BIOLOGICAL SCIENCE

BOTANY BRIDGE COURSE

INDEX

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.

1.1.1 Characters of living organisms

1.1.1.1 Growth : All living organisms grow in two ways i) Increase in mass ii) increase in number of individuals.

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. Non living objects exhibit growth by accumulation of materials on the surface. In living organisms growth is from inside. Therefore growth cannot be taken as defining property of living organisms. A dead organism does not grow.

1.1.1.2. Metabolism: All living organisms are made of chemicals. These chemicals 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 living organism is called Metabolism. All plants, animals, fungi and microbes exhibit metabolism. But non-living objects does not exhibit metabolism. So, metabolism is a defining feature of all living organisms without exception.

1.1.1.3. Reproduction: It is one of the characteristic of living organisms. In multicellular organisms, reproduction refers to the production of progeny, the features are more or less similar to those of parents. Organisms reproduce sexually and by asexual means also. Lower

organisms like *yeast* and *Hydra* reproduce by budding. The fungi, the filamentous algae, the protonema of masses, all easily reproduce 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. Further there are many organisms which do not reproduce (sterile worker bees, infertile human couples, Mules, etc.,). Hence reproduction also cannot be an all-inclusive defining characteristic of living organisms. Of course, no non-living object is capable of reproduction.

1.1.1.4. Ability to sense: The most obvious and technically complicated feature of all living organisms is the ability to sense their surroundings and response to these environmental stimuli which could be physical, chemical or biological. This response to the 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 and 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.

1.1.1.5. Interactions: 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 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 organizational 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 visit 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 the earth. We should remember here that as we explore new areas and even old ones, new organisms are continuously being identified.

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.

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 the organisms to sense the surroundings.

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

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.

Metabolism : It refers to the sum total of all the chemical reactions occurring in the body of an organism.

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

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

Spore: It is an asexual unicellular reproductive unit which directly develops into 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.

VERY SHORT ANSWER TYPE QUESTIONS

1. Why are living organisms classified?

2. What is growth?

3. Define metabolism.

4. What is Biodiversity?

5. What is irritability?

6. Differentiate between meiospores and mitispores.

SHORT ANSWER TYPE QUESTIONS

1. What is meant by living? Write any three defining features of living forms.

EXERCISES

1. What are the distinctive characteristics exhibited by living organisms? Discuss them in brief.
2. Life forms exhibit 'Unity in diversity'. Discuss with teacher.

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 the plants in to trees, shrubs and herbs. He also divided the animals into two groups, those which had red blood and those did not.

2.1 TWO KINGDOM CLASSIFICATION

In Linnaeus time a **Two kingdom system** of classification with Plantae and Animalia kingdoms was developed that included all plants and animals respectively. This system did not distinguish between the eukaryotes and prokaryotes, unicellular and multicellular organisms and photosynthetic 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 cell wall in their cells. This placed together groups which widely differed in other characteristics. It brought together the prokaryotic bacteria and the *blue green algae* with other groups which are eukaryotic. It also grouped together the unicellular organisms and the multicellular ones, say, for example *Chlamydomonas* and *Spirogyra* were placed together under algae. The classification did not differentiate the heterotrophic fungi and the autotrophic green plants. Hence the Two kingdom classification used for a long time was found inadequate.

2.2 FIVE KINGDOM CLASSIFICATION

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 (*Chalmydomonas*, *Chlorella*, *Paramoecium* and *Amoeba* (earlier they were placed under plant and animal kingdoms respectively). The fungi were placed in a separate kingdom.

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	Multicellular/ loose tissue	Tissue/organ	Tissue/ organ/ organ system
Mode of nutrition	Autotrophic (chemosynthetic and photosynthetic) and heterotrophic (saprophytic/ parasitic)	Autotrophic (Photosynthetic) and Heterotrophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosyn-thetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

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 kingdom 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.

2.2.1 KINGDOM MONERA

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

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2.2.1.1 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. It contains pseudomurein instead of peptidoglycon. 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.

2.2.1.2 Eubacteria: Eubacteria are the most abundant micro-organisms. They occur almost every where. Many of them live in or on other organisms as parasites and some are symbionts. Based on the shape, bacteria are grouped under categories**.** The spherical **Coccus (pl: Cocci),** the rod shaped **Bacillus** (Pl: Bacilli), the coma shaped **Vibrium** (pl: Vibrio) and spiral shaped **Spirillum** (pl: Spirilla) (Fig2.1).

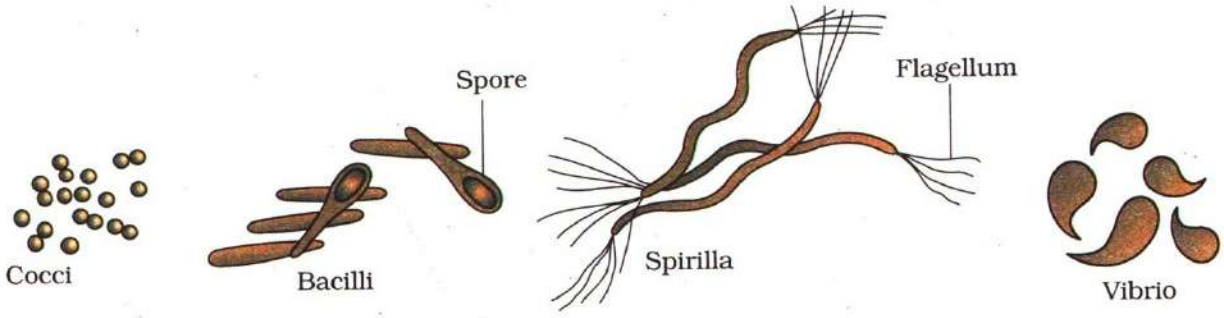


Figure 2.1 Bacteria of different shapes

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 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 behaviour. Some of the bacteria are **Autotrophs** i.e., they synthesize their own food from simple inorganic substrates. They may be photoautotrophs or chemoautotrophs. The vast majority of bacteria are **heterotrophs** i.e., they do not synthesize their own food and depend on other organisms (**parasites**) or on dead organic matter (**saprophytes or decomposers**) for food. They are helpful in making curd from milk, production of antibiotics and nitrogen fixation in legumes. Reproduce mainly by **fission,** under unfavourable conditions,

they produce **spores.** They also reproduce by a sort of sexual reproduction by adopting a primitive type of DNA transfer from one bacterium to the other.

Cyanobacteria: They are also called **blue green algae.** They 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. Some of these organisms can fix atmospheric nitrogen in specialised cells called **heterocysts.** e.g., *Nostoc* and *Anabaena*.

2.2.1.3 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 plants and animals. They were previously called pleuroneumonia like organisms. They causes **witches broom** in plants and **pleuro pneumonia** in cattle and **mycoplasmal urethritis** in humans.

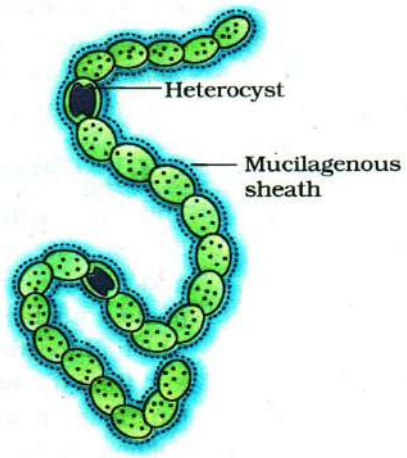


Figure 2.2 A filamentous blue-green algae – *Nostoc*

2.2.1.4 Actinimycetes

The **actinomycetes** are branched filamentous bacteria which form radiating colonies in culture. Most of them are saprophytic and decomposers. Some are parasites as in *Mycobacterium* and *Corynebacterim*. A number of antibiotics are produced by actinomycetous members especially the genus ***Streptomyces*.**

2.2.2 KINGDOM PROTISTA

All single celled eukaryotes are placed under Protista, but the boundaries of this kingdom are not well defined. 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 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.

2.2.2.1 Chrysophytes

This group includes Diatoms and Desmids (golden algae). They are found in fresh water as well as in marine water. 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 fit together as in a soap box. The walls are embedded with silica. The diatoms left behind large amount of cell walls in their habitat; this accumulation over billions of years referred to as **'diatomaceous earth' or 'kieselghur'**.

Uses: Diatoms are the chief producers in the oceans. Kieselghur is used in filtration of oils and syrups and used as polishing agents.

2.2.2.2 Dinoflagellates

These organisms are mostly marine and photosynthetic. They appear yellow, green, blue, brown 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. 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 show Bioluminescence (*Noctiluca*). The red dinoflagellate like *Gonyaulax* undergo such rapid multiplication that they make the sea appear red (red tides in Mediterranean sea). Toxins released by such large numbers may even kill other marine animals such as fishes.

2.2.2.3 Euglenoids

Majority of them are **fresh water organisms** found in stagnant water. Instead of 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. On the membrane of the reservoir a photosensitive stigma or eye spot is present. Though they are photosynthetic in the presence of sunlight, when deprived of sunlight they behave like heterotrophs by predating on other smaller organisms. E.g: Euglena.

2.2.2.4 Slime moulds

Slime moulds are saprophytic protists. The multinucleated mass of protoplasm is surrounded by a plasmamembrane. 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, it differentiates and forms **fruiting bodies** bearing spores at their tips. The spores are extremely resistant and survive for many years, even under adverse conditions. The spores are dispersed by air currents.

2.2.2.5 Protozoans

All protozoans are heterotrophs and live as predators or parasites. They are believed to be primitive relatives of animals. They do not contain cell wall. The protoplasm is surrounded by plasma membrane. There are four major groups of protozoans. They are Amoeboid protozoans (Amoeba), flagellated protozoans (Trypanosoma), Ciliated protozoans (Parmoecium) and sporozoans (Plasmodium).

2.2.3 KINGDOM FUNGI

The fungi constitute a unique kingdom of heterotrophic organisms. They show a great diversity in morphology and habitat. Fungi are cosmopolitan and occur in air, water, soil and on animals and plants. When the bread develops a mould or the orange rots it is because of fungi. The common edible mushroom is also a fungi. (Fig. 2.5). 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 of the fungi are source of antibiotics. e.g., *Penicillium.*

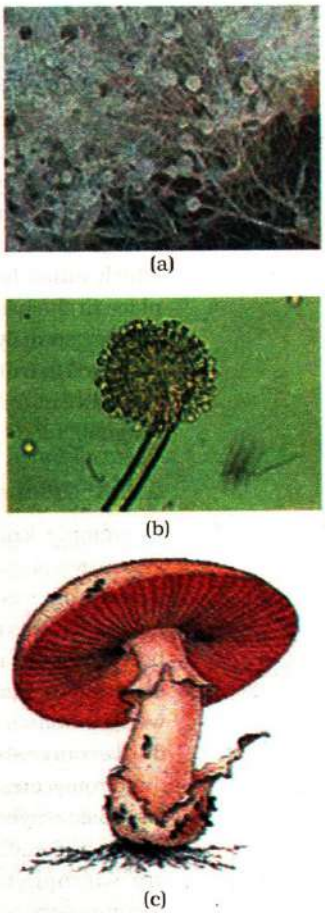


Figure 2.5 Fungi: (a) *Mucor* (b) *Aspergillus* (c) *Agaricus*

The fungi are filamentous with the exception of yeasts which are unicellular. Their bodies consists of long, slender, thread -like structures called **hyphae**. The net work of hyphae is known as **mycelium**. Some hyphae are continuous tubes filled with multinucleated cytoplasm-these are called coenocytic hyphae. Others have cross walls or septae in their hyphae. The cell walls of fungi are composed of **chitin** and 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 the roots of higher plants as **mycorrhizae**.

Reproduction in fungi can takes place by vegetative means - fragmentation, fission and budding. Asexual reproduction is by spores called conidia or zoospores or sporangiospores and sexual reproduction is by oospores, ascospores and basidiospores. The various spores are produces in distinct structures called fruiting bodies. The sexual cycle involves 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 mycelium, mode of spores formation and fruiting bodies form the basis for the division of the kingdom into various classes viz., Phycomycetes (*Rhizopus* and *Albugo*), Ascomycetes (*Yeast* and *penicillium*), Basidiomycetes (*Agaricus* and *Puccinia*), Deuteromycetes (*Trichoderma* and *Colletotrichum*).

2.2.4 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.

2.2.5 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.

2.2.6 VIRUSES, VIROIDS AND PRIONS

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

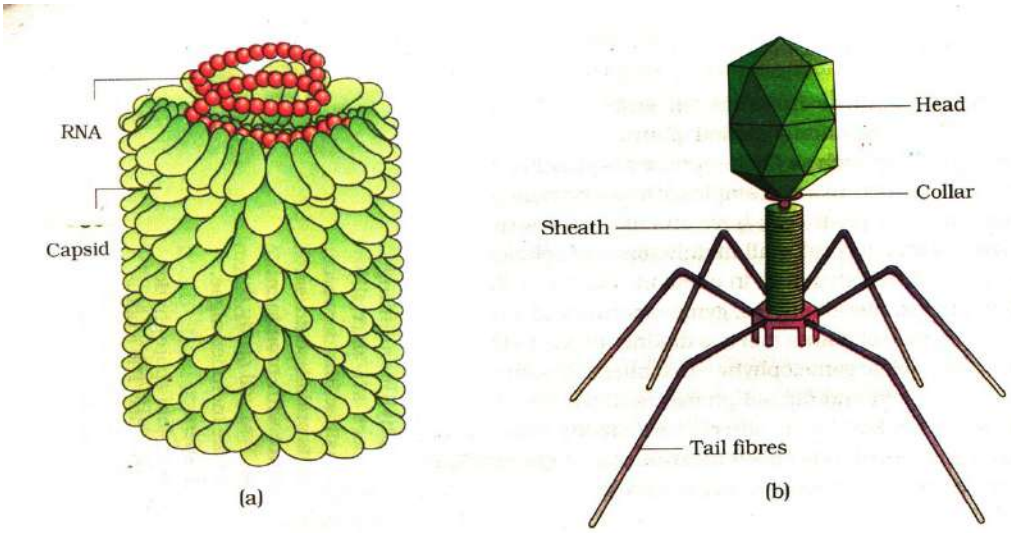


Figure 2.6 (a) Tobacco Mosaic Virus (TMV) (b) Bacteriophage

2.2.6.1 Viruses

These did not find in any 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. RNA containing viruses are Tobacco mosaic virus (TMV) (Fig. 2.6 a)and Human Immuno Virus (HIV). Virus which infect bacteria are called bacteriophages (Fig. 2.6 b) and contain DNA as their genetic material.

2.2.6.2 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.

2.2.6. 3 Prions

These 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'.

SUMMARY

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

GLOSSARY

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

Aplanospore: A non-motile, thin walled spore.

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

Biogas: It is produced by anaerobic fermentation of biomass like dung of animals.

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) organised 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.

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

Holophytic nutrition: It is obtaining nourishment by the ingestion of solid organic 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.

Parasites: They depend on other organisms for food.

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

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

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

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

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 adopted for dispersal and surviving for extended periods of time in unfavourable conditions.

Tree: It is a large woody perennial plant.

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

VERY SHORT ANSWER TYPE QUESTIONS

1. How are viroids different from viruses?
2. Who proposed five kingdom Classification?
3. Name two diseases caused by Mycoplasmas.
4. State two economically important uses of Bacteria.

SHORT ANSWER TYPE QUESTIONS

1. Write the role of fungi in our daily life?
2. Give the salient features and importance of chrysophytes.
3. Give a brief account of Dinoflagellates.

EXCERCISES

1. Biological classification of plants and animals was first proposed by

(A) Aristotle (B) Linnaeus (C) Whittaker (D) Bentham and Hooker

2. Five kingdom classification was based on

(A) Cell structure (B) Thallus organisation (C) Mode of Nutrition (D)All of the above

3. The Smallest living organism with cell wall belong to

(A) Mycoplasma (B) Slime mould (C) Cyanobacteria (D) Bacteria

4. Which type of bacteria are responsible for production of biogas?

(A) Halophiles (B) Thermoacidophiles (C) Methanogens (D) BGA

5. *Nostoc* and *Anabaena* can fix atmospheric nitrogen in specialised cells known as _____

References :

NCERT BOOK

BIO NEET - Hariom Gangwar

CHAPTER 3

SCIENCE OF PLANTS - BOTANY

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 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 in 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, clothes 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 (Heiroglyphics). By 2000B.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. **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**.

During the Renaissance period of **16th and 17th centuries**, the period of herbalists, experimental studies on plants living in natural surroundings had acquired significance. Herbalists identified and described medicinal plants in their books called **herbals**. During this period **Gaspard Bauhin** (1623) published 6000 plants introducing Binomial Nomenclature for

the first time. Biology emerged as a science during 17th**century. Robert Hooke** discovered the cell and 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 Malphighi.**

In 18th **century**, there was a progress in the areas of Taxonomy and Physiology. The Sweedish Botanist **Carolus Von Linnaeus** popularized the **Binomial Nomenclature** System and also proposed the **Sexual system of Classification**. During this period, physiologist **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 19th Century, there was a considerable progress in different branches of Botany. **Gregor Johann Mendel** (Czechoslovakia) marked the beginning of Genetics. He conducted Hybridization experiments on pea plants and introduced the 'Laws of inheritance' (1866), became popular as the 'Father of Genetics'. Ecological studies began with the works of scientists like **Haeckel** and others. **Decandolle, Endlicher, Bentham and Hooker** were famous taxonomist proposed different types of classifications.

During 20th **century,** rapid development in Botany, particularly in Cell Biology, discoveries or innovations viz., mutations in plants by **Hugo de vries** (1901); role of **chromosomes** in heredity by **Sutton** 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 gene by **H.G. Khorana**; technique of tissue culture by **Hanning, Shimakura, Skoog, White, Nitsch, Maheswari** and **electron microscope** was invented by **Knoll** and **Ruska** during this century. Twentieth centuary also witnessed great advances in Plant Physiology; identification of Auxins by **Went**, discovery of citric acid cycle by **Hans Krebs**, crystalization of the enzyme Urease by **J.B. Sumner**, light reaction of photosynthesis by **Robert Hill**, discovery of C_3 - Pathway by **Melvin Calvin**, C_4 - pathway by **Hatch and Slack**. Indian scientist **Prof. V.S. Rama Das** and his students also made contributions to C_4 - photosynthesis.

3.3 SCOPE

From ancient times, man realized the importance of plants and their products, the problems like decreasing resources and increasing population could be solved to great extent by enhancing crop yield through Green Revolution and also developing disease, pest resistant crops, utilizing the **principles of biotechnology**. Progress in applied fields like Agriculture, Hortiulture, 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. The knowledge on role of plant hormones is useful for breaking of seed dormancy, herbicidal control of weeds, artificial ripening of fruits and rooting of stem cuttings for vegetative propagation. Experiments in tissue and organ culture have made it possible to produce large number of plants in the laboratory. Production of antibiotics, bioinsecticides, single cell proteins (*Spirulina*, *Chlorella*) etc., is also made possible by thorough study of these product yielding 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., usage of **biofertilizers** (*Azolla, Nostoc*) 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

During 19^{th} and 20^{th} 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 branches are outlined below:

Branches of Botany

1. **Morhology** 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 2 parts.
   a) **External morphology** is the study of description of external characters of plant organs like root, stem and leaf etc.
   b) **Internal morphology** is the study of internal structures of different plant organs. It has 2 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 and flower etc**.**
2. **Cell Biology or Cytology** 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 development, structure and all other aspects related to microspores or pollen grains**.**
5. **Taxonomy or Systematic Botany** deals with the study of 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. **Paleobotany** deals with the study of fossil plants. It help 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. **Plant Pathology** is the study of causes, symptoms and methods of control of plant diseases.
11. **Phycology** is the study of all aspects related to algae which are chlorophyllous and autotrophic thallophytes.
12. **Mycology** deals with the study of fungi which are non-chlorophyllous heterotrophic thallophytes.
13. **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.
14. **Bryology** is the study of bryophytes (Amphibians of plant kingdom).
15. **Pteridology** is the study related to pteridophytes, also known as vascular cryptograms.

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 16^{th} and 17^{th} centuries. It emerged as specific science, Botany during 17^{th} century with the development of allied sciences. During 18^{th} century, there was a progress in the areas of Taxonomy and Physiology. During 19^{th} century, there was a considerable amount of progress in different branches of Botany. During 20^{th} 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 Agriculture, Horticulture and 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. 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 essay study and understanding, Botany is divided into different branches.

