shape to the cell and protects the cell from mechanical damage and infection; it also helps in cell-to-cell interaction and acts as barrier to undesirable macromolecules. Algae have cell wall, made of cellulose, galactans, mannans and minerals like calcium carbonate, while in other plants it consists of cellulose, hemicellulose, pectins and proteins. The cell wall of a young plant cell, the **primary wall** is capable of growth, which gradually diminishes as the cell matures and the secondary wall is formed on the inner (towards membrane) side of the cell. In many plants as the cells mature, the secondary cell wall is formed by the addition of new cell wall materials viz., lignin, suberin, pectin and cutin into cellulose interfibrillar spaces. In some cell types like in xylem, the secondary wall exhibits unthickened areas called pits to support intercellular transport.

The middle lamella is a first formed layer of cell wall and develops from the cell plate during cell division. In a mature plant cell it is the outermost layer of cell wall. It is mainly composed of calcium pectate and holds or glues the different neighbouring cells together. The cell wall and middle lamellae may be traversed by plasmodesmata which connect the cytoplasm of neighbouring cells.

9.5.3 Endomembrane System

While each of the membranous organelles is distinct in terms of its structure and function, many of these are considered together as an endomembrane system because their functions are coordinated. The endomembrane system includes endoplasmic reticulum (ER), golgi complex, lysosomes and vacuoles. Since the functions of the mitochondria, chloroplast and peroxisomes are not coordinated with the above components, these are not considered as part of the endomembrane system.

9.5.3.1 The Endoplasmic Reticulum (ER)

K.R. Porter (1953) first coined (used) the term endoplasmic reticulum to describe thread like structures in the cell. Electron microscopic studies of eukaryotic cells reveal the presence of a network or reticulum of tiny tubular structures scattered in the cytoplasm that is called the endoplasmic reticulum (ER) (Figure 9.5). Hence, ER divides the intracellular space into two distinct compartments, i.e., luminal (inside ER) and extra luminal (cytoplasm) compartments.

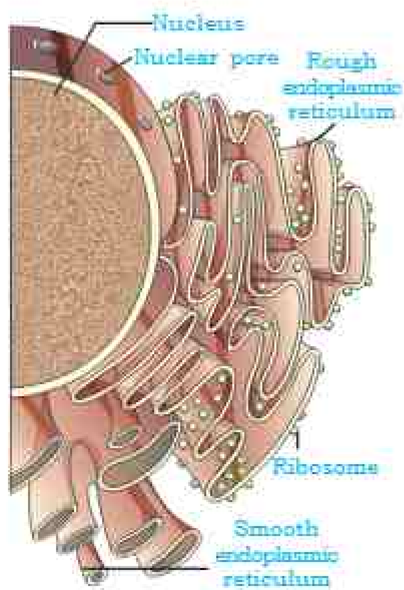


Fig 9.5 : Endoplasmic reticulum

The ER often shows ribosomes attached to their outer surface. The endoplasmic reticulum bearing ribosomes on their surface is called rough endoplasmic reticulum (RER). In the absence of ribosomes, they appear smooth and are called smooth endoplasmic reticulum (SER). RER is frequently observed in the cells actively involved in protein synthesis and secretion. They are extensive and continuous with the outer membrane of the nucleus. The smooth endoplasmic reticulum is the major site for synthesis of lipid. In animal cells, lipid-like steroidal hormones are synthesized in SER.

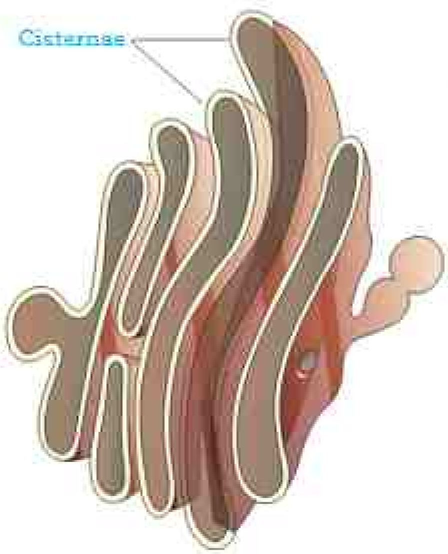


Fig : 9.6 Golgi apparatus

9.5.3.2 Golgi apparatus

Camillo Golgi (1898) first observed densely stained reticular structures near the nucleus. These were later named Golgi bodies after him. They consist of many flat, disc-shaped sacs or cisternae of 0.5μm to 1.0μm diameter (Figure 9.6). These are stacked parallel to each other. Varied number of cisternae are present in a Golgi complex. The Golgi cisternae are concentrically arranged near the nucleus with distinct convex *cis* or the forming face and concave trans or the maturing face. The *cis* and the *trans* faces of the organelle are entirely different, but interconnected.