GLOSSARY

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

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

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

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

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

VERY SHORT ANSWER TYPE QUESTIONS

1. Explain how the term Botany has emerged**.**
2. Who are herbalists?
3. Who discovered cell?
4. What is paleobotany ?
5. Which group of plants are called amphibians of plant kingdom?
6. What are the group of plants that live as symbionts in lichens?

SHORT ANSWER TYPE QUESTIONS

1. Explain in brief the scope of Botany in relation to Agriculture and Horticulture.
2. What are the different branches of Botany that deals with morphology of plants.

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** (fresh water and marine water) plants. They also occur in a variety of other habitats: on moist stones, soils and wood. They are **unicellular, multicellular, colonial or filamentous.** Some of them also occur in association with fungi to form Lichens 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 contains special pigments, Phycobillins. The **reserve food** is generally Starch.

The Algae reproduce by **vegetative, asexual** and **sexual** methods. Vegetative reproduction is by Fragmentation. **Asexual** reproduction is by the production of different types of spores, most common being the **Zoospores**. **Sexual** reproduction takes place through fusion of gametes by either **Isogamous, Anisogamous** or **oogamous** type.

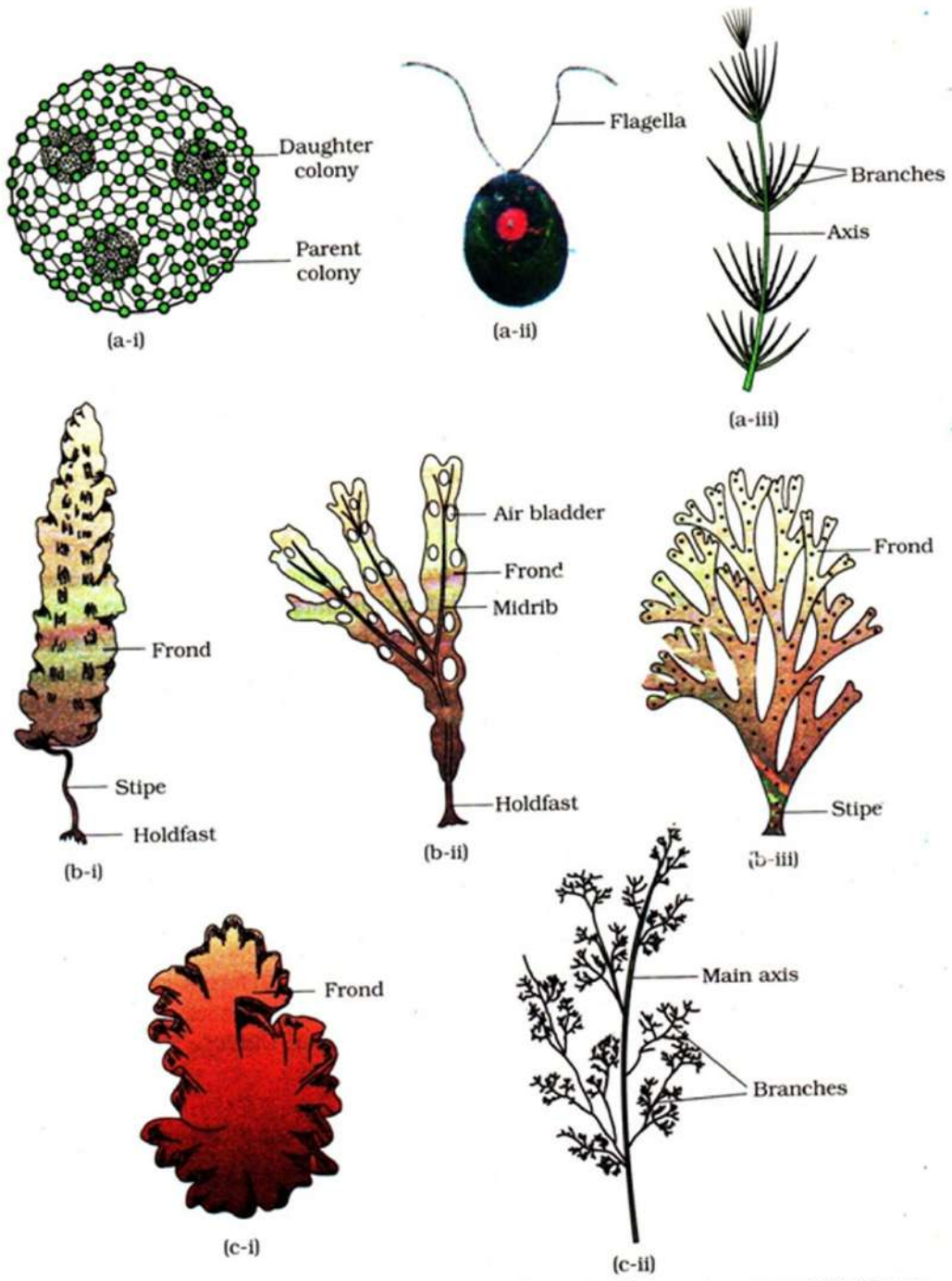


Figure 4.1 Algae : (a) Green algae (i) *Volvox* (ii) *Chlamydomonas* (iii) *Chara*
(b) Brown algae (i) *Laminaria* (ii) *Fucus* (iii) *Dictyota*
(c) Red algae (i) *Porphyra* (ii) *Polysiphonia*

Algae are **useful** to man in many ways. At least a half of the total carbon dioxide fixation on earth is carried out by algae through **Photosynthesis**. 70 species of marine algae like *Porphyra, Laminaria and Sargassum* are used as **food. Agar,** is obtained from red algae *Gelidium* and *Gracilaria.* **Iodine** is extracted from kelps like *Laminaria*. Unicellular algae *Chlorella, Spirulina* are used as food supplements by space travellers. On the basis of pigmentation algae are classified into **three main classes:** Chlorophyceae, Phaeophyceae and Rhodophyceae.

Table 4.1 Divisions of algae and their main characteristics

Class	**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	Freshwate, 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 ester	Absent	Fresh water (some), brackish Water, salt water (most)

4.2 BRYOPHYTES

Bryophytes include the various liverworts, hornworts and mosses that are found commonly in moist shady 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.

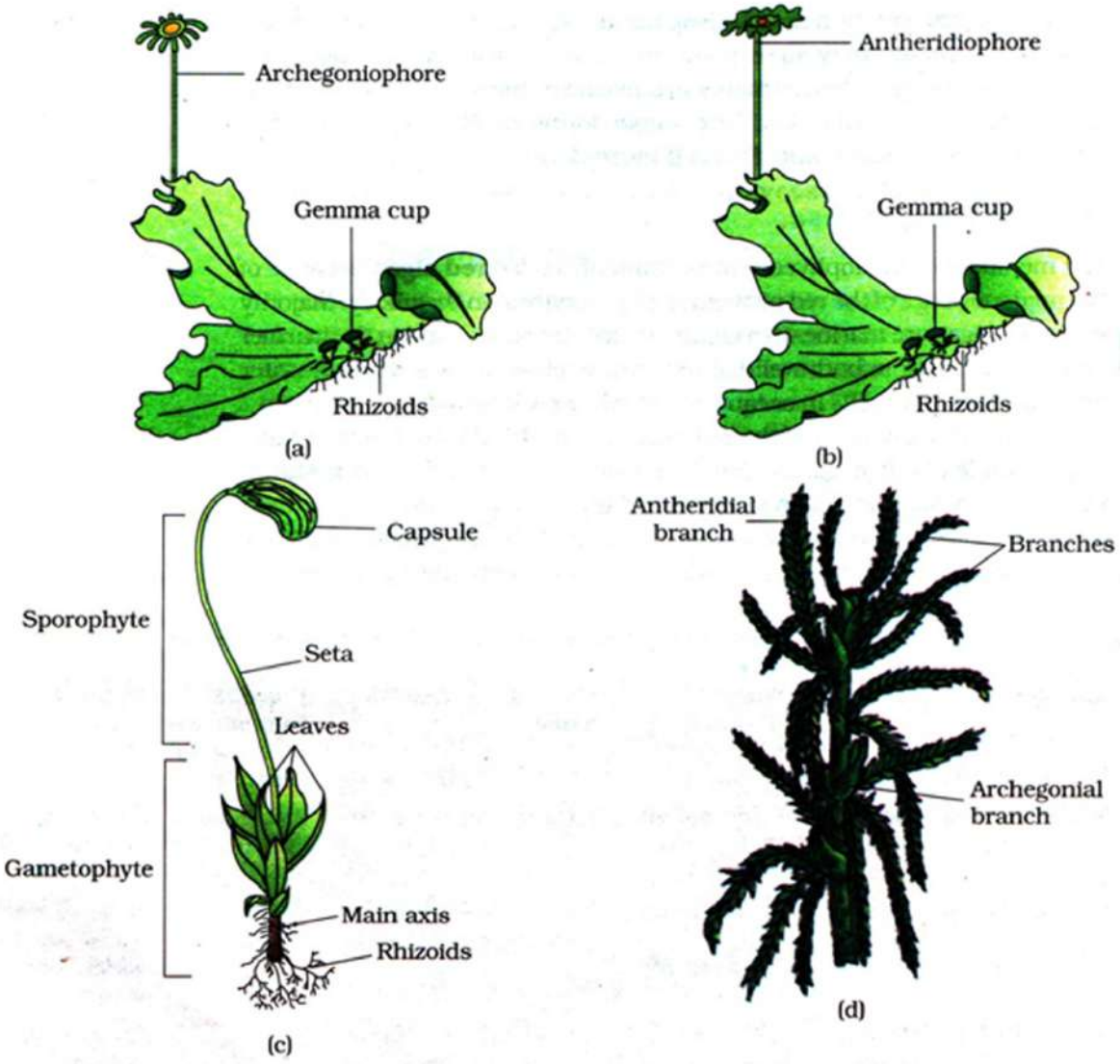


Figure 4.2 Bryophytes: A liverwort – *Marchantia* (a) Female thallus (b) Male thallus Mosses – (c) *Funaria*, gametophyte and sporophyte (d) *Sphagnum* gametophyte

The plant body of bryophytes is more differentiated than that of algae. It is the thallus like and prostrate or erect, and attached to the substratum by unicellular or multicellular **rhizoids**. They lack roots, stem or leaves. The main plant body of the bryophyte is haploid. It produces gametes, hence it is called **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 single egg. The antherozoids are released in water come in contact with archegonium. An atherozoid fuses with the egg to produce the zygote. This is called **zooidogamous oogamy**. Zygote do not undergo meiosis immediately, they produce a multicellular body called **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.** The bryophytes are divided into three classes viz., Hepaticopsida (Liverworts), Anthocerotopsida (Hornworts) and Bryopsida (Mosses).

4.3 PTERIDOPHYTES

Pteridophytes include **Club mosses, horsetails, ferns** etc. Evolutionarily, they are the **first terrestrial plants to possess vascular tissues.** They are frequently grown as ornamentals. 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.

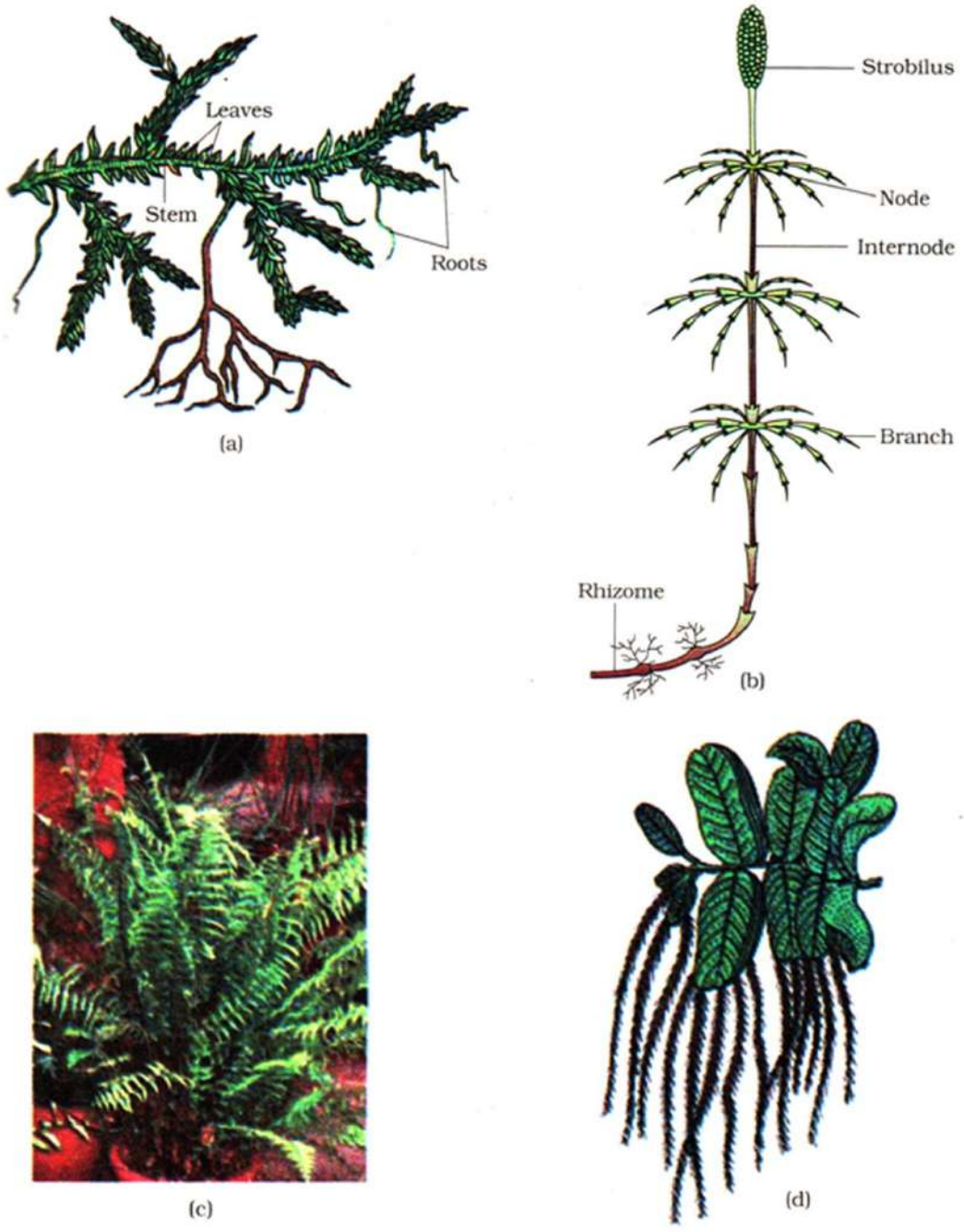


Figure 4.3 Pteridophytes : (a) *Selaginella* (b) *Equisetum* (c) Fern (d) *Salvinia*

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 S*elaginella* or large (macrophylls) as in ferns. The sporophytes bear sporangia on leaf-like appendages called **Sporophylls.** The development of sporangium may be **lepto-sporangiate** or **eusporangiate.** The 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 as **Homosporou**s pteridophytes. e.g. *Pteris, Psilotum*. But in some plants there are two kinds of spores are formed i.e, megaspores and microspores are called **heterosporous** pteridophytes. e.g, *Selaginella and Salvinia.* In some cases, sporophylls may form distinct compact structures called Strobili or cones (*Sellaginella*, *Equisetum*). The spores germinate and give rise to inconspicuous small multicellular free living, mostly photosynthetic thalloid gametophytes called prothalli (sin. Prothallus). These gametophytes require cool, damp, shady places to grow. The gametophytes bear male and female sex organs called Antheridia and Archegonia respectively. These sex organs are **multicellular, jacketed and sessile.** In heterosporous plants, the megapores and microspores germinate and give rise to female and male gametophytes respectively. water is required for transfer of antherozids. 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 zygote into embryos takes place within the female gametophytes. This event is a precursor to the **seed habit,** considered an important step in evolution.

The pteridophytes are further classified into Four classes namely Psilopsida (*Psilotum*), Lycopsida (*Selaginella, Lycopodium*), Sphenopsida (*Equisetum*) and Pteropsida (*Pteris Adiantum* etc., commonly called Ferns).

4.4 GYMNOSPERMS

The Gymnosperms (gymnos: naked, sperma: seed) 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 after 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 gaint wood tree **Sequoia** is one of the tallest tree species. *Gingo* is considered to be a living fossil (figure 4.4.c). The roots are generally tap roots, but roots in some genera have fungal association in the form of mycorrhiza (*Pinus*). While in some others (*Cycas*) small specialised roots are associated with N_2 -fixing cyanobacteria (*Nostoc* and *Anabaena)* The stems are unbranched (*Cycas* figure 4.4(a)) or branched *Pinus* (figure 4.4 (b)). The leaves may be simple or compound. In conifers, the needle like leaves reduce the surface area. Their thick cuticle and sunken stomata also help to reduce water loss.

(c) Ginkgo

Anatomically 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 two kinds of spores, microspores and megaspores 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 microsporohylls and microsporangia are called microsporangiate or male strobili (similar to male flower). 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 megasporangiate or female strobili (similar to female flower). The microsporophlls (male) or mega sporophylls (female) may be borne on the same tree *(Pinus*) or

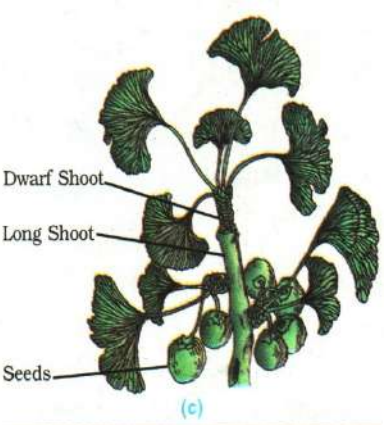


Figure 4.4 Gymnosperms:
(a) *Cycas* (b) *Pinus* (c) *Ginkgo*

on different trees (*Cycas).* The diploid tissue present inside the ovule called **Nucellus,** is protected by layers called integuments and the composite structure is called an ovule. One cell of the nucellar tissue differentiated into megaspore mother cell. It divides meiotically to form four megaspores. One of the megaspore enclosed within the megasporangium develops into a multicellular female gametophyte that bears two or more archegonia or female sex organs. The multicellular female gametophyte is retained within the megasporangium is also called **endosperm.**

Unlike bryophytes and pteridophytes, in gymnosperms the male and female gametophytes do not have an independent free- living existence. They remain within the sporangia retained on sporophytes. The pollen grain is released from the microsporangium. The pollination is direct and anemophilous. The pollen tube carrying the male gametes grows towards the 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. Zygote develops into embryo and the ovules develop into seeds. These seeds are naked and not covered by fruit wall.

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 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 meters). The root system of these plants is taproot or adventitious system. 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 organ in a flower are the **stamens**. Each stamen consists of a filament with an anther at tip. In the anthers, microspore mother cells undergo meiosis and produce pollen grains. The female sex organ is the **pistil or the carpel**. Pistil consists of an ovary enclosing one to many ovules, within ovules a megaspore mother cell undergo meiosis and produces four megaspores. Usually only one megaspore develops into a highly reduced female gametophyte termed **embryo-sac.** 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 fuse to produce a diploid secondary nucleus.

Fig 4.5 Angiosperms: (a) A Dicotyledon (b) A Monocotyledon

The pollen grains after dispersal from the anther are carried by wind, water or various biotic agents like animals to the stigma of a pistil. This is called **pollination,** it is indirect type unlike in Gymnosperms. The Pollen grains germinate on stigma produces pollen tubes, they passes through style and reach the ovule and enter into embryo sac where two male gametes are discharged. One of the male gametes fuses with egg cell to form zygote (**Syngamy**). The second 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 this event is termed as **double fertilisation** an event unique to angiosperms. The fertilisation is **siphonogamous oogamy**. After this zygote develops into embryo and the PEN develops into endosperm which provide nourishment to the developing embryo. The synergids and antipodals degenerate after fertilisation. The ovules develops into seeds and the ovary develop into fruit.

Based on number of cotyledons in the seed, angiosperms are divided into two classes, dicotyledons and monocotyledons (figure 4.5).

SUMMARY

Plant kingdom includes algae, bryophytes, pteridophytes, gymnosperms and angiosperms. Algae are chlorophyll-bearing simple, thalloid, autotrophic and large aquatic organisms. Depending on the types of pigments and 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. They possess root-like, stem-like and leaf- like structures. The bryophytes are divided into liverworts, hornworts and mosses. The main plant body of a bryophyte is gamete-producing and is called a Gametophyte. It bears male sex organs called antheridia and female sex

organs called archegonia. The male and female gametes produced to form zygote which produces multicellular body called a sporophyte. It produces haploid spores, the spores germinate to form gametophyte.

In pteridophytes the main plant is a sporophyte which is differentiated into true roots, stem and leaves. These organs posses well-differentiated vascular tissues. The sporophytes bears 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 sporophylls. The sporophylls-microsporophylls and megasporophylls- are arranged spirally on axis to form male and female cones, respectively. The pollen grains germinate 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 organ (pistil) are borne in a flower. Each stamen consists of a filament and an anther. Anther produces pollen grains after meiosis. The pistil consists of an ovary enclosing one to many ovules. Within the ovule is the female gametophyte or embryosac which contains the egg cell. The pollen tube enters the embryo-sac where two male gametes are discharged. One male gamete fuses with egg cell (syngamy) and other fuses with diploid secondary nucleus (triple fusion). This phenomenon of two fusions is called double fertilisation and is unique to angiosperms. The angiosperms are divided into two classes-the dicotyledons and the monocotyledons.

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 female gamatangium is archegonium.

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 trachaeophytes.

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

Spermatophytes: These are seed plants with or without fruits.

Sporophyte: It is a diploid spore producing 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.

Zoospore: Flagellated motile spores.

Very Short Answer Type Questions.

1. What is the basis of classification of Algae?
2. What are the two stages found in the Gametophyte of Mosses?
3. Name the Gymnosperms which contain mycorrhiza?
4. Name the corolloid roots respectively?

Short Answer type Questions.

1. Differentiate between Red Algae and Brown Algae?
2. Differences between homosporous and heterosporous Pteidophytes with examples?
3. Draw labeled diagrams of female Thallus and male Thallus of a liverwort.

EXERCISES

1. An autotrophic and a heterotroic organism live together. What is such an association termed as ?
2. Why does *Spirogyra* belong to algae ?
3. Both gmnosperms and Angoisperms bear seeds, then why are they classified separately ?
4. Fucoxanthin pigment is found in
   (A) Green algae (B) Brown algae (C) Red algae (D) All of the above
5. Seed habit originated in some
   (A) Bryophytes (B) Pteridophytes (C) Gymnosperms (D) Angiosperms

CHAPTER 5

MORPHOLOGY OF FLOWERING PLANT

The wide range in the structure of higher plants 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 fruit**.**

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., adaptations 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 pat of the flowering plant is the root system while the portion above ground forms the shoot system (Figure 5.1). Generally the root shows positive geotropism while the stem shows positive phototropism.

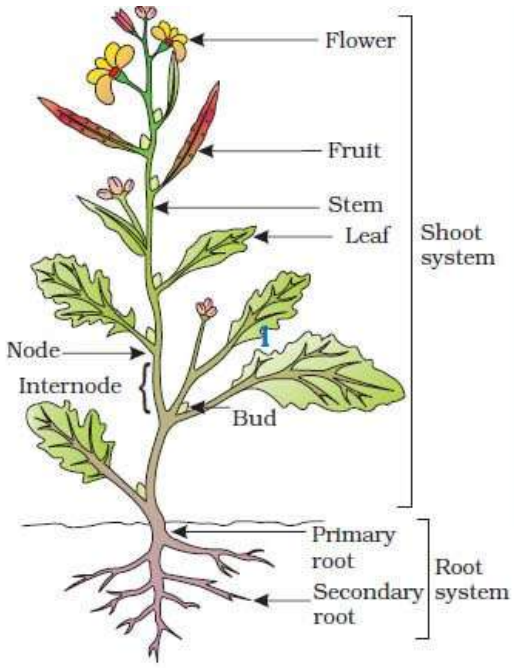


Figure 5.1 Parts of a flowering plant

5.1 The Root

Root is the underground main axis of the plant body and is originally the prolongation of the radicle of the embryo.

5.1.2 Types of root system

There are two types of root systems in Angiosperms. They are

1. Tap root system and
2. Adventitious root system

1.Tap root system

In this system, the main root or the tap root develop from the radicle of the embryonal axis of the geminating seed. The tap root grows vertically in to the soil and produces lateral branches endogenously and obliquely in acropetal manner. This system is commonly found in dicotyledonous plants.

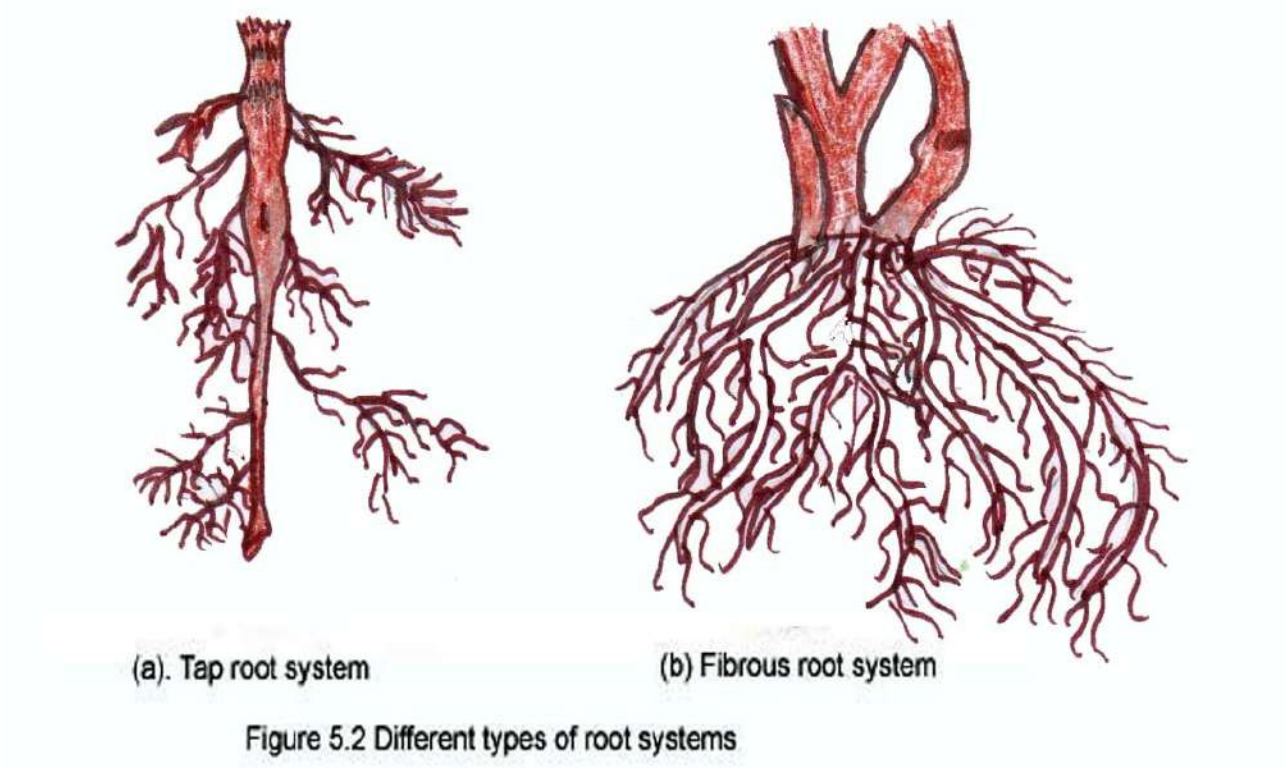


Figure 5.2 Different types of root systems

2. Adventitious root system

In this system the radicle is short lived and degenerates after some time, later a number of new roots develop from the base of the stem as fibres. These roots are called fibrous roots and the root system is called fibrous root system. As the root system develops from parts of the plant other than radicle this is called adventitious root system. This system is commonly found in monocotyledonous plants.

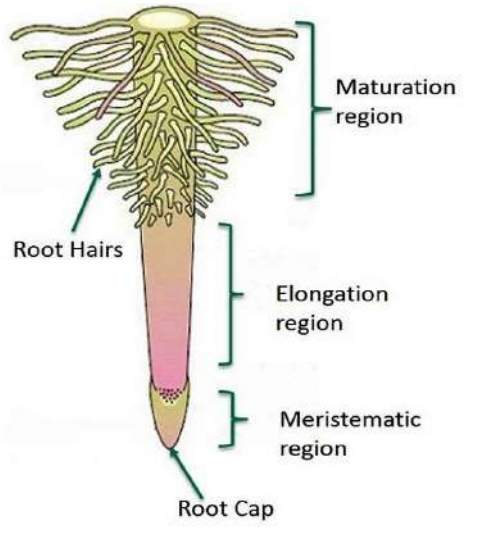


Figure 5.3 The regions of the root tip

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.

5.1.3 Regions of the Root

The root is covered at the apex by a thimble –like structure called the root cap. It protects the tender apex of the root as it makes it way through the soil. A few millimetres above the root cap is the region of meristematic activity. The cells of this region are very small, thin-walled and with dense protoplasm. They divide repeatedly the cells proximal to this region undergo rapid elongation and enlargement and are responsible for the growth of the root in length. This region is called the region of elongation. The cells of the elongation zone gradually differentiate and mature. Hence, this zone, proximal to region of elongation, is called the region of maturation. From this region, some of the epidermal cells form very fine and delicate, thread-like structures called root hairs. These root hairs absorb water and minerals from the soil.

5.1.4 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. These are called root modifications. These are of different types.

1. **Storage roots or Tuberous roots**: Tap roots of carrot, turnip, radish and fibrous roots in *Asparagus* become swollen due to storage of food.

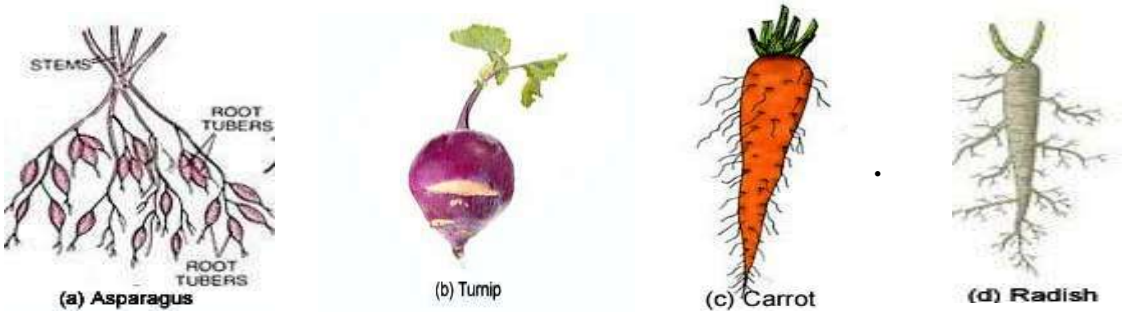
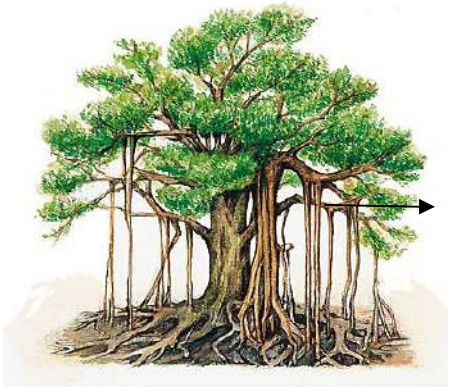


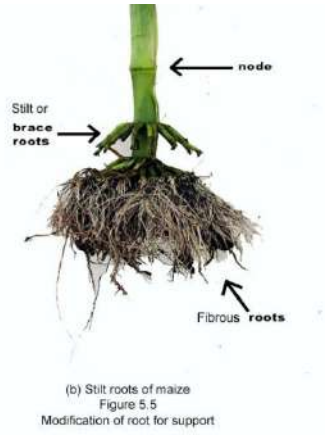
Figure 5.4 Storage roots

2. Prop roots or pillar roots

In Banyan tree they grow like pillars and give support to branches.



Prop root



(b) Stilt roots of maize
Figure 5.5
Modification of root for support

a) Prop roots of Banyan

5.5 Modifications of root for support

3. Stilt roots: The stems of Maize and Sugarcane have supporting roots coming out of the lower nodes of the stem. These are called Stilt roots.

Figure 5.6 (a). Pnuematophores of Avicennia

4. Respiratory roots or Pneumatophores

The mangrove plants like *Rhizophora* and *Avicinnea* roots grow upwards and contain pores called pneumathodes and the roots called Pneumatophores. They help to get oxygen**.**

5. Velamen roots or Epiphytic roots

Epiphytes do not have a direct contact with soil, therefore Epiphytes develop specialized roots to absorb moisture from the atmosphere. These roots are called Velamen roots. e.g: *Vanda*

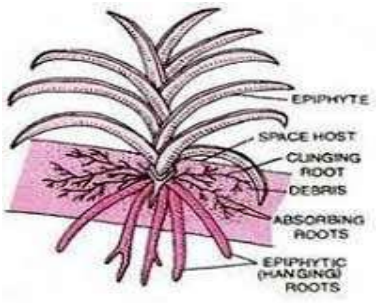


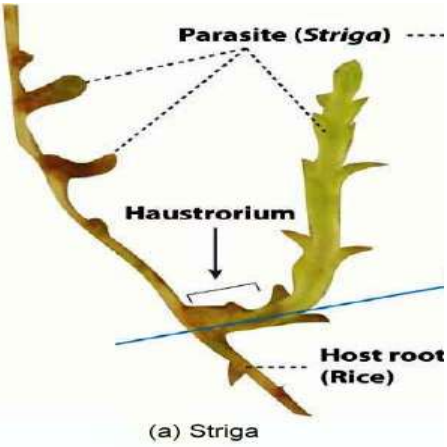
Figure5.6 (b) Velamen roots of Vanda

6. Parasitic roots or Haustorial roots

Plants which depend on other plants completely or incompletely for their food are called parasitic plants.

Complete parasites are leafless, cannot synthesise their food materials. They absorb food from the phloem and water from xylem of the host by haustoria. e.g*: Cuscuta, Rafflesia*.

Incomplete parasites bear leaves, so they can prepare their food. The haustoria of this parasites penetrate only into the xylem of the host to absorb water and minerals. e.g*: Viscum*, *Striga.*



(a) Striga

Figure 5.7 Haustorial (parasitic) roots (b) Cuscuta

7. Nodular roots

In members of Fabaceae, bacteria known as *Rhizobium* inhabit the root system to fix atmospheric nitrogen forming nodules. Such roots are called nodular roots. e.g: Ground nut.

Figure 5.8 (a). Nodular roots of ground nut

8. Photosynthetic roots or Assimilatory roots

In some epiphytes like *Taeniophyllum* the stem and leaves are absent the roots of these plants become aerial, flattened and green to synthesise food materials by Photosynthesis.

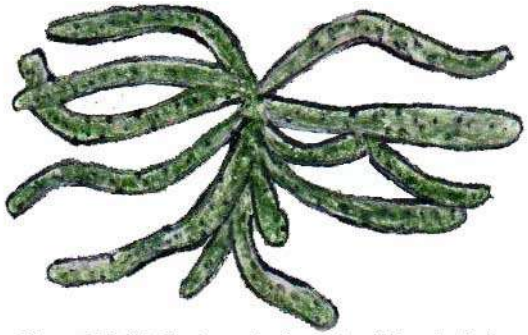


Figure 5.8 (b) Photosynthetic roots of Taeniophyllum

5.2 THE STEM

The system which grows aerially in a plant is called shoot system. It develops from the plumule of the embryo. The axis of the shoot system is called Stem. The stem bears nodes and internodes. The region of the stem where leaves are borne 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

Like roots, the stems are also undergo modifications to perform some special functions.

Based on nature, the stem modifications are of three types. They are

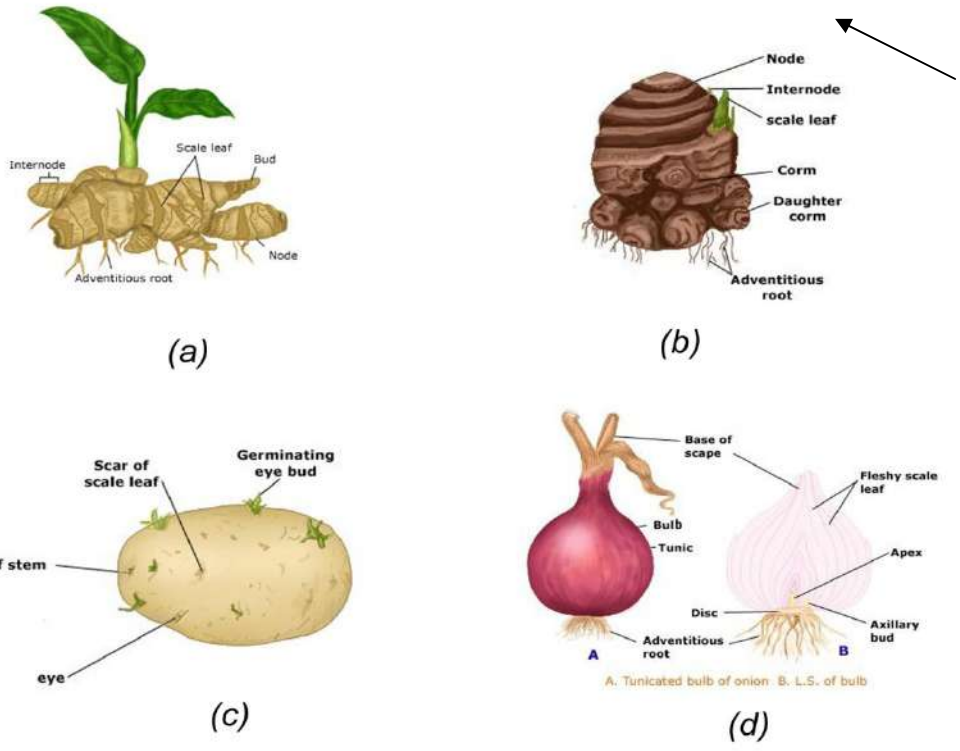
I. Underground stem modifications
II. Aerial stem modifications
III. Sub –aerial stem modifications

i) Underground stem modifications

Normally stems are aerial. But in some plants they grow below the soil. Such type of stems are called underground stems. They store food materials and also act as organs of vegetative propagation and perennation. They are

1. **Rhizome**: It is an underground stem which grows horizontally below the soil. E.g*: Zingiber* (ginger), *Curcuma*.
2. **Corm:** It grows vertically in the soil at a particular depth. E.g: *Amorphopalus* (zaminknd) and *Colocasia.*
3. **Stem Tuber**: In some plants, the underground branches store food materials and become tuberous. These are called stem tubers. e.g*: Solanum tuberosum* (potato)

4. **Bulb:** The leaf bases (scale leaves) store food and water and become fleshy. e.g: Onion.



(a) Rhizome of ginger (b) Corm of Colocasia (c) Stem tuber of potato (d) Bulb of Onion

5.9 Under ground stem modifications

ii) Aerial stem modifications:

Aerial stems of several plants show many modifications such as:

1. Stem Tendril: Some weak stemmed plants produce wiry coiled sensitive and delicate organs useful for climbing which may develop either from axillary buds as in gourds (cucumber, pumpkins, watermelon) or terminal buds as in (grape vine).

2. Thorns: These are hard woody pointed structures meant for protection. Axillary bud develop into thorn in *Bougainvillea*, terminal bud in *Carissa.*

3. Phylloclades: In the plants growing in drought areas and deserts, the leaves are modified into scale leaves or spine to reduce transpiration. In such plants the main stem or branches are modified into green leaf like structures, these leaf like stems are called 'phylloclades'. e.g: *Opuntia* .

4. Cladophylls: In *Asparagus*, the branches of limited growth that are modified to perform photosynthesis are called cladophylls.

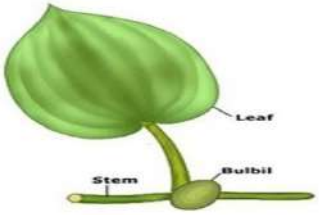
5. Bulbils: In some plants the vegetative buds (*Dioscorea)* and floral buds (*Agave*) are modified into condensed branches. They store food materials. These modified buds are called bulbils. when they detach from the parent plant they develop adventitious roots. They help in vegetative propagation.