The golgi apparatus principally performs the function of packaging materials to be delivered either to the intra-cellular targets or secreted outside the cell. Materials to be packaged in the form of vesicles from the ER fuse with the *cis* face of the golgi apparatus and move towards the maturing face. This explains, why the golgi apparatus remains in close association with the endoplasmic reticulum. A number of proteins synthesised by ribosomes on the endoplasmic reticulum are modified in the cisternae of the golgi apparatus before they are released from its *trans* face. Golgi apparatus is the important site of formation of glycoproteins and glycolipids. In plants, golgi apparatus involves in the synthesis of cell wall materials and also plays a role in the formation of cell plate during cell division.

9.5.3.3 Lysosomes

These are membrane bound vesicular structures formed by the process of packaging in the golgi apparatus. The isolated lysosomal vesicles have been found to be very rich in hydrolytic enzymes (hydrolases) capable of digesting carbohydrates, proteins, lipids and nucleic acids (lipases, proteases, carbohydrases, nucleases). These enzymes are optimally active at the acidic pH. Under starvation conditions, lysosomes digest cellular contents by releasing hydrolyzing enzymes and cause death of cells. This is called autolysis.

9.5.3.4 *Vacuoles*

The vacuole is the membrane-bound space found in the cytoplasm and most common to plant cells.. It contains sap mainly composed of water, metabolic bye-products, excretions and other waste materials. In some plant cells, vacuolar sap also contains some pigments like anthocyanin which impart colour to the plant part. The vacuole is bound by a single membrane called tonoplast. In plant cells, the vacuoles can occupy up to 90 per cent of the volume of the cell and play important role in osmoregulation.

In plants, the tonoplast facilitates the transport of a number of ions and other materials against concentration gradients into the vacuole. Hence their concentration is significantly higher in the vacuole than in the cytoplasm.

In *Amoeba* the **contractile vacuole** is important for excretion. In many cells as in protists, **food vacuoles** are formed by engulfing the food particles.

9.5.4 Mitochondria

Mitochondria (sing.: mitochondrion), unless specifically stained, are not easily visible under the microscope. The number of mitochondria per cell is variable depending on the physiological activity of the cells. In terms of shape and size also,

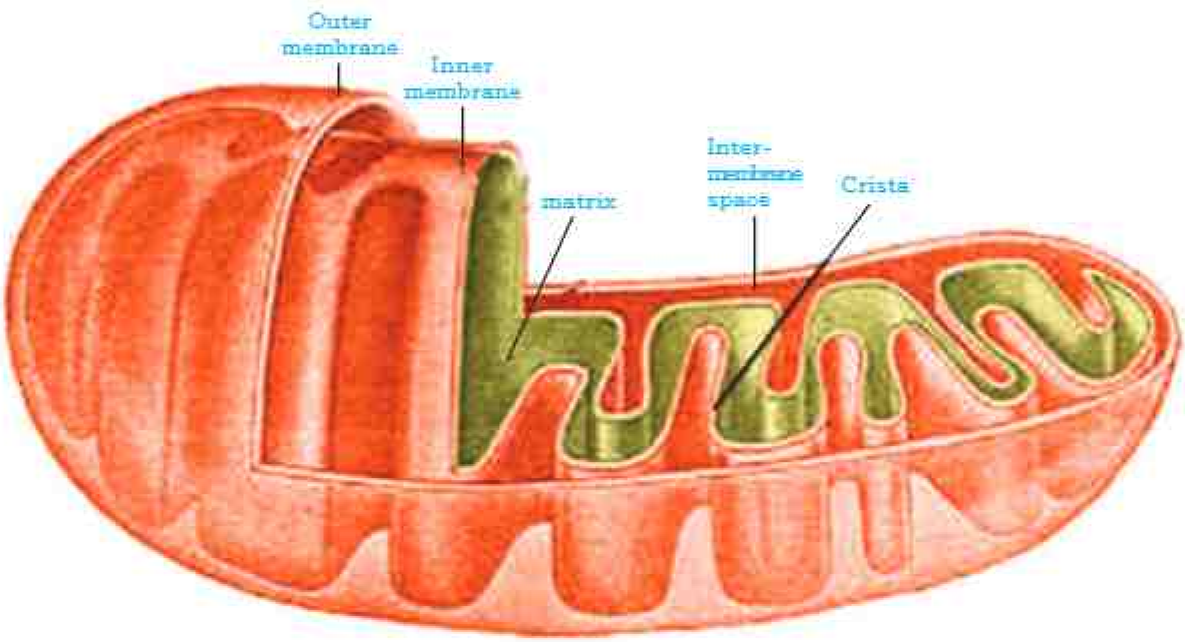


Fig 9.7 : Structure of mitochondrion (Longitudinal section)

considerable degree of variability is observed. Typically it is sausage-shaped or cylindrical having a diameter of 0.2-1.0 µm (average 0.5 µm) and length 1.0-4.1µm. Each mitochondrion is a double membrane-bound structure with the outer membrane and the inner membrane dividing its lumen distinctly into two aqueous compartments, i.e., the outer compartment and the inner compartment. The inner compartment is called the matrix. The outer membrane forms the continuous limiting boundary of the organelle. The inner membrane forms a number of infoldings called the cristae (sing.: crista) towards the matrix (Figure 9.7). The cristae increase the surface area. The two membranes have their own specific enzymes associated with the mitochondrial function. Mitochondria are the sites of aerobic respiration. They produce cellular energy in the form of ATP, hence they are called 'power houses' of the cell. The matrix also possesses single circular DNA molecule, a few RNA molecules, ribosomes (70S) and the components required for the synthesis of proteins. The mitochondria divide by fission.

9.5.5 Plastids

Plastids are found in all plant cells and in euglenoides. These are easily observed under the microscope as they are large. They bear some specific pigments, thus imparting specific colours to the part of the plant which posseses them. Based on the type of pigments plastids, can be classified into chloroplasts, chromoplasts and leucoplasts.

The chloroplasts contain chlorophyll and carotenoid pigments which are responsible for trapping light energy essential for photosynthesis. In the chromoplasts fat soluble **carotenoid** pigments like carotene, xanthophylls and others are present. This gives the part of the plant a yellow, orange or red colour. The leucoplasts are the colourless plastids of varied shapes and sizes with stored nutrients: **Amyloplasts** store carbohydrates (starch), e.g., potato; **elaioplasts** store oils and fats whereas the **aleuroplasts** store proteins.

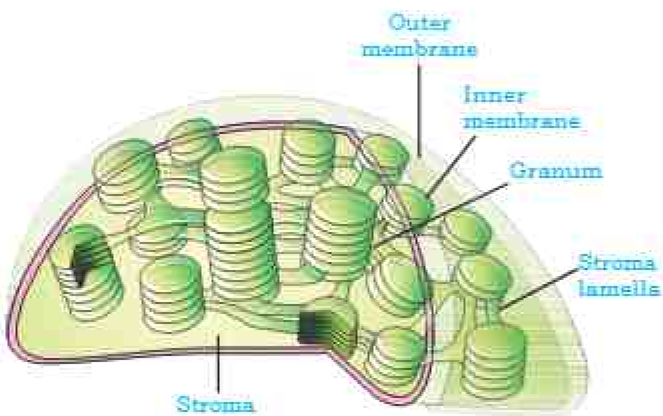


Figure 9.8 : Sectional view of chloroplast

Majority of the chloroplasts of the green plants are found in the mesophyll cells of the leaves. These are lens-shaped, oval, spherical, discoid or even ribbon-like organelles having variable length (5-10µm) and width (2-4µm). Their number varies from 1 per cell of the *Chlamydomonas*, a green alga to 20-40 per cell in the mesophyll.

Like mitochondria, the chloroplasts are also double membrane bound. Of the two, the inner chloroplast membrane is relatively less permeable. The space limited by the inner membrane of the chloroplast is called the stroma. A number of organised flattened membranous sacs called the **thylakoids,** are present in the stroma (Figure 9.8). Thylakoids are arranged in stacks like the piles of coins called grana (singular: granum) or the intergranal thylakoids. In addition, there are flat membranous tubules called the stroma lamellae connecting the thylakoids of the different grana. The membrane of the thylakoids encloses a space called a lumen. The stroma of the chloroplast contains enzymes required for the synthesis of carbohydrates and proteins. It also contains small, double-stranded circular DNA molecules and ribosomes. Photosynthetic pigments are present in the thylakoids. The ribosomes of the chloroplasts are smaller (Prokaryotic, 70S) than the cytoplasmic ribosomes (Eukaryotic, 80S).

9.5.6 Ribosomes

Ribosomes are the granular structures first observed under the electron microscope as dense particles by George Palade (1953). They are composed of ribonucleic acid (RNA) and proteins and are not surrounded by any membrane. The eukaryotic ribosomes are 80S while the prokaryotic ribosomes are 70S. Here 'S' stands for the sedimentation coefficient (expressed in Svedberg unit); it is indirectly a measure of density and size. Both types of ribosomes are composed of larger and smaller subunits. 70S ribosome contains 50s and 30S subunits while the other type contains 60S and 40S subunits. The two subunits in both types of ribosomes associate with each other in the presence of magnesium ions. Ribosomes provide space as well as enzymes for the synthesis of proteins.