(a)

(b)

(c)

(d)



(e)

(a) Stem tendril (b) Thorn (c) Phylloclade (d) Cladophyll (e) Bulbil

5.10 Aerial stem modifications

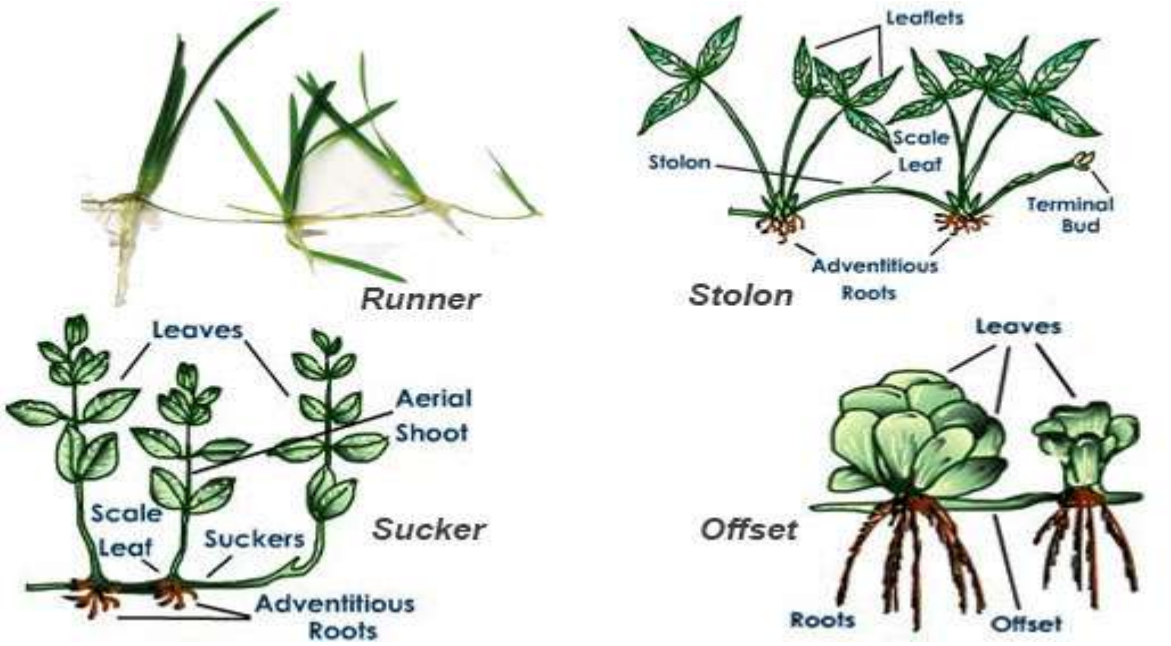
iii) Sub-aerial stem modifications:

1. Runners: In some plants the weak stems creep on the soil and are rooted at every node. when the internodes break off, they lead an independent life. These weak stemmed plants are called 'runners'. e.g: *Oxalis.*

2. Stolons: In some plants like *Nerium, Jasminum* long slender branches arise from the base of the stem grow obliquely downwards. when these branches touch the soil they produce adventitious roots. These branches are called 'stolons'.

3. Suckers: In some plant like *Chrysanthemum*, banana and pineapple part of the stem is in the soil. Underground branches grow obliquely upward from the axillary buds of nodes present below the soil. These branches produce many adventitious roots from their lower surface. These underground branches are called 'suckers'.

4. Offsets: In some aquatic plants like *Pistia* and *Eichhornia* the stem is reduced to a disc like structure. Many leaves are developed from this stem is rosette manner. The axillary buds of these leaves develop into short one internodal length of branch grow horizontally above the water. These branches are called 'offsets'.



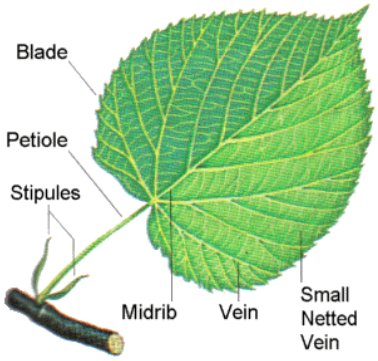
5.11 Sub Aerial Stem modifications

All these sub-aerial stem modifications are also useful for vegetative propagation.

5.3. The Leaf

Leaves are lateral appendages developed exogenously from the nodes of the stem or on the branches. The leaves are usually flat and green. Axillary buds develop in the axil of the leaf. They are the most important vegetative organs for photosynthesis.

5.3.1 Parts of leaf: Leaf has four parts. 1. Leaf base 2. Stipule, 3.Petiole and 4. Lamina.



5.12 Parts of a leaf

1. **Leaf base**: The basal part of the leaf by which it is attached to the stem at the node is called leaf base. In some leguminous plants, the leaf base may become swollen, which is called Pulvinous.
2. **Stipule:** The small green, lateral appendages present on either side of the leaf are called 'stipule'.
3. **Petiole:** The stalk like structure which connects the lamina to the stem is called petiole. The petiole helps in exposing the lamina to light.
4. **Lamina or Leaf blade**: The green expanded part of the leaf with veins and vein lets is called 'lamina'. All the important functions of the leaf are performed in this part only.

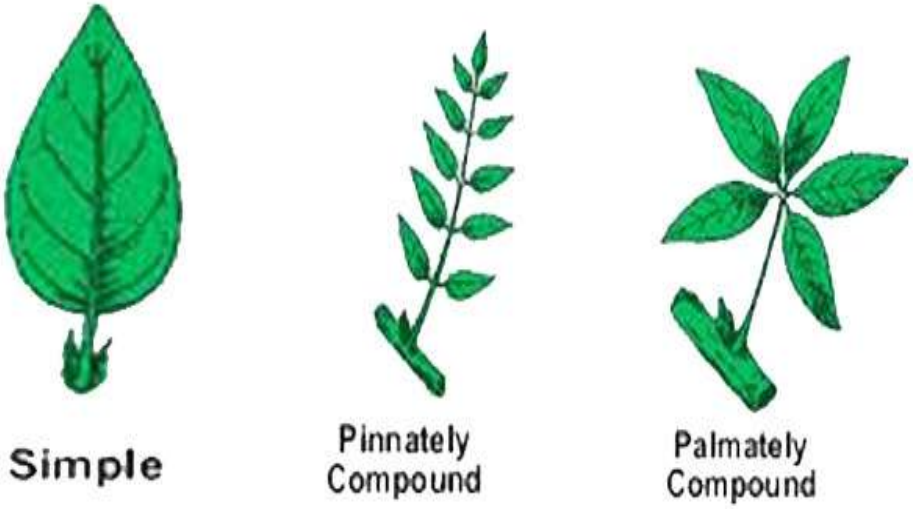
5.3.2 Venation: The arrangement of veins and vein lets in the lamina of leaf is termed as 'venation'. In angiosperms the venation is of two types.

1. Reticulate venation: This type of venation is commonly found in dicots. In this the midvein and lateral veins form a network.
2. Parallel venation: It is commonly found in the monocots. In this the veins run parallel to each other in the lamina.

5.3.3 Types of Leaves : Based on the morphology the leaves are classified in to two types. 1) Simple leaves: In this, the petiole bears one lamina at its apex. The lamina is either lobed or unlobed. e.g: *Annona* and *Psidium* (5.13 a).

2) Compound leaves: The lamina is dissected up to the midrib or up to tip of the petiole to form many leaflets (5.13 b).

The compound leaves may be of two types: i) Pinnately compound leaves: a number of leaflets are present on a common axis called rachis. e.g: Neem.



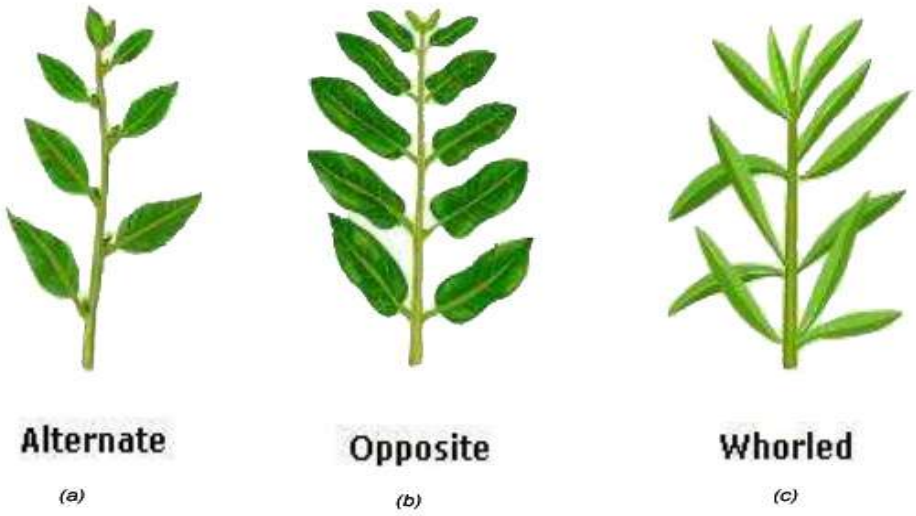
ii) Palmately compound leaves: The leaflets are attached at a common point. i.e. at the tip of petiole. e.g: *Bombax ceiba* (silk cotton 5.13 c).

5.13 Types of leaves

5.3.4 Phyllotaxy

The mode of arrangement of leaves on the stem and branches is called phyllotaxy. This is usually of three types:

1. **Alternate phyllotaxy**: A single leaf arises at each node in alternate manner. e.g. *Hibiscus,* mustard.
2. **Opposite phyllotaxy**: A pair of leaves arise at each node and lie opposite to each other. e.g. *Calotropis*, Guava.
3. **Whorled phyllotaxy**: If more than two leaves arise at a node and form a whorl. e.g. *Nerium, Alstonia.*

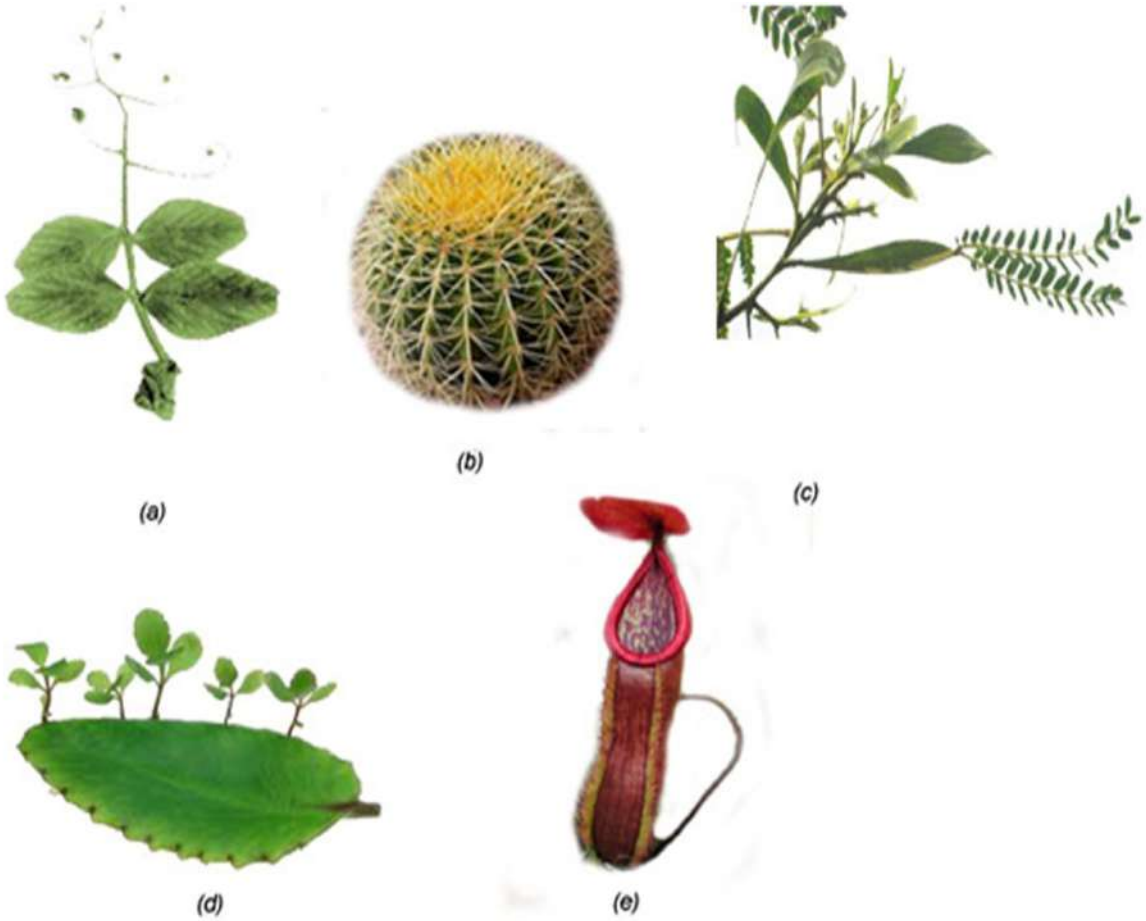


5.14 Types of Phyllotaxy

5.3.5 Modifications of leaves

Leaves are often modified to perform functions other than photosynthesis. The leaf modifications are of the following types.

1. **Tendrils:** In weak stemmed plants, the entire leaf or any part of it modify into tendrils. They provide mechanical support to the plant and also help in climbing. e.g: Peas, *Smilax.*
2. **Spines:** In some plants, the leaves are modified into sharp, pointed spines. They help in reducing the rate of transpiration in xerophytic plants and also protect from herbivorous animals. e.g: *Acacia, Cacti.*
3. **Phyllode**: In *Acacia melonoxylon,* the normal leaf is bipinnately compound develop in the seedling stage, but it soon falls off. So in these plants the petiole is modified into green flattened winged structure performing photosynthesis.
4. **Scale leaves**: In some xerophytic plants and underground stems, the leaves are reduced to small, colourless, dry membranous structures called 'scale leaves'. The fleshy leaves of onion and garlic store food.
5. **Reproductive leaves**: In *Bryophyllum* epiphyllous buds which arise from the notches of leaves develop adventitious roots and when they detach, develop into individual plants. They help in vegetative propagation.
6. **Insectivorous leaves or Trap leaves:** Plants growing in nitrogen deficient soils depend on organisms like insects for their nitrogen requirements. In order to attract the insects, catch them and digest the insect proteins, the leaves of these plants modify into trap leaves. e.g: *Nepenthes* (pitcher plant), *Dionea* (Venus Fly-trap)



(a) Leaf tendril (b) spines (c) Phllode (d) Reproductive leaves (e) Trap leaves

Figure 5.15 Leaf modifications

5.4 THE INFLORESCENCE

The arrangement of flowers on the peduncle (floral axis) is termed as 'inflorescence'. The flower is a modified shoot where in the shoot apical meristem changes to floral meristem. Internodes do not elongate and the axis gets condensed. The apex produces different kinds of floral appendages laterally at successive nodes instead of leaves. Depending on whether the apex gets converted into a flower or continues to grow, two major types of inflorescence are defined- 1) Racemose 2) Cymose.

5.4.1 Racemose or Indefinite Inflorescences: In this type the peduncle grows indefinitely and produces a number of flowers in acropetal manner or Centripetal manner.

Arrangement of older flowers at the bottom and younger ones at the top of the elongated peduncle is called **acropetal arrangement**. The peduncle does not terminate into a flower. In **centripetal arrangement**, the older flowers are present near the periphery and younger ones at the centre of the reduced discoid peduncle.

In these racemose inflorescence the peduncle may be unbranched (simple type) or branched (compound type). Flowers with pedicels are called 'pedicillate'. In some flowers the pedicels are absent and they are called 'sessile'.

Based on presence or absence of pedicels the racemose inflorescences are mainly of two types.

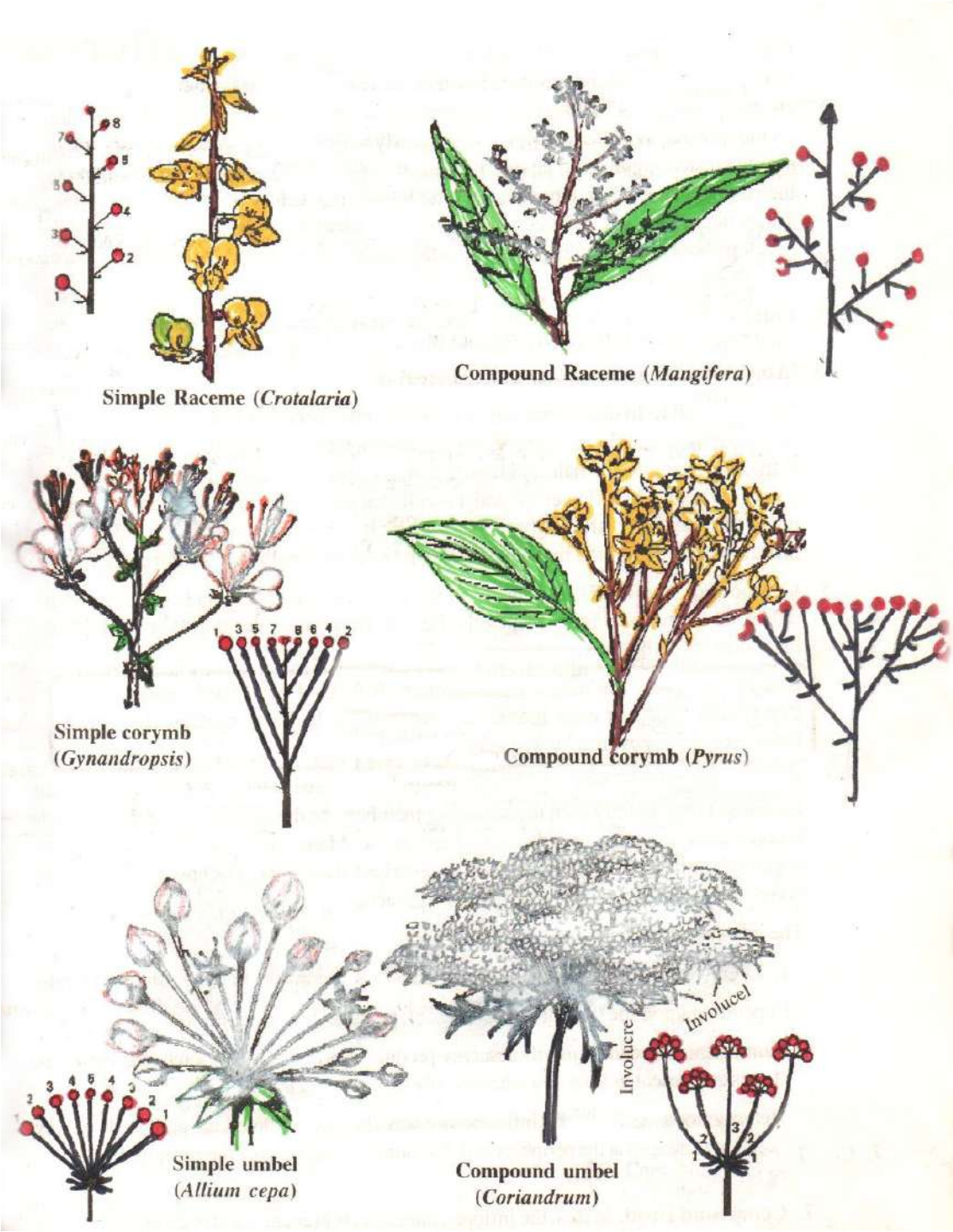
A) Racemose inflorescences with pedicillate flowers.

B) Racemose inflorescences with sessile flowers.

A) Racemose inflorescences with pedicillate flowers:

They are following types.