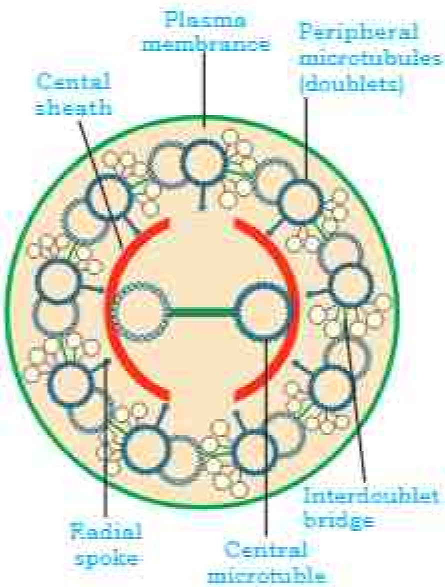
9.5.7 Cytoskeleton

An elaborate network of filamentous proteinaceous structures present in the cytoplasm is collectively referred to as the **cytoskeleton**. Eukaryotic cells contain three major components of cytoskeleton: microfilaments, intermediate filaments and microtubules. The cytoskeleton in a cell is involved in many functions such as mechanical support, maintenance of cell shape, cell motility, intracellular transport, signaling across the cell and karyokinesis (movement of chromosomes during cell division).

9.5.8 Cilia and Flagella

Cilia (sing.: cilium) and flagella (sing.: flagellum) are hair-like outgrowths of the cell membrane. Cilia are small structures which work like oars, causing the movement of either the cell or the surrounding fluid. Flagella are comparatively longer and responsible for cell movement. The prokaryotic bacteria also possess flagella but

(a)



(b)

Fig 9.9 Section of cilia/ flagella showing different parts:
(a) Electron micrograph
(b) Diagrammatic representation of internal structure

these are structurally different from that of the eukaryotic flagella.

The electron microscopic study of a cilium or the flagellum shows that they are covered with plasma membrane. Their core called the **axoneme,** possesses a number of microtubules running parallel to the long axis. The axoneme usually has nine pairs of doublets of radially arranged peripheral microtubules, and a pair of centrally located microtubules. Such an arrangement of axonemal microtubules is referred to as the 9+2 array (Figure 9.9). The central tubules are connected by bridges and are also enclosed by a central sheath, which is connected to one of the tubules of each peripheral doublet by a radial spoke. Thus, there are nine radial spokes. The peripheral doublets are also interconnected by linkers. Both the cilium and flagellum emerge from centriole-like structure called the basal bodies.

9.5.9 Centrosome and Centrioles

Centrosome is an organelle usually containing two cylindrical structures called centrioles. They are surrounded by amorphous pericentriolar materials. Both the centrioles in a centrosome lie perpendicular to each other in which each has an organisation like the cartwheel. They are made up of nine evenly spaced peripheral fibrils of tubulin. Each of the peripheral fibril is a triplet. The adjacent triplets are also linked. The central part of the centriole is also proteinaceous and called the **hub**, which is connected with tubules of the peripheral triplets by radial **spokes** made of protein. The centrioles form the basal body of cilia or flagella, and spindle fibres that give rise to spindle apparatus during cell division in animal cells.

9.5.10 Nucleus

Nucleus as a cell organelle was first described by Robert Brown as early as 1831. Later the material of the nucleus stained by the basic dyes was given the name **chromatin** by Flemming. The interphase nucleus (nucleus of a cell when it is not dividing) has highly extended and elaborate nucleoprotein fibres called chromatin, nuclear matrix and one or more spherical bodies called **nucleoli** (sing.: nucleolus) (Figure 9.10). Electron microscopy has revealed that the nuclear envelope, which consists of two parallel membranes with a space between (10 to 50 nm) called the **perinuclear space**, forms a barrier between the materials present inside the nucleus and that of the cytoplasm. The outer membrane usually remains continuous with the endoplasmic reticulum and also bears ribosomes on it.

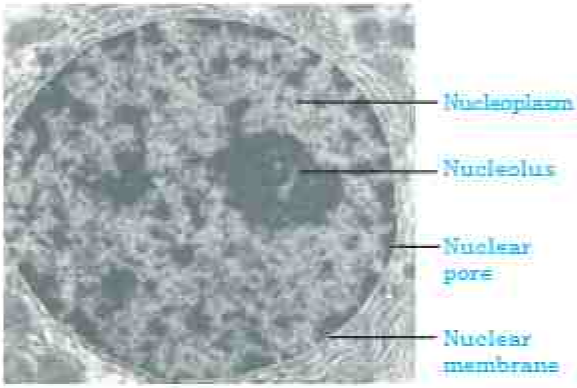


Fig 9.10 : Structure of nucleus

At a number of places the nuclear envelope is interrupted by minute pores, which are formed by the fusion of its two membranes. These nuclear pores are the passages through which movement of RNA and protein molecules takes place in both directions between the nucleus and the cytoplasm. Normally, there is only one nucleus per cell; variations in the number of nuclei are also frequently observed. *Can you recollect names of organisms that have more than one nucleus per cell?* Some mature cells even lack nucleus, e.g., erythrocytes of many mammals and sieve tube cells of vascular plants. *Would you consider these cells as 'living'?*

The nuclear matrix or the **nucleoplasm** contains nucleolus and chromatin. The nucleoli are spherical structures present in the nucleoplasm. The content of nucleolus is continuous with the rest of the nucleoplasm as it is not a membrane bound structure. It is a site for active ribosomal RNA synthesis. Larger and more numerous nucleoli are present in cells actively carrying out protein synthesis.

You may recall that the interphase nucleus has a loose and indistinct network of nucleoprotein fibres called chromatin. But during different stages of cell division, cells show structured **chromosomes** in place of the nucleus. Chromatin contains DNA and some basic proteins called **histones**, some non-histone proteins and also RNA. A single human cell has approximately two metre long thread of DNA distributed among its forty six (twenty three pairs) chromosomes.

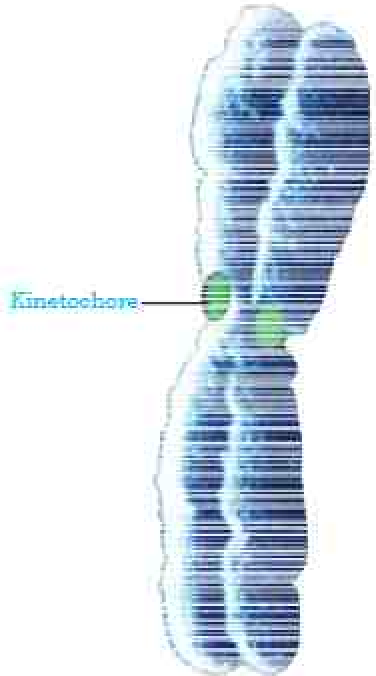


Fig 9.11 : Choromosome with kinetochore

Every chromosome essentially has a primary constriction or the **centromere** on the sides of which disc shaped structures called **kinetochores** are present (Figure 9.11). Based on the position of the centromere, the chromosomes can be classified into four types (Figure 9.12). The **metacentric** chromosome has middle centromere forming two equal arms of the chromosome. The **sub-metacentric** chromosome has centromere nearer to one end of the chromosome resulting into one shorter arm and one longer arm. In case of **acrocentric** chromosome the centromere is situated close to its end forming one extremely short and one very long arm, whereas the **telocentric** chromosome has a terminal centromere.

Sometimes a few chromosomes have non-staining secondary constrictions at a constant location. This gives the appearance of a small fragment called the **satellite**.

When viewed under electron microscope, chromatin appears as "beads-on-string". The beads are now known as "nucleosomes". A typical nucleosome contains 200 bp of DNA double helix wrapped (two turns) around a core of histone octamer having two copies of each of four types of histone proteins viz., H2A, H2B, H3 and H4. H1 histone molecule lies outside the nucleosome core and seals the two turns of DNA by binding at the point where DNA enters and leaves the core. The DNA that