1) **Simple Raceme**: The peduncle is simple, unbranched, elongated, producing many pedicillate, bracteates flowers in acropetal manner. e.g. *Crotalaria.*
2) **Compound Raceme**: It is also called Panicle. In this the peduncle is branched and each branch resembles a simple raceme. e.g: *Mangifera.*
3) **Simple corymb** : In this type the lower flowers have longer pedicels and apical flowers have shorter pedicels. Thus all the flowers are brought more or less to the same height. e.g. *Cassia*.
4) **Compound corymb** : Peduncle is branched and each branch is produced in to a simple corymb. e.g. Cauliflower.
5) **Simple Umbel** : The peduncle is condensed and unbranched. Many pedicillate and bracteates flowers arise from its apex in a cluster. At the base of the flowers, all the bracts form a whorl called 'involucre'. All the flowers open in a centripetal manner. e.g. Onion.
6) **Compound umbel**: The peduncle is branched and each branch produces a simple umbel at its apex. e.g. Carrot. (figure 5.16)



5.16 A Racemose inflorescences with pedicillate flowers

B) Racemose inflorescences with sessile flowers: They are of following types.

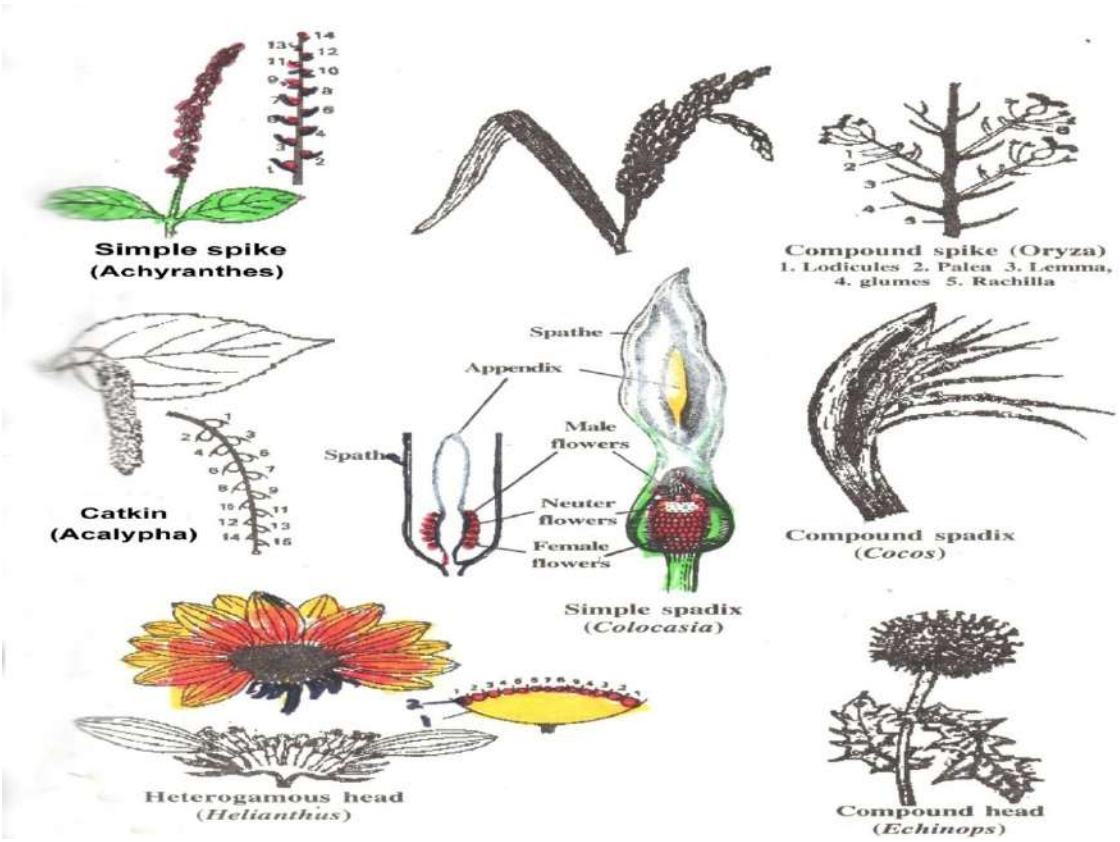
1. **Simple spike**: The peduncle is unbranched and produces bracteates, sessile flowers acropetally. e.g. *Achyranthes.*

2. **Compound Spike**: In this inflorescence, the peduncle is branched and grows indefinitely. The branches produce bracteates, sessile flowers acropetally. e.g. Members of Poaceae like grasses.

3**. Simple Spadix** : In this the peduncle is fleshy, unbranched and produces many sessile, bracteate, unisexual flowers acropetally. One of the bracts is modified into thick leathery structure called 'spathe'. It covers the entire inflorescence. e.g. *Colocasia.*

4. **Compound spadix** : The peduncle is branched and on the branches many sessile unisexual flowers develop acropetally. E.g. *Cocos* and *Musa*.

5**. Head inflorescence** : It is highly evolved inflorescence among the racemose types, mainly Seen in Asteraceae members like *Tridax* and Sunflower. In this inflorescence the peduncle is condensed into a flattened disc called receptacle. Many unisexual and bisexual flowers (florets) are closely arranged on this receptacle in centripetal manner. The entire inflorescence is covered by an involucres of bracts. (figure 5.16 B)



5.16

B Recemose inflorescences with sessile flowers.

5.4.2. Cymose or Definite inflorescence

In this type of inflorescence, the growth of the peduncle is stopped due to the development of a flower at its apex. The bracts on the axis below this flower produce branches. These branches also terminate into a single flower. The flowers are produced either in basipetal manner or centrifugal manner.

Arrangement of older flowers at the top and younger ones at the bottom of the elongated peduncle is called **'basipetal arrangement'**. In **'Centrifugal arrangement'** the older flowers are present at the centre and younger ones near the periphery of the condensed peduncle.

The cymose inflorescences are of following types.

1. **Solitary cyme :** The inflorescence axis is unbranched and bears a single flower at its apex. In *Hibiscus* the solitary flower is axillary. In *Datura* it is terminal in position.
2. **Simple cyme or Cymule**: In this inflorescence axis terminates into a flower. Below this flower the main axis produces two lateral branches which also end in a flower. Thus three flowered inflorescence is formed. The flowers are arranged in basipetal manner. e.g. *Jasminum* and *Bougainvillea*.
3. **Monochasial cyme**: In this the inflorescence axis terminates into a flower and produces only one branch from its basal bract. This branch also grows definitely and ends with a flower. In this way single branches develop to form an axis. e.g. *Solanum* and *Hamelia*.
4. **Dichasial cyme**: In this type the inflorescence axis terminating into a flower, it produces two lateral branches below it. Each branch in turn ends into a flower. These two branches repeat the same type of growth. As two branches are developed each time, it is called 'dichasial cyme'. E.g. *Clerodendron* and *Ipomea.*
5. **Polychsial cyme**: In this type inflorescence axis terminates into a flower and produces many lateral branches form the base of it. These branches also terminate each into a single flower. As this type of branching is continued more than two branches are formed on the peduncle. Hence it is called polychasial cyme. e.g*: Nerium*. (firure 5.17)

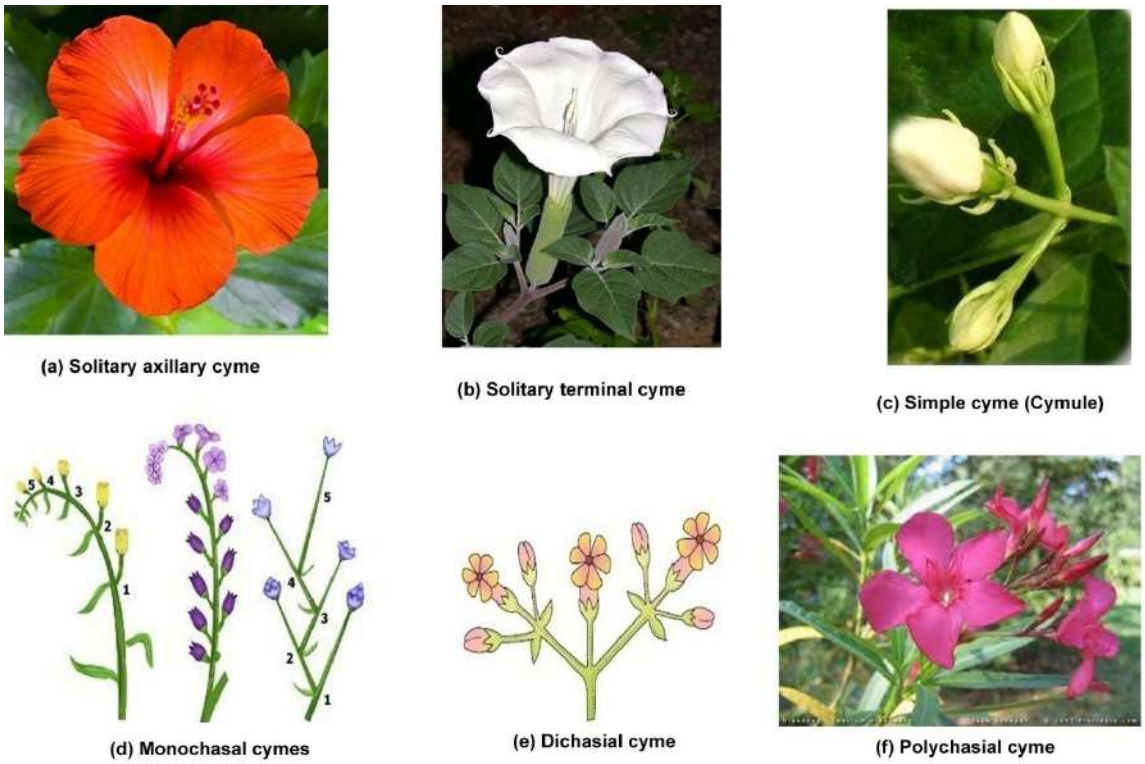


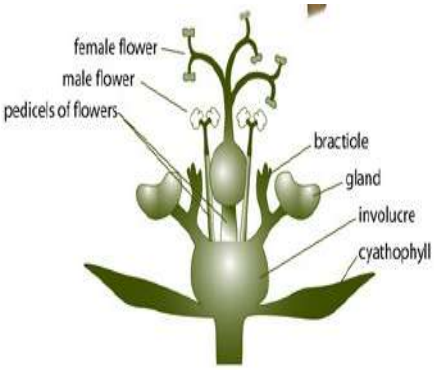
Figure 5.17 Cymose inflorescences

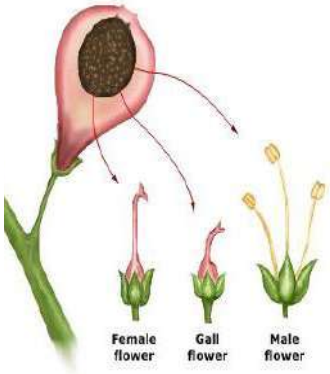
5.4.3 Special types of Inflorescences

Due to modifications in some inflorescences the arrangement and opening of the flowers remain special. So they are called special inflorescence which include the following types.

1. **Verticillaster** : It is a special type of inflorescence found in the family Lamiaceae. This type of inflorescence consists of flowers that arise in the axils of leaves arranged opposite to each other at every node. In the axil of each leaf, the flowers are developed initially in dichasial cyme and later monochasial scorpioid cyme. E.g. *Leucos.*
2. **Cyathium**: It is a single flower like inflorescence found in euphorbiaceae members. The inflorescence is covered by a deep cup like involucres of bracts. At the centre of this cup there is a single female flower represented by a long stalked tricarpellary syncarpous pistil. Encircling this female flower, many male flowers are arranged in scorpioid cyme. E.g: *Cyathium* and *poinsettia.*
3. **Hypanthodium**: It is a fruit like inflorescence. The inflorescence axis condensed and forms a fleshy, cup like structure with an apical opening. Small, sessile, unisexual flowers develop on the inner wall of the cup. 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. After fertilization the whole inflorescence becomes the fig fruit. e.g . *Ficus* (figure 5.18 c).





(a) Verticellaster of Leucas (b) cyathium of Euphorbia (c) Hypanthodium of Ficus

Figure 5.18 Special inflorescences

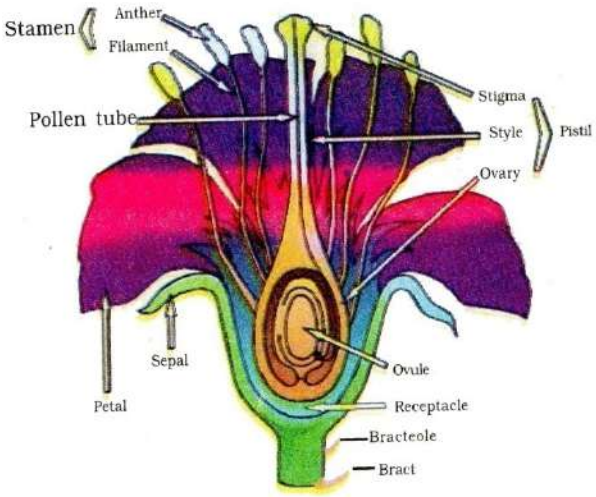
5.5 FLOWER

Flower is a modified and condensed shoot useful for reproduction. Modified leaves are present on this definitely growing shoot.

'Flower is a modified Shoot'- stated by famous scientists like Linnaeus, Gaspard Bauhin, Goethe and Decandolle.

5.5.1 Parts of a typical flower

In an angiospermic flower the apical part of pedicel is called 'thalamus'. In a typical flower there are four sets of floral leaves. They are 1.Calyx 2.Coralla 3. Androecium 4. Gynoecium or pistil. Both calyx and corolla are also called non- essential organs, and are also together known as the perianth. The androecium and gynoecium are called 'essential organs' because they are meant for reproduction. When a flower has both androecium and



gynoecium, it is bisexual. A flower having either stamens or carpels is called unisexual. (Figure 5.19)

Figure 5.19 Parts of a typical angiospermic flower

5.5.2. Symmetry: Based on their symmetry, the flowers may

i) **Actinomorphic**: When it can be divided into two exactly equal halves by any vertical section passing through the centre. e.g. *Hibiscus*

ii) **Zygomorphic:** When a flower can be divided into two similar halves by one vertical section only. e.g. *Dolichos*.

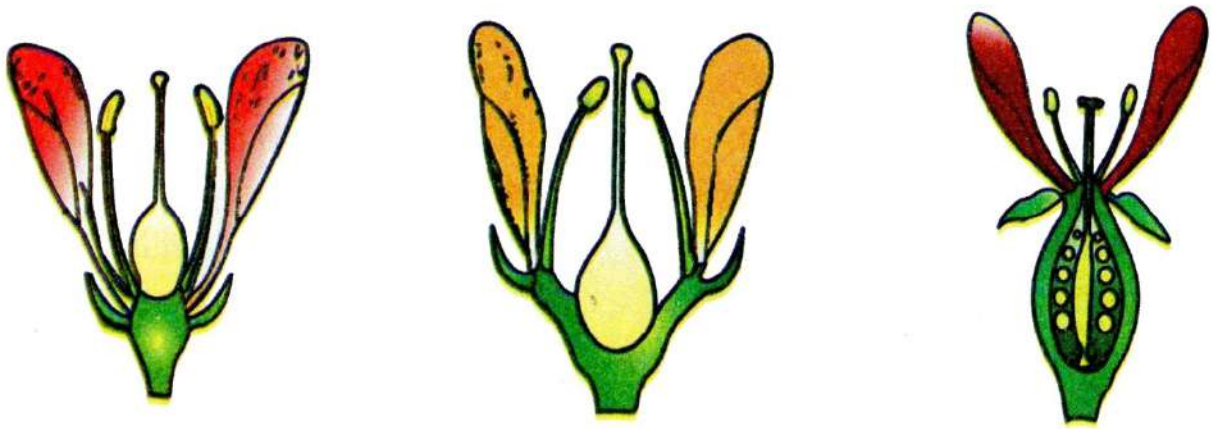
iii) **Asymmetric**: The flower can not be cut into two equal halves in any plane. e.g. *Canna.*

A flower may be trimerous, tetramerous or pentamerous when the floral appendages are in multiples of 3, 4 or 5, respectively. Flowers with bracts found at the base of the pedicel are called **bracteate** and without bract are called **ebracteate.** .

5.5.3 Postion of gynoecium on the thalamus

Based on position of gynoecium on the thalamus in relation to the other floral parts, flowers are divided into 3 types.

1. **Hypogynous** : The gynoecium is arranged at the apex of conical thalamus. The remaining floral parts are arranged at the base of the gynoecium. In this, the ovary is called 'superior' e.g*: Hibiscus*
2. **Perigynous**: Thalamus is saucer shaped with a centrally located gynoecium. The remaining floral parts are arranged along the margins. In this flower the ovary is said to be 'half-inferior' e.g. *Tephrosia*.
3. **Epigynous**: In this the thalamus is a deep cup like sturucture, inside which the gynoecium is arranged. The remaining floral parts are arranged above the level of ovary. so, the ovary is called inferior. e.g: *Tridax*. (figure 5.20)



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

Figure 5.20 Position of floral parts on the thalamus

5.5.4 Detailed description 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.

5.5.4.1 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).

5.5.4.2 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).

Aestivation : The mode of arrangement of sepals or petals in floral bud is known as aestivation. It is of different types.

1. **Valvate :** In this type of aestivation the perianth lobes are arranged closely with small gaps between them. They remain free or united. e.g: Calyx of *Hibiscus*.
2. **Twisted** : In this type of aestation the perianth lobes overlap one another i.e., one margin of perianth lobe is covered by the next one. e.g: Coralla of *Datura* and *Hibiscus.*
3. **Imbricate** : In this type of aestivation each perianth overlaps the perianth lobes present posterior to it. so, the overlapping is antero-posterior. e.g: Coralla of Caesalpiniaceae.
4. **Vexillary:** In this type of aestivation each perianth lobe covers the perianth lobe present anterior to it. So overlapping is postero-anterior. e.g: corolla of Fabaceae. (figure 5.21)

(a) Valvate (b) Twisted (c) Imbricate (d) Vexillary

Figure 5.21 Types of aestivation in corolla

5.5.4.3 ANDROECIUM:

Androecium is composed of stamens. Each stamen which represents the male reproductive organ consists of a stalk or 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 Staminodes. 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 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.*

5.5.4.4. GYNOECIUM

It is the female reproductive organ of the flower and is made up of one or more carpels. A carpel consists of three parts namely basal swollen portion called ovary, a middle elongated portion called the style and an apical portion known as stigma. 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 are called apocarpous. e.g: Lotus and Rose. when carpels are fused they are called syncarpous. e.g: Mustard and Tomato. After fertilisation, the ovary develops into a fruit and ovules develop into seeds.

Placentation: The arrangement of ovules within the ovary is known as placentation. The placentation is of the following types.