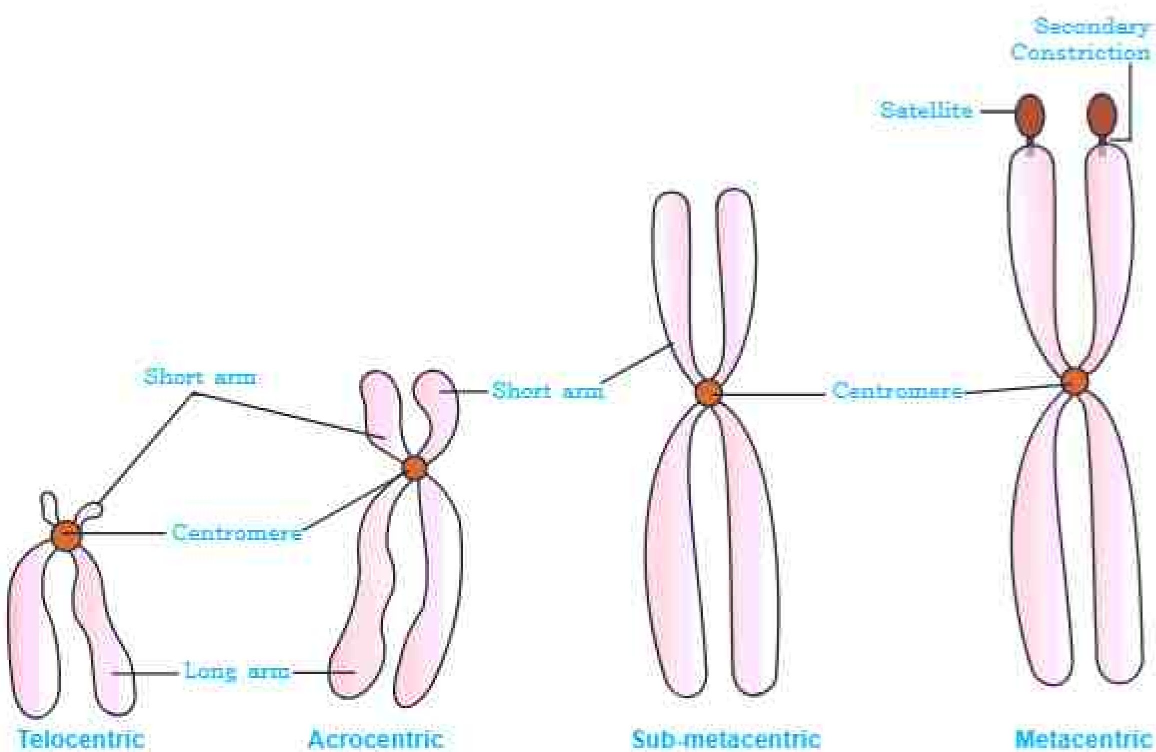


Fig 9.12 : Types of choromosomes based on the position of centromere

continues between two successive nucleosomes is called linker DNA (Figure 9.13). The association between negatively charged DNA and positively charged histones allows for meaningful DNA packaging inside the nucleus. The beads-on-string structure in chromatin is packaged to form chromatin fibres that are further coiled and condensed to form the chromosomes.

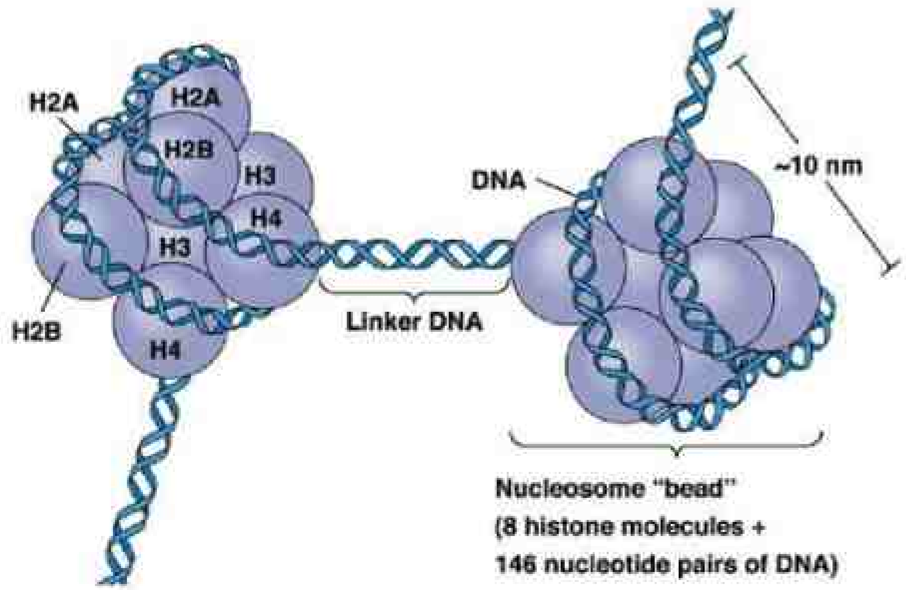


Figure 9.13 Nucleosome model

9.5.11 Microbodies (Peroxysomes and Glyoxysomes)

Peroxysomes and glyoxisomes are often called microbodies. These are spherical membrane bound minute organelles more commonly found in plant cells. Peroxysomes are involved in the catabolism of long chain fatty acids and play important role in the synthesis of phospholipids. Other known peroxisomal function includes the involvement in photorespiration and protection of cells from toxic effects of hydrogen peroxide. Glyoxysomes are generally found in fat rich germinating seeds (Castor) and these contain the enzymes of glyoxylate cycle which convert stored lipids to carbohydrates.

SUMMARY

All organisms are made of cells or aggregates of cells. Cells vary in their shape, size and activities/functions. Based on the presence or absence of a membrane bound nucleus and other organelles, cells and hence organisms can be named as eukaryotic or prokaryotic.

A typical eukaryotic cell consists of a cell membrane, nucleus and cytoplasm. Plant cells have a cell wall outside the cell membrane. The plasma membrane is selectively permeable and facilitates transport of several molecules. The endomembrane system includes ER, golgi complex, lysosomes and vacuoles. All the cell organelles perform different but specific functions. Centrosome and centriole form the basal body of cilia and flagella that facilitate locomotion. In animal cells, centrioles also form spindle apparatus during cell division. Nucleus contains nucleoli and chromatin network. It not only controls the activities of organelles but also plays a major role in heredity.

Endoplasmic reticulum contains tubules or cisternae. They are of two types: rough and smooth. ER helps in the transport of substances, synthesis of proteins, lipoproteins and glycogen. The golgi body is a membranous organelle composed of flattened sacs. The secretions of cells are packed in them and transported from the cell. Lysosomes are single membrane structures containing enzymes for digestion of all types of macromolecules. Ribosomes are involved in protein synthesis. These occur freely in the cytoplasm or are associated with ER. Mitochondria help in oxidative phosphorylation and generation of adenosine triphosphate. They are bound by double membrane; the outer membrane is smooth and inner one folds into several cristae. Plastids are pigment containing or nutrient storing organelles found in plant cells only. In plant cells, chloroplasts are responsible for trapping light energy essential for photosynthesis. The grana, in the plastid, is the site of light reactions and the stroma for biosynthetic phase of photosynthesis. The green coloured plastids are chloroplasts, which contain chlorophyll, whereas the other coloured plastids are chromoplasts, which may contain other pigments like carotene and xanthophyll. The nucleus is enclosed by nuclear envelope, a double membrane structure with nuclear pores. The inner membrane encloses the nucleoplasm and the chromatin material. Nucleosomes, the basic structural units, are packed into chromatin fibers that are in turn coiled and condensed to form chromosome. Thus, cell is the structural and functional unit of life.

GLOSSARY

Active transport: Transmembrane transport requiring energy mostly as ATP.

Antibiotics: Antimicrobial substances produced by some microbes.

Axoneme: The core part of a cilium or flagellum that consists of microtubules in a typical 9+2 array.

Carotenoids: Terpenoid pigments abundant in chromoplasts that impart yellow, orange or red colour.

Cell organelles: Membrane bound or unbound structures found in the cytoplasm of cells.

Chromatin: Thread like coloured material of the eukaryotic nucleus.

Cytoskeleton: Elaborate network of filamentous proteinaceous structures found in the cytoplasm of eukaryotic cells.

Glycocalyx: A layer outside bacterial cell wall usually made of polysaccharides.

Histones: Basic proteins associated with DNA.

Kinetochore: Disc shaped structures located in the centromeric part of the chromosome.

Mesosome: Membrane infolding in some bacteria that helps in cell wall formation and DNA replication.

Passive transport: Transmembrane transport not requiring energy i.e., Movement down the concentration gradient.

Plasmids: Small circular DNA found outside genomic DNA in many bacteria.

Satellite: A round terminal part of the chromosome present beyond the secondary constriction in some chromosomes.

Endomembrane System: A group of cell organelles with coordinated functions (ER, Golgi, lysosomes and vacuoles).

Thylakoids : Flattened membranous sacs present inside chloroplasts.

VERY SHORT ANSWER TYPE QUESTIONS

1. What is the significance of vacuole in a plant cell ?
2. What does 'S' refer in a 70S & and 80S ribosome ?
3. Mention a single membrane bound organelle which is rich in hydrolytic enzymes.
4. What are gas vacuoles ? State their functions ?
5. What is the function of a polysome ?
6. What is the feature of a metacentric chromosome ?
7. What is refered to as satellite chromosome ?
8. What are microbodies ? What do they contain ?
9. What is middle lamella made of ? What is its functional significance ?
10. What is osmosis ?
11. Which part of the bacterial cell is targeted in gram staining ?
12. Which of the following is not correct?
    (a) Robert Brown discovered the cell.
    (b) Schleiden and Schwann formulated the cell theory.
    (c) Virchow explained that cells are formed from pre-existing cells.
    (d) A unicellular organism carries out its life activities within a single cell.

13. New cells generate from
    (a) bacterial fermentation
    (b) regeneration of old cells
    (c) pre-existing cells
    (d) abiotic materials
14. Match the following

(a) Cristae	(i) Flat membranous sacs in stroma
(b) Cisternae	(ii) Infoldings in mitochondria
(c) Thylakoids	(iii) Disc-shaped sacs in Golgi apparatus

15. Which of the following is correct:
    (a) Cells of all living organisms have a nucleus.
    (b) Both animal and plant cells have a well defined cell wall.
    (c) In prokaryotes, there are no membrane bound organelles.
    (d) Cells are formed *de novo* from abiotic materials.