1. **Marginal placentation**: The ovules are born along the ventral suture of ovary. e.g*: Dolichos*.
2. **Parietal placentation**: The ovules are borne on the inner walls of the ovary. e.g: *Brassica* and *cucurbita*.
3. **Axile placentation**: In this ovules are attached to a central axis present in the bi or multilocular ovary. e.g: *Hibiscus* and Tomato.
4. **Free central placentation**: This placentation the ovules are borne on central axis without septa. e.g: *Dianthus* and primerose.
5. **Basal placentation**: In this, the ovules are few or reduced to one and are borne at the base of the ovary. e.g*: Tridax* and *Helianthus.*(figure 5.22)

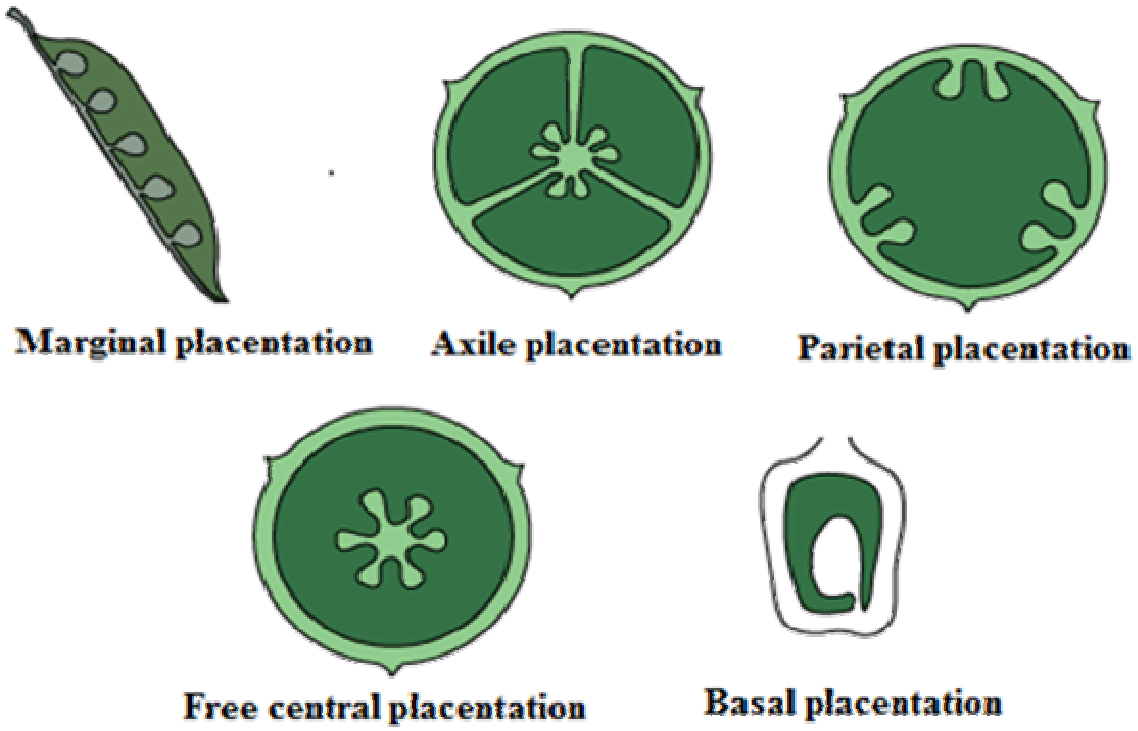


Figure 5.22 Types of Placentations

5.6 THE FRUIT

The fruit is the characteristic feature of the flowering plants. It is developed from the ovary after fertilisation. If a fruit is formed without fertilisation of ovary it is called a parthenocarpic fruit. Parthenocarpy may be natural or induced. This phenomenon is applied for the commercial production of seedless fruits e.g: Banana and grapes.

In most plants, by the time the fruit develops from the ovary, other than floral parts degenerate and fall off. However in a few plants such as apple, cashew, strawberry etc, the thalamus or pedicel also contribute to fruit formation. Such fruits are called false fruits. Most of the fruits develop only from the ovary and are called true fruits.

Generally the fruit consists of a wall, Pericarp and seeds. Based on nature of pericarp fruits are of two types 1. Fleshy fruits 2. Dry fruits

5.6.1 FLESHY FRUITS

The pericarp become fleshy at the time of ripening. It can be divided into the outer epicarp, the middle mesocarp and the inner endocarp. These are further divided into five types.

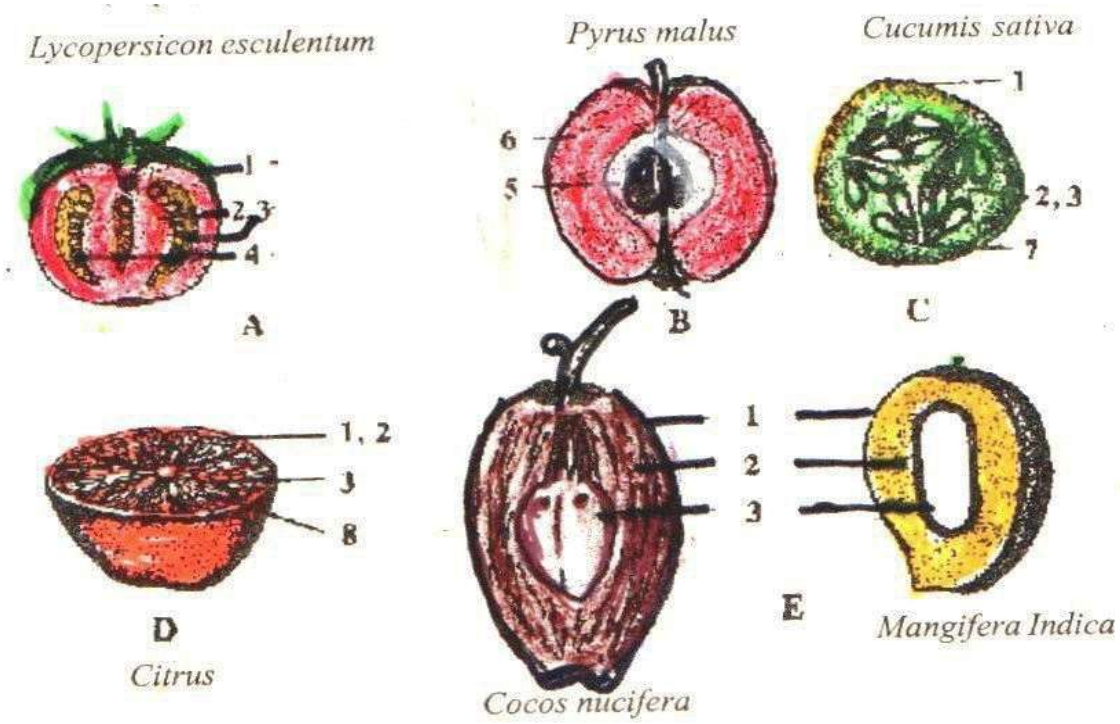
1. Berry: It is developed from ovary of bi or multicarpellary syncarpous gynoecium. The mesocarp and endocarp are fused to form pulp. e.g: *Lycopersicon* (tomato) and *Musa* (banana).

2. Pome: It is a fleshy fruit developed from inferior ovary of bi or multicarpellary, syncarpous inferior ovary of gynoecium surrounded by fleshy thalamus. e.g: *Pyrus malus* (apple).

3. Pepo: It is developed from the tricarpellary syncarpous unilocular inferior ovary of gynoecium. e.g: *Cucurbita maxima* (cucumber)

4. Hesperidium: It is developed from multicarpellary syncarpous multilocular superior ovary of the gynoecium. It is characterised by leathery epicarp with many volatile glands, papery mesocarp and endocarp wall bears juicy hairs. eg: *Citrus* species.

5. Drupe: It is developed from mono or multicarpellary syncarpous superior ovary of the gynoecium. The fruit is characterised by stony endocarp. e.g. *Mangifera indica* (mango) and *Cocos nucifera* (coconut) (Figure 5.23).



Fleshy fruits A. Berry B. Pome C. Pepo D. Hesperidium E. Drupe
1. Epicarp 2. Mesocarp 3. Endocarp 4. Seed 5. True fruits
6. Fleshy thalamus 7. Placenta 8. Juicy Hairs

Figure 5.23 Types of Fleshy fruits

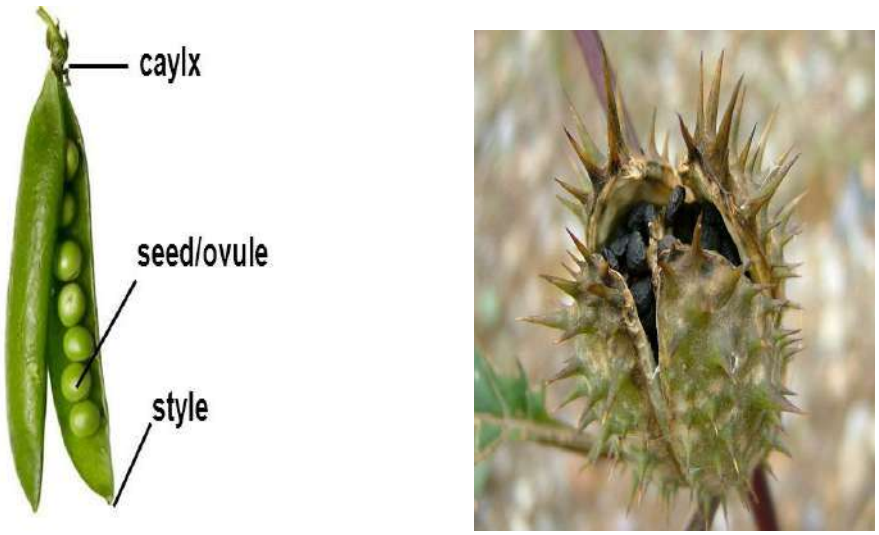
5.6.2 DRY FRUITS

In this the pericarp remains dry and undifferentiated when ripe. They are of three types. i) Dry dehiscent ii) Dry indehiscent iii) Schizocarpic.

I) Dry dehiscent: These fruits dehisce and liberate the seeds at maturity.

a) Legume: The fruits of pea and beans dehisce dorsiventrally into two halves and are called Legume .E.g: Pea and beans.

B) Capsule: A capsule dehisces in different ways and liberate the seeds. e.g: Cotton and *Datura.*



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

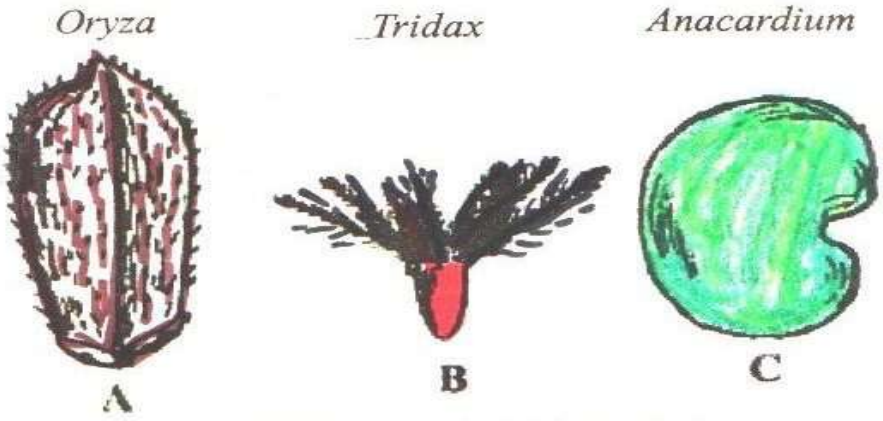
Figure 5.24 Dry dehiscent fruits

ii) Dry indehiscent: These dry fruits are normally one seeded and never dehisce even at maturity. These fruits are of following types.

a) Caryopsis: It develops from monocarpellary unilocular ovary of gynoecium. The pericarp and seed coat fuse together in grasses such as *Oryza* (rice).

b) Cypsella: It develops from bicarpellary, syncarpous unilocular inferior ovary of gynoecium. This fruit is characterised by persistant pappus like calyx.

c) Nut: It develops from multicarpellary syncarpous, unilocular ovary and the pericarp is stony. e .g. *Anacardium* (Cashew nut).



Caryopsis of Oryza Cypsella of Tridax Nut of Anacardium

Figure 5.25 Dry indehiscent fruits

iii) Schizocarpic: these are dry fruits which show the characters of both the dehiscent as well as indehiscent fruits. The fruits of Acacia and Castor split into one seeded bits called mericarps. The seeds present in the mericarps are liberated only after disintegration of the pericarp.

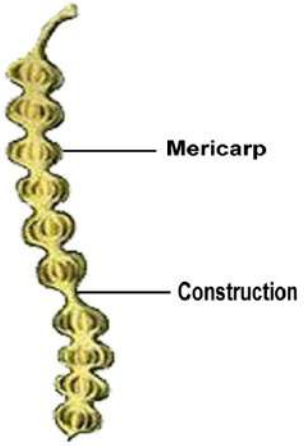


Figure 5.26 Schizocarp of Acacia

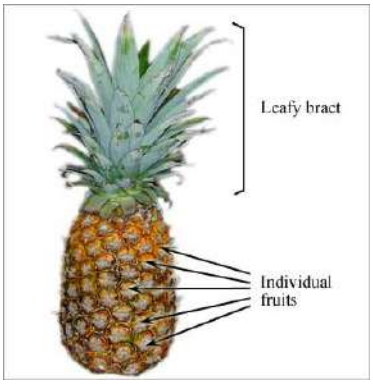
5.6.3 AGGREGATE FRUITS

These are the true fruits which develop from ovaries of multicarpellary, apocarpus gynoecium of a single flower. Ovary of each carpel develops into a fruitlet; such bunch of fruitlets are called aggregate fruit. e.g: *Annona squamosa* (custard apple) and *polyalthia* (Nara mamidi). (figure 5.27)

Figure 5.27 Aggregate fruit of custard apple

5.6.4 COMPOSITE FRUITS OR MULTIPLE FRUITS

These fruits are developed from complete inflorescence along with its component parts. The fruits developed from all the flowers of the inflorescence are associated closely and form one single composite fruit at maturity. E.g: *Ananas sativus* (pine apple) and *Artocarpus.* (Jack fruit) (figure 5.28)



5.28 Compound fruit of pineapple

5.7 THE SEED

The ovules after fertilisation develop into seeds. A seed is made up of a seed coat and an embryo. The embryo is made up of an embryonal axis and one (as in wheat, maize) or two cotyledons (as in gram and pea).

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. Genarally, 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 feature of stems like the presence of nodes and internodes. Multicellular hair and positively phototrophic 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 exogenously 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 sepals, petals, ovules etc., after fertilization, the ovary converted into fruit and ovule into seed. A fruit developing fertilized

ovary is called 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 fruit like structure is called False fruit. Based on nature of fruit wall, true fruits may be fleshy or dry. Fleshy fruits may be berries, drupes, pomes, pepos or hesparidiums. 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 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.

Androecium: The whorl of stamens in a flower that represent the male reproductive organ.

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

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

Bract: A thin membranous leaf like structures from the apex towards base of an axis.

Bracteoles: Thin, membranous structures that are formed on the pedicles 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 below the soil**.**

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

Epiphyllous stamens: Stamens attached to the perianth.

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

Geotropism: The influence of gravity on the growth.

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

Incomplete flower: A flower 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.

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

Mericarp: The one seeded bits of schizocarpic fruits.

Modification: A permanent morphological change in an organ in order to perform special function.

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.

Pericarp: The wall of the fruit which is differentiated into epicarp,mesocarp and 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 gives rise to shoot system.

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

Radicle: The tip of the embryonic axis which gives rise to root system.

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 a flower without stalk**.**

Sorosis: The compound 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.

Syconus: The compound fruit that develops from hypanthodium inflorescence.

Thalamus: The dilated tip of the pedicel.

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

Zygomorphic flower: The flowerthat can be cut intotwo equal halves in one verticalplane.

Very Short Answer type Questions

1. What type of specialized roots found in epiphytic plants?
2. Define Venation.
3. How do dicots differ from monocots with respect to venation?
4. Which organ is modified to trap insects in insectivorous plants?
5. What type of inflorescence is found in fig trees?
6. Define placentation.
7. What type of placentation is found in Dianthus?
8. What is meant by parthenocarpic fruit?
9. Why certain fruits are called false fruits?
10. Name two examples o plants having false fruits.
11. Name any two plants having single seeded dry fruits.
12. What are aggregate fruits? Give two examples.
13. Define schizocarpic dry fruits.

Short Answer type Questions

1. Explain with examples different types of phyllotaxy.
2. Describe any two special types of inflorescences.
3. Describe in brief the fleshy fruits studied by you.
4. Explain how root is modified to perform different functions. (any four).
5. Explain how stem is modified variously to perform different functions.(any four).
6. Explain with examples different types of aestations?
7. Describe any four types placentations found in flowering plants?

EXERCISES

1. Needle like Phylloclades are found in which which plants?
2. Which family shows naked flowers?
3. Why do plants like Nepenthes trap insects?
4. Which part of the in cashew plant form the false fruit?
5. Which type of fruit known as if it develops from apocarpous ovary of a single flower?

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 span of different plants varies from a few days to 1000+ years.

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 certainity, 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.

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.

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 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 parents. Asexual reproduction is common among single-celled organisms, and in plants with relatively simple organisations. Many single-celled organisms like protists and Monerans reproduce by binary fission (figure 6.1 a). 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 6.1 b).

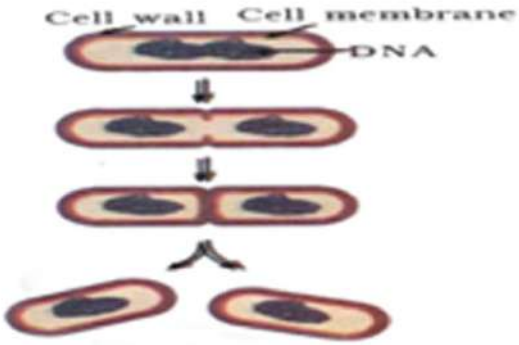


Figure 6.1 (a) Binary fission in bacteria

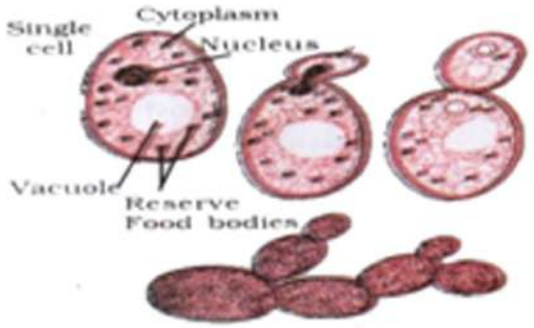


Figure 6.1 (b) Budding in Yeast

Several members of the kingdom Fungi and simple plants such as Algae reproduce through special asexual reproductive structures called **spores** (Figure 6.2). The spores produced by mitosis in some algae such as *Chlamydomonas,* which are motile are known as zoospores. The spores produced by the common bread mould i.e.. *Rhizopus* are non-motile, these are produced in sporangia.

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

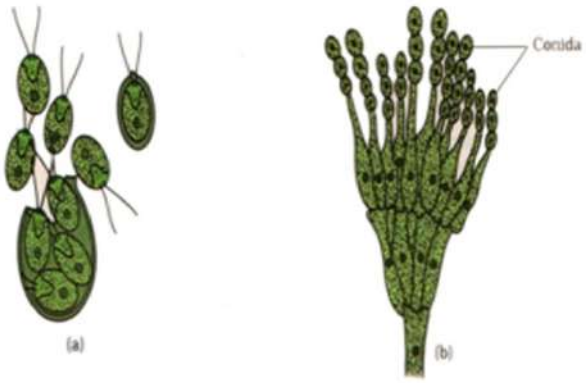


Figure 6.2 Asexual Reproductive Structures

a. Zoospores of *Chlamydomonas*

b. Conidia of *Pencillium*

Figure 6.3 Gemmae in liver worts

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 separated 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 6.3).

In flowering plants the units of **vegetative propagation** such as **runner, stolon, sucker, offset, rhizome, corm, tuber, bulb, bulbil, reproductive leaves** (described in Chapter5) are capable of giving rise to new offspring (Fig 6.4).

These structures are called **Vegetative propagules**. Plants produced vegetatively or asexually are called **clones.**

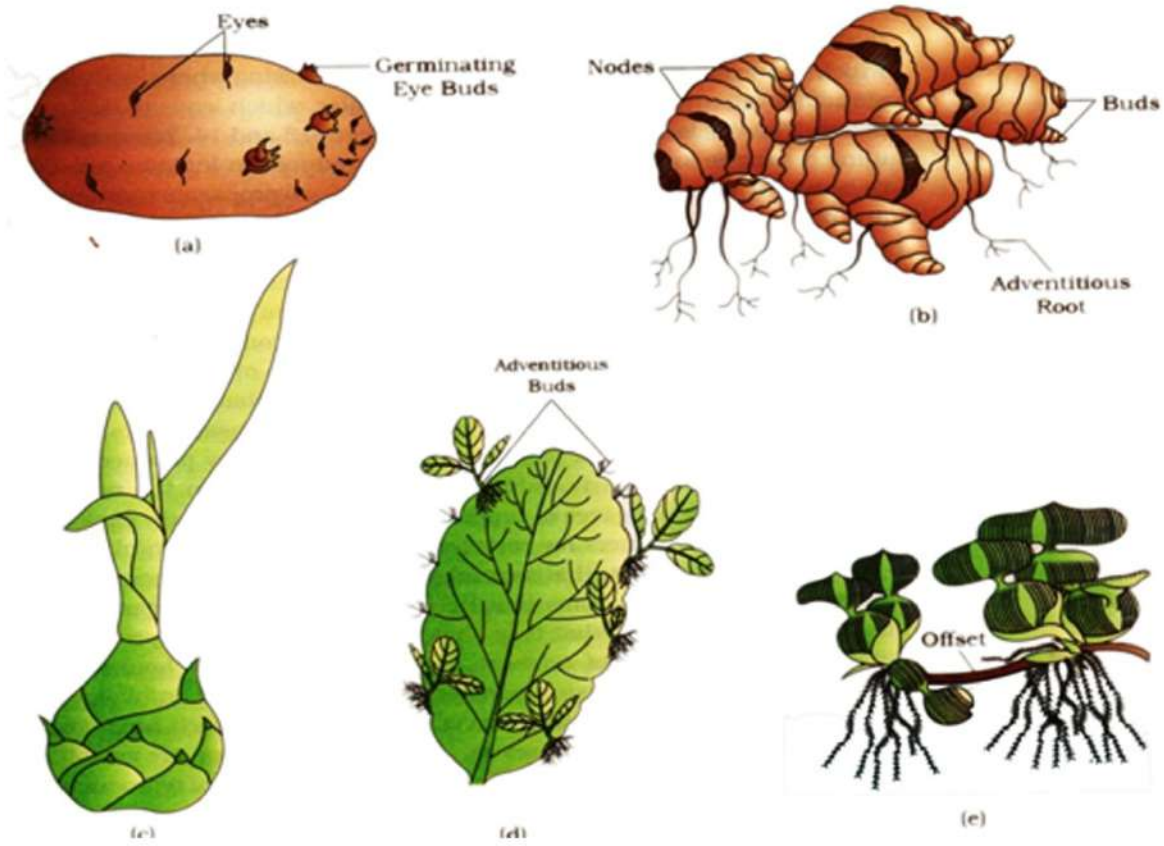


Figure 6.4 Vegetative propagules in angiosperms: (a) Eyes of Potato: (b) Rhizome of ginger: (c) Bulbil of Agave; (d) Leaf buds of Bryophyllum; (e) Offset of water hyacinth.