SHORT

7. What are plasmids? Describe their role in bacteria ?
8. What are histones? What are their functions?
9. What is Cytoskeleton? What functions is it involved in?
10. What is endomembrane system? What cell organelles are not included in it? Why?
11. Distinguish between active transport and passive transport.
12. What are mesosomes? What do they help in?
13. What are nucleosomes ? What are they made of ?
14. How do neutral solutes move across the plasma membrane? Can the polar molecules also move across it in the same way? If not, then how are these transported across the membrane?
15. Name two cell-organelles that are double membrane bound. What are the characteristics of these two

systems.Anatomy of Dicotyledonous and Monocotyledonous plants - Root, Stem and Leaf.Secondary growth in Dicot stem and Dicot root.	
UNIT-VII: PLANT ECOLOGY **Chapter 13 : Ecological Adaptations, Succession and Ecological Services** Introduction.Plant communities and Ecological adaptations: Hydrophytes, Mesophytes and Xerophytes. Plant succession.Ecological services – Carbon fixation, Oxygen release and pollination (in brief).	**12**

BOARD OF INTERMEDIATE EDUCATION, A.P, HYDERABAD

MODEL QUESTION PAPER

Time : 3 hrs] [Max Marks : 60

SECTION – A (10 X 2 = 20)

Answer all the questions (Very short answer type)

1. What is growth? What is the difference between the growth in living organisms and growth in non-living objects?
2. What is the principle underlining the use of cyanobacteria in agriculture fields for crop improvement?
3. Mention the ploidy of the following?
   (a) Leaf cell of a moss
   (b) PEN in a dicotyledon
   (c) Meristen cell of monocot
   (d) Gemma cell in Marchantia
4. Why certain fruits are called false fruits? Name two examples of plants having false fruits?
5. What is the Morphology of cup like structure in cyathium? In which family it is found?
6. Explain the scope and significance of 'Numerical Taxonomy'?
7. What are microbodies ? What do they contain?
8. Glycine and Alanine are different with respect to one substituent on the α – carbon. What are the other common substituent groups?
9. Assume that the average duplication time of E. coli is 20 minutes. How much time will two E. coli cells take to become 32 cells ?
10. Climax stage is achieved quickly in secondary succession as compared to primary succession. why ?

SECTION – B (4 X 6 = 24)

Answer any six questions (Short answer type)

11. Explain in brief the scope of Botany in relation to agriculture, Horticulture and medicine?
12. Give the salient features and importance of chrysophytes ?
13. Give a brief account on the phases of the life cycle of an angiosperm plant ?
14. Describe essential floral parts of plants belonging to Liliaceae ?
15. Describe centrosome ?
16. Though redundantly described as a resting phase, interphase does not really involve rest. Comment?
17. A transverse section of the trunk of a tree shows concentric rings which are known as annual rings. How are these rings formed ? What is the significance of these rings ?
18. Define plant succession. Differentiate primary and secondary successions?

SECTION – C (2 X 8 = 16)

Answer any two questions (Long answer type)

19. Explain how stem is modified variously to perform different functions?
20. Describe the process of fertilization in angiosperms ?
21. Describe the internal structure of dorsiventral leaf with the help of a labeled diagram?

Botany I Year - Revised Questions

UNIT	Chapter	VSAQ		SAQs		LAQs		Remarks
		Deleted	Added	Deleted	Added	Deleted	Added	
I	1. The Living World	–	–	–	–	–	–	No change
	2. Biological Classification	–	–	–	–	–	–	No change
	3. Science of Plants Botany	–	–	–	–	–	–	No change
	4. Plant Kingdom	–	–	–	–	–	–	No change
II	5. Morphology of Flowering Plants	Q.No. 25, 26	–	–	–	–	–	
III	6. Modes of Reproduction	–	–	–	1. Describe briefly the somatogenetic with suitable example 2. Describe sexuality in living organisms	Q.No. 2		

Botany I Year - Revised Questions

UNIT	Chapter	VSAQ		SAQs		LAQs		Remarks
		Deleted	Added	Deleted	Added	Deleted	Added	
	7. Sexual reproduction in flowering plants	Q. 20	1. What is meant by scutellum? in which type of seeds it is present? 2. Define with examples endospermic and non-endospermic seeds	Q.No. 3 & 4	1. Describe briefly different types of pollination			
IV	8. Taxonomy of Angiosperms	–	–	–	–	–	–	No changes
V	9. The unit of life			Q.No. 1, 2, 17 & 19	1. Describe the cell-organalle that contain chlorophyll 2. Describe the structure and function of cell ortganalle that can be considered as power house of the cell 3. Describe the structure of nucleus			

Botany I Year - Revised Questions

UNIT	Chapter	VSAQ		SAQs		LAQs		Remarks
		Deleted	Added	Deleted	Added	Deleted	Added	
V	10. Biomolecules	–	1. What are primary and secondary metabolites. Give examples	Q.No. 2, 6	1. Write a brief account on polysaccharides	–	–	
VI	11. Cell Cycle and Cell Division	Q.No. 18, 20, 21			1. Replace with Q.(3) - describe the events of prophase-I 2. Replace with Q.(4) - Mention the significance of meiosis			
VII	12. Histology and anatomy of Flowering plants	–	–	–	–	–	–	No change
	13. Ecological adoptation succession & ecological services	–	–	–	–	–	–	No change