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.

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?

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. For sake of convenience, these sequential events may be grouped into three distinct stages namely, the **pre- fertilisation, fertilisation** and the **post- fertilisation** events.

6.3.1.1 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.

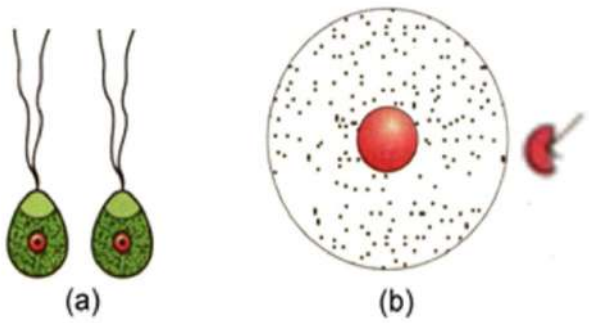


Figure 6.5A Isogametes of Cladophora (an alga) b) Heterogamets of Fucus (an alga)

6.3.1.2 Gametogenesis

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 similar in appearance that it is not possible to categorize them into male and female gametes. They are called homogametes (isogametes). e.g: *Cladophora* (Figure6.5 a). However, in majority of sexually reproducing organisms the gametes produced are of two morphologically distinct types (heterogametes) (Figure 6.5 b). In such organisms, the male gamete is called the antherozoid or sperm and the female gamete is called the egg. eg: *Funaria, Fucus.*

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 6.6 a) or on different plants (Unisexual (Figure 6.6 b). In several fungi and plants, terms such as **homothallic** (Fungi) and **monoecious** (plants) are used to denote the bisexual condition and **heterothallic** (Fungi) and **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 present on the same individual (monoecious figure 6.6 c) or on separate individuals (dioecious).

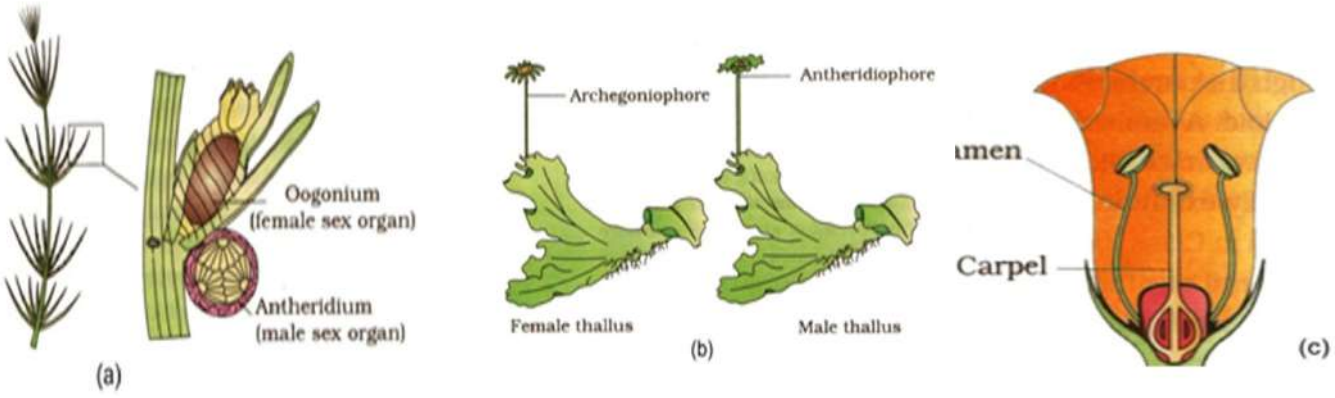


Figure 6.6 Diversity of sexuality in organisms a) Monoecious plant (Chara) b) Dioecious plant (Marchantia) c) Bisexual flower (sweet potato)

6.3.1.3 Gamete Transfer

After their formation, male and female gametes must be physically brought together to facilitate fusion (fertilisation). In a majority of organisms, male gamete is motile and the female gamete is stationary. Exceptions are a few fungi and in algae in which both types of gametes are motile. 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. 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. 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 shed, come in contact with the stigma. But the cross pollinating plants (including dioecious plants), a specialised 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.

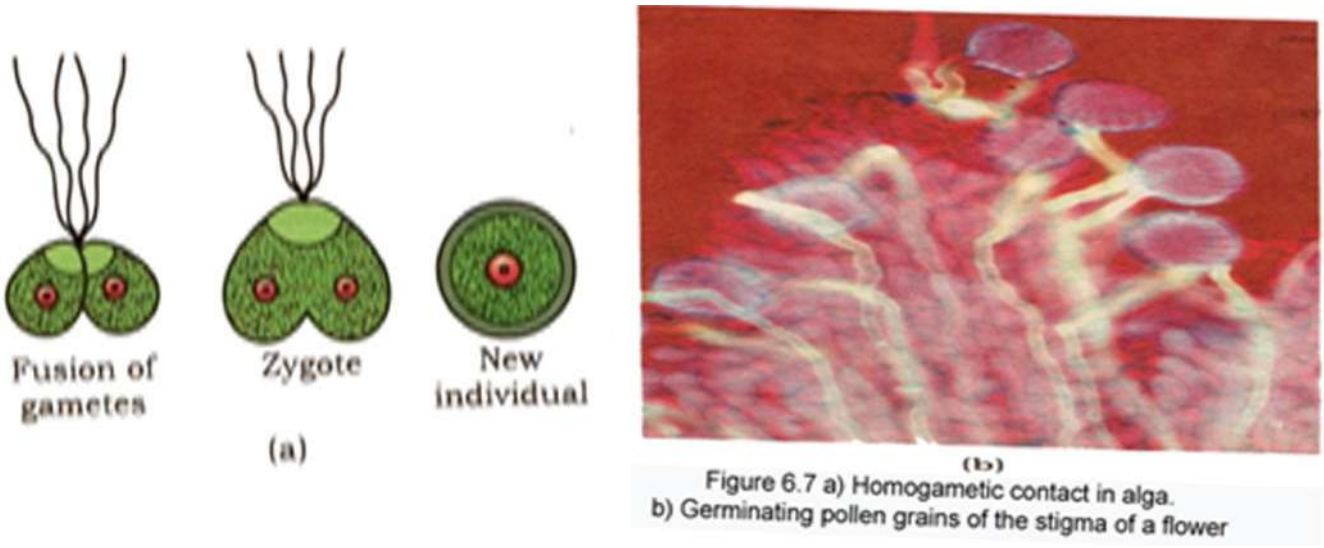


Figure 6.7 a) Homogametic contact in alga.
b) Germinating pollen grains of the stigma of a flower

6.3.1.4 Fertilisation

The most vital event of sexual reproduction is perhaps the fusion of gametes. This process is called syngamy results in the formation of a diploid zygote. Sometimes fruits are produced from flower without fertilisation. It is the development of an embryo from an unfertilised female gamete, and this phenomenon is known as Parthenogenesis. 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 organism. This type of gametic fusion is called external fertilisation. In many terrestrial organisms, belonging to fungi, and in a majority of

plants (bryophytes, pteridophytes, gymnosperms and angiosperms), syngamy occurs inside the body of organism, hence the process is called internal fertilisation.

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), where as in those exhibiting internal fertilisation, zygote is formed inside the body of the organism. 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 zygote. During embryogenesis, zygote undergoes cell division (mitosis) and cell differentiation.

In flowering plants, the zygote is formed inside the ovule. After fertilisation the sepals, petals and stamens of the flower wither and fall off. 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 6.8). After dispersal, the 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.** It is the strategy to lower the environmental stress and ensuring successful establishment of plantlet.

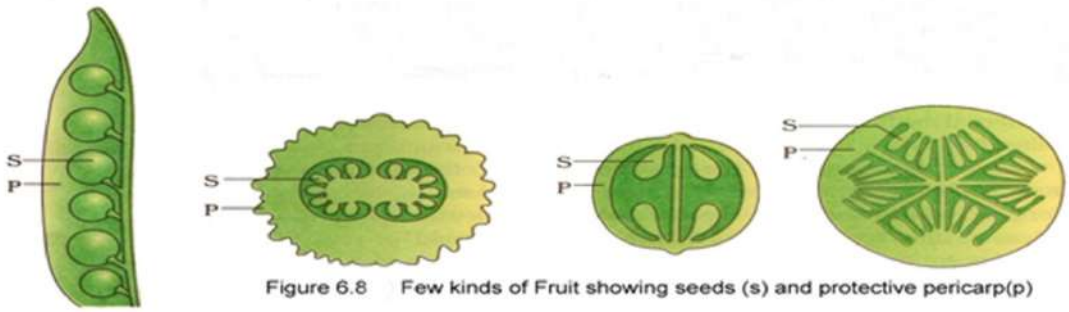


Figure 6.8 Few kinds of Fruit showing seeds (s) and protective pericarp(p)

6.4 AN OVERVIEW OF THE ANGIOSPERM LIFE CYCLE

In the Angiosperms or flowering plants, the pollen grains and ovules are developed in specialized structures called flowers. 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 the ovules are present highly reduced female gametophytes termed embryo sac. 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 antipodals 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 tube enters 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 involvement of two fusions, this event is termed as double fertilisation, an event unique to angiosperms. The zygote develops into an embryo and the PEN develops into endosperm which provides nourishment to the developing embryo. The synergids and antipodals degenerate after fertilisation. The life cycle of an angiosperm is shown in Figure 6.9. 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.

Fertilisation gives rise to a multicellular diploid sporophyte which produces haploid spores via meiosis and a few celled gametophyte. This type of life cycle is called a diplohaplontic life cycle.

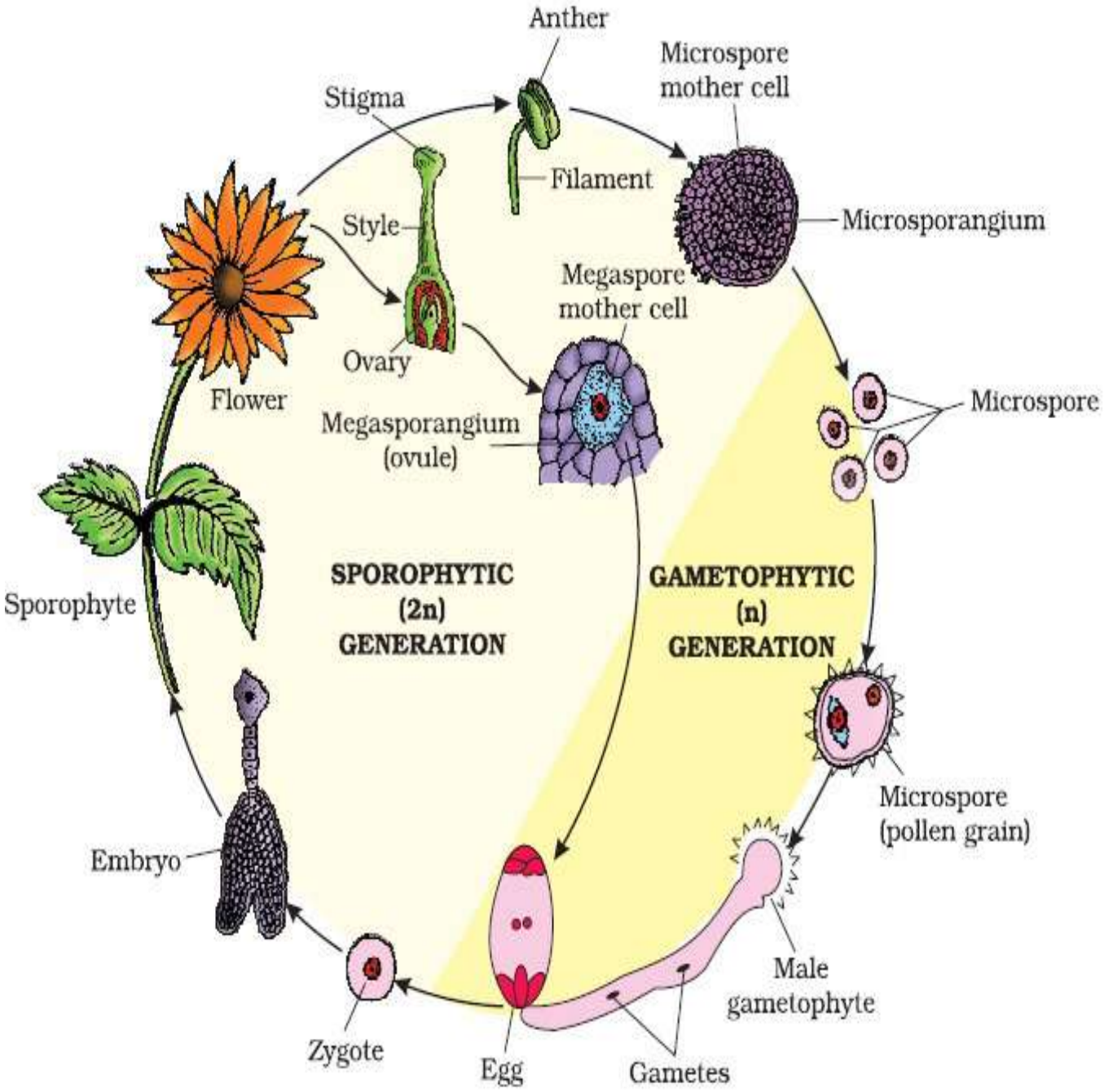


Figure 6.9 Life cycle of an angiosperm

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 sexually 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 reproduction.

Sexual reproduction involves the formation and fusion of gametes. It is complex and slower process as compared to asexual reproduction. Events of sexual reproduction may be categorized into pre-fertilisation, fertilization and post-fertilisation events. Pre- fertilization events include gametogenesis and gamete transfer while post-fertilisation events include the formation of zygote and embryogenesis. 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. In, angiosperms a special process called pollination ensures the transfer of pollen grains to stigma. Syngamy (fertilization) occurs between the male and female gametes. Syngamy leads to the formation of a specialized cell called zygote. The process of development of embryo from the zygote is called embryogenesis.

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

GLOSSARY

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

Budding: Reproduction of some unicellular organisms (such as yeasts) by growth and specialization followed by the separation by construction 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 the pant body breaks into fragments by mechanical methods.

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

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.

Monoecious: Presence of both male 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): It is enclosure in which spores are formed.

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

Syngamy: The fusion of two gametes in fertilization.

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.

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. Hoe do liver worts reproduce vegetatively?
3. Define Vivpary with an example.
4. What do the following parts of a flower develop into after fertilisation?
   A) Ovary B) Ovules

SHORT ANSWER TYPE QUESTIONS

1. List the changes observed in angiosperm flower subsequent to pollination and fertilisation?
2. Justify the statement 'Vegetative reproduction is also a type of asexual reproduction'.

EXERCISES

1. Why is reproduction essential for organisms?
2. Why is the offspring formed by asexual reproduction referred to as clone?

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. Can you name the parts in a flower in which the 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 male and female reproductive structures, the androecium and the gynoecium, differentiate and develop.

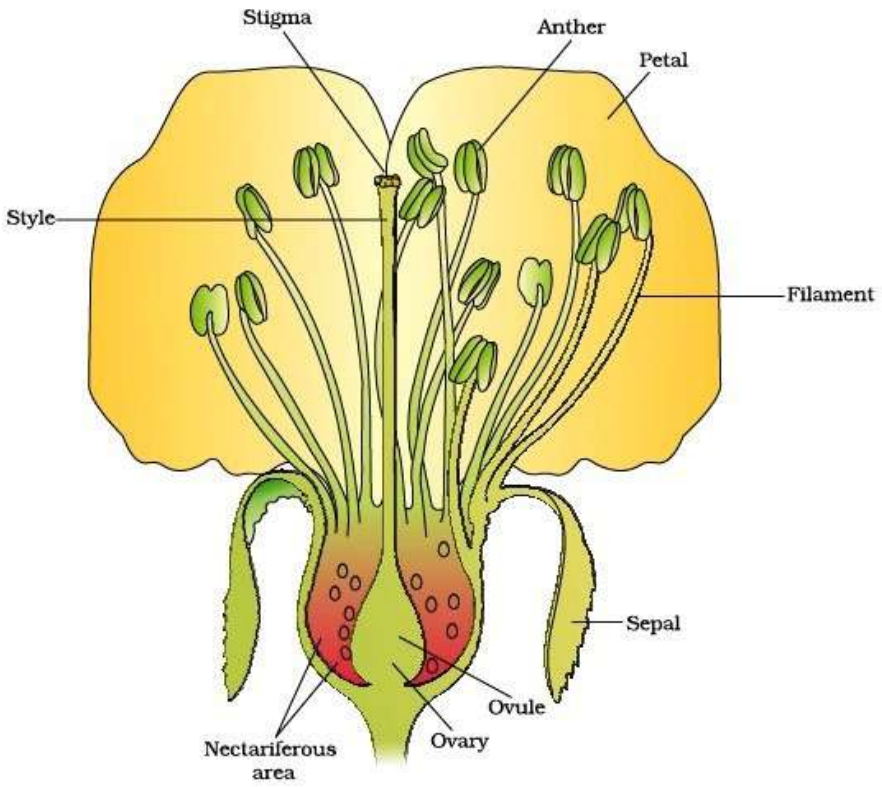


Figure 7.1 Diagrammatic representation of L.S of a Flower

7.1.1 Stamen, Microsporangium and Pollen Grain

A typical stamen consists of the long and slender stalk called the filament, and the terminal generally bilobed structure called the anther (Figure 7.2 a). 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.

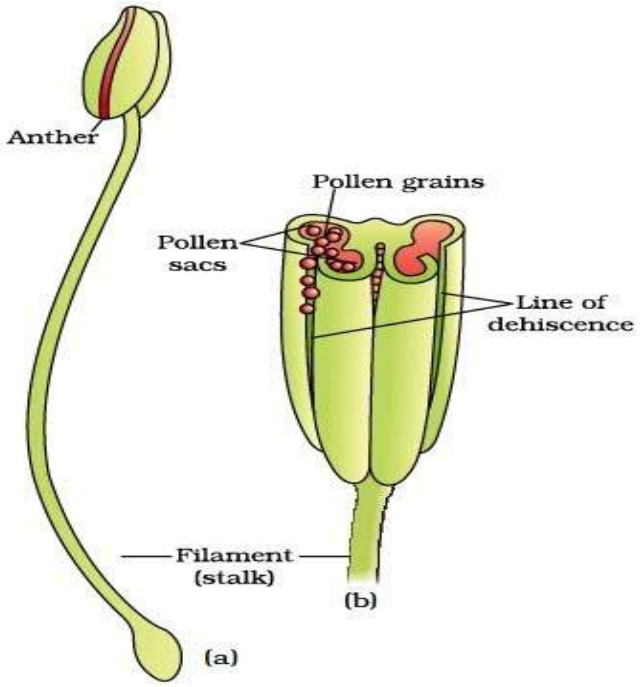


Figure 7.2 (a) A typical stamen (b) three - dimensional cut section of an anther

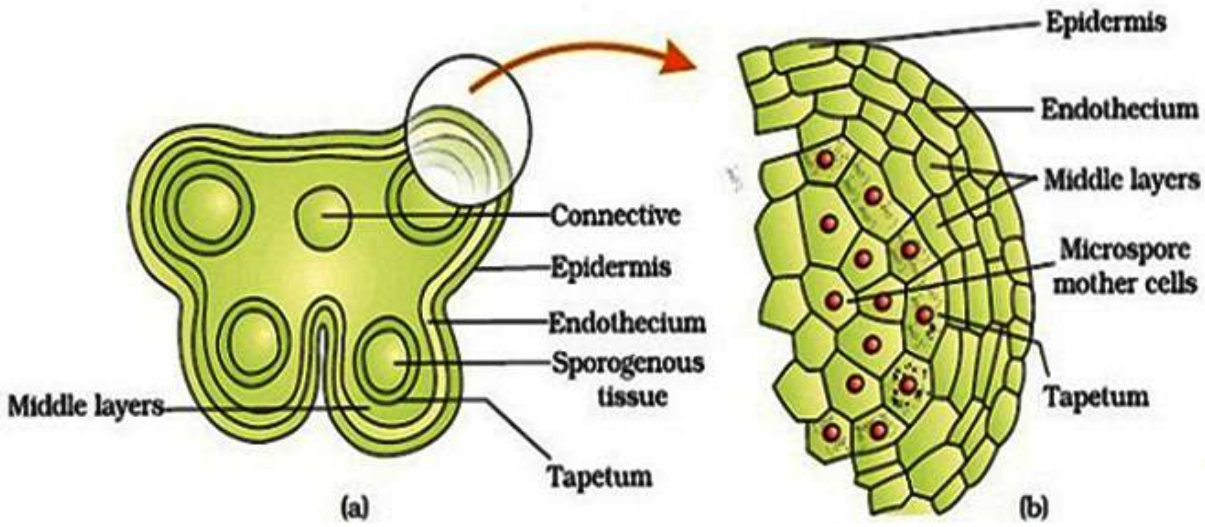


Figure 7.3 (a) Transverse section of a young anther
(b) Enlarge view of one microsporangium showing wall layers

Structure of Anther

A typical angiosperm anther is bilobed with each lobe bears two pollen chambers or pollen sacs placed longitudinally (Figure7.2b). Each pollen chamber represents a microsporangium. Thus a dithecous anther (two lobed anther) comprises of four pollen sacs. The two microsporangia are separated by a strip of sterile tissue.

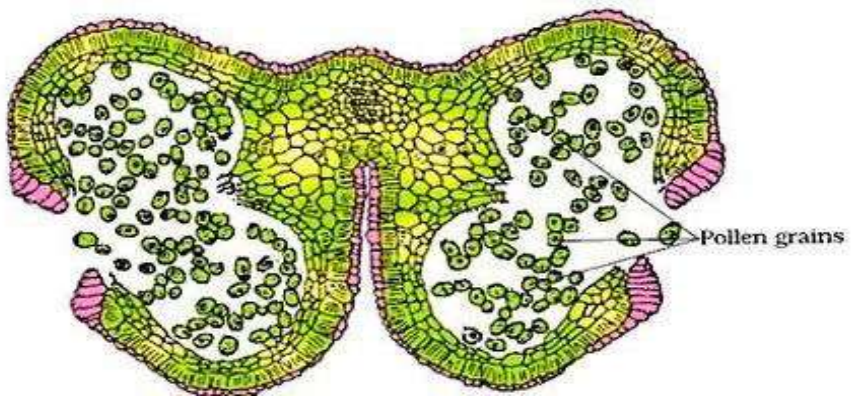


Figure 7.3 (c) A mature dehisced anther.

Structure of microsporangium

Each microsporangium of an anther at maturity, consists of sporogenous tissue covered by Four wall layers (Figure 7.3 b).

I. Anther wall: It consists of epidermis, endothecium, middle layers and tapetum.

1. **Epidermis:** It is one celled thick outer layer useful for protection. The epidermal cells present between two pollen sacs are thin walled and constitute 'stomium' which is useful for the dehiscence of pollen sacs. The stomium degenerates by the time the spore mother cells undergo divisions.
2. **Endothecium**: It is present below the epidermis. The cells of this layer are expanded radially to form fibrous thickenings of cellulose. The thickenings are hygroscopic. When endothcial cells lose water, they contract and help in the dehiscence of pollen sacs.
3. **Middle layers**: Beneath the endothecium there are thin walled cells arranged in one to five layers which constitute middle layers.
4. **Tapetum:** The layer present below the middle layers is called tapetum. It is the innermost layer of anther wall which encircles the sporogenous tissue. The cells in this layer are large, with thin walls, abundant cytoplasm and prominent nuclei. Generally the cells of tapetum are bi or multinucleate. Tapetum is the nutritive tissue which supplies

nourishment to the developing sporogenous tissue and by the time the anther dehisces, the tapetum is completely utilised.

II. Sporogenous tissue

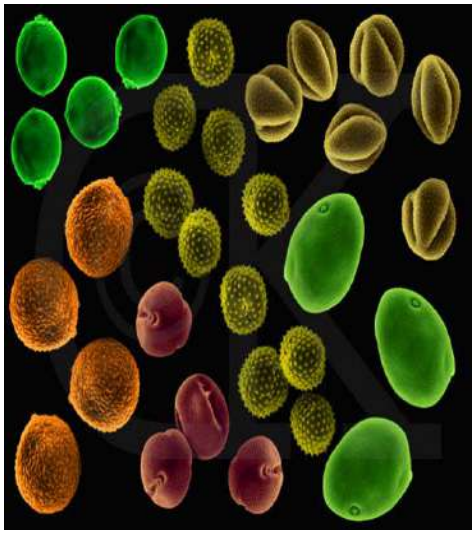
The tissue present inside the anther wall is called sporogenous tissue and this is fertile in nature. It is diploid in nature. The cells in this tissue undergo mitotic divisions to form microspore mother cells

Microsporogenesis: The diploid microspore mother cells formed from the sporogenous tissue divide meiotically to form microspores.

Each microspore mother cells forms a tetrad of microspores. The process is known as microsporogenesis. Older microspores particularly after their release from the tetrads are referred to as pollen grains. Pollen grains are haploid (n), unicellular and uninucleate. (diagrams)

Pollen grain: The Pollen grains represent the male gametophytes. Pollen grains are generally spherical or oval or of various shapes with (Figure 7.4) two layered spore wall. The outer layer is called 'exosporium or exine' and it is made up of most resistant material known as sporopollenin. Thin circular places in exine are called 'germ pores'. Pollen grains well preserved as fossils because of the presence of sporopollenin.

The inner wall of the pollen grain is called intine. It is thin and continuous layer made up of cellulose and pectin. The cytoplasm of pollen grain is surrounded by a plasma membrane. When pollen grain is mature it contains two cells, the vegetative cell and generative cell. The vegetative cell is bigger and the generative cell is small (7.5 b). In over 60 percent of angiosperms, pollen grains shed at this two celled stage. 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).



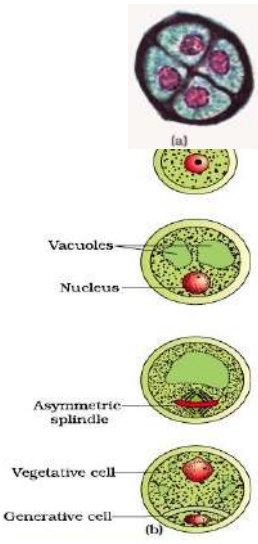


Figure 7.4 Scanning electron micrographs of a few pollen grains

Figure 7.5 (a) Enlarged view of a pollen grain tetrad (b) Stages of a microspore maturing in to a pollengrain

7.1.2 The Pistil, Megasporangium (ovule) and Embryo sac

The gynoecium represents the female reproductive part of the flower. The gynoecium may consists 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 7.6 a,b) or may be free (apocarpus e.g; *Annona*, *Michaelia*) (Figure 7.6 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 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. Arising from the placenta are the megasporangia, commonly called ovules. The number of ovules in the ovary may be one (wheat, paddy, sunflower) to many (papaya, water melon, orchids).

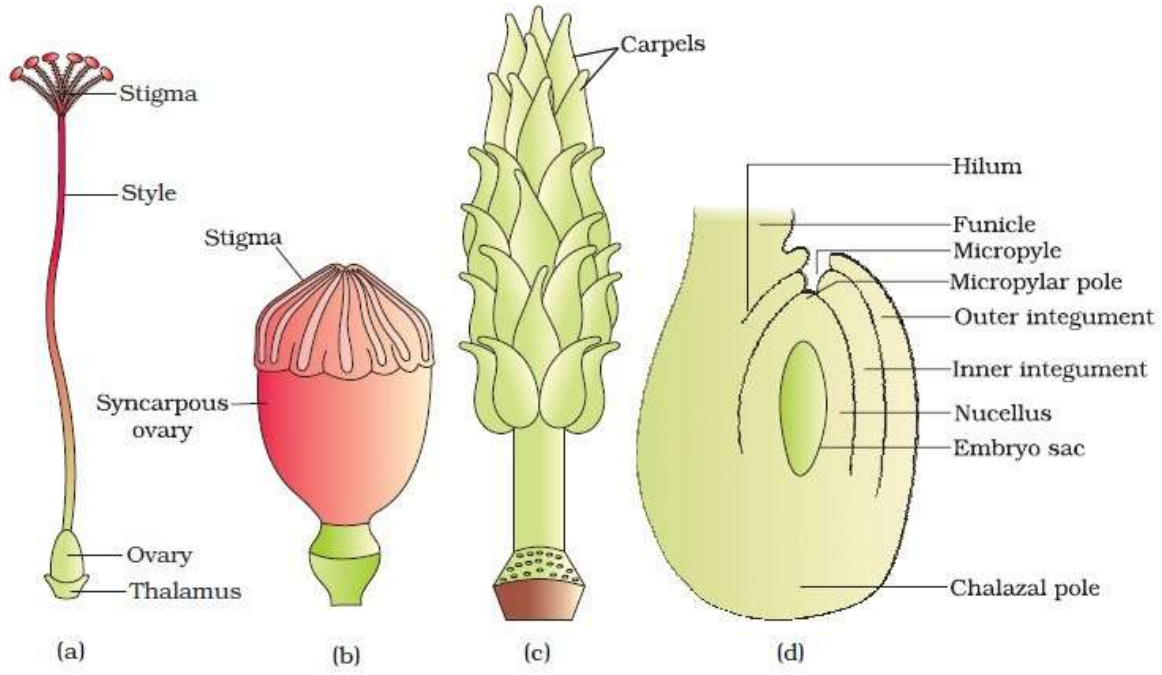


Figure 7.6 (a) A dissected flower of Hibiscus showing pistil (other floral parts have been removed)
(b) Multicarpellary, syncarpous pistil of *papaver*
(c) A multicarpellary, apocarpous gynoecium of *Michelia*

(d) A diagrammatic view of typical anatropous ovule

The Megasporangium (ovule)

Ovules are considered as integumented megasporangia. In the ovary they are attached to the placenta by the slender stalk known as funiculus. The point of attachment of the body of the ovule to its stalk (funiculus) is known as hilum. The ovules contains a diploid nutritive tissue called the 'nucellus'. Covering this tissue there are one or two protective membranes which are called the 'integuments'(7.6 b). Based on number of integuments, the ovules are classified into three types.

a) **Ategmic ovules**: The nucellus of the ovule is not covered by the integuments. E.g*; Loranthus, Balanophora*.

b) **Unitegmic ovules:** The ovules are covered by single integument. E.g: Asteraceae, Solanaceae members.

c) **Bitegmic ovules**: Nucellus is covered by two integuments. E.g: Monocots, polypetalae members of dicots.

The integuments and the nucellus unite at the base of the ovule. This place is called 'Chalaza.' The integuments do not cover the nucellus completely but leave an apical opening. This apical pore is called 'micropyle'. Hence the anterior part of the ovule is called micropylar end and posterior part is called 'Chalazal end'. Each ovule encloses a large embryo sac or female gametophyte. An ovule generally has a single embryo sac formed from a megaspore through reduction division. Many types of ovules are found in angiosperms. Based on position of micropyle in relation to the funiculus and other parts of the ovule, ovules are of the following types.

Types of ovules:

1) **Orthotropus ovule**: It is straight ovule. In this type of ovule the micropyle, chalaza and funiculus are arranged on the same vertical line (Figure 7.7a). e.g: *Polygonum.*
2) **Anatropous ovule**: It is inverted ovule and the degree of curvature of the body of the ovule is 180^0 In this, the ovule bends back alongside the funiculus so that the micropyle lies close to the funiculus (Figure 7.7 b). e.g: Asteraceae family members.
3) **Campylotropous ovule:** In this type also, body of the ovule is placed at right angles to the

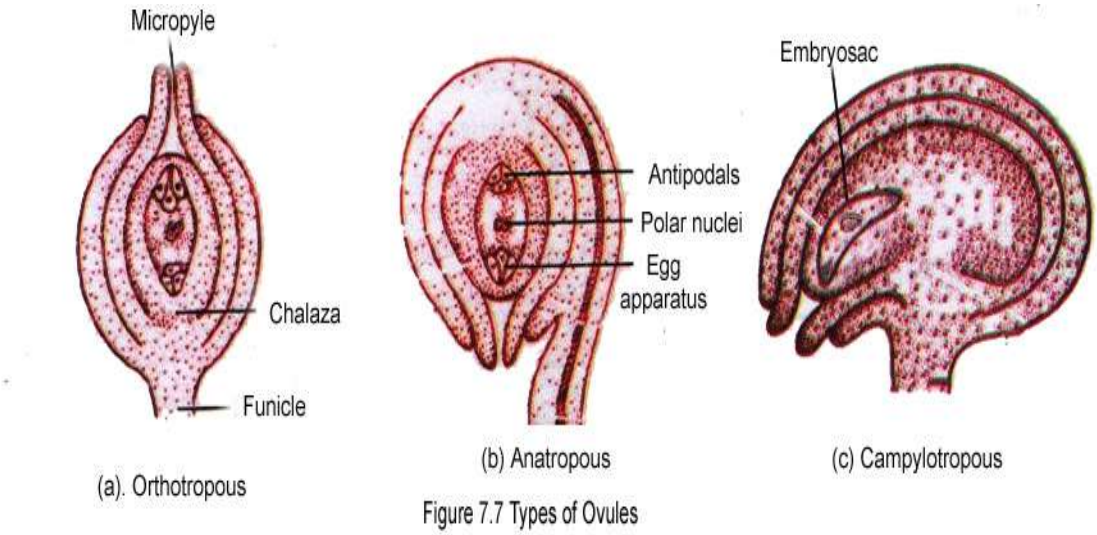
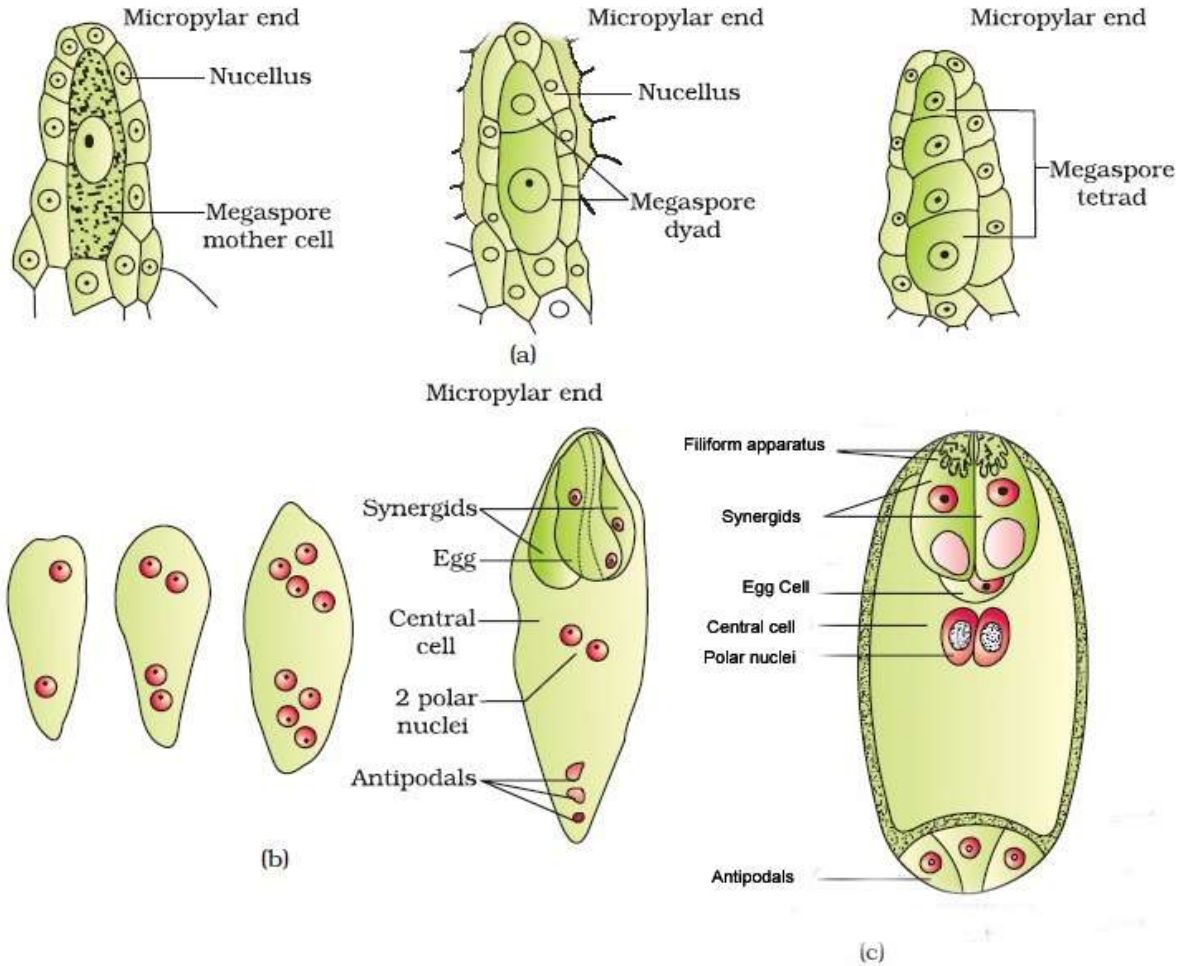


Figure 7.7 Types of Ovules

funiculus. The embryo sac is straight or slightly curved (Figure 7.7 c). e.g: Fabaceae and Brassicaceae.

Megasporogenesis & development of embryo sac:

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. The MMC undergoes meiotic division forming a tetrad of megaspores and are arranged linearly (Figure 7.8 a). The upper three megaspores arranged towards micropyle degenerate and lower fourth one remains functional. It is called 'functional megaspore'. It act as a mother cell for development of an embryo sac or female gametophyte. The nucleus of the functional megaspore divides simultaneous mitotic divisions and form eight nuclei (Figure 7.8 b). Out of eight nuclei the three nuclei present near the micropylar end develop into an egg apparatus with the formation of cell walls. The three nuclei present near the chalazal end develop into antipodals with the development of cell walls. The two polar nuclei migrate



from the poles towards the centre of the embryo sac fuse to form a diploid 'secondary nucleus' and it is enclosed in a central cell. This eight nucleated and seven celled embryo sac is called **female gametophyte** (7.8 c).

Figure 7.8 (a) Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores.
(b) 2, 4 and 8-nucleus stages of embryo sac and a mature embryo sac
(c) A diagramatic representation of the mature embryo sac.

Structure of female gametophyte

The female gametophyte of angiosperms is called 'embryo sac'. It is called 'polygonum type'. Since it was first studied in *Polygonum divaricatum* by Strasburger. The embryo sac has Three parts: 1. Egg apparatus 2. Antipodals 3. Central cell.

1. **Egg apparatus**: The three cells are grouped together at the micropylar end constitute the egg apparatus. The middle cell of the egg apparatus is big and act as an 'egg cell'. The remaining two cells present on either side are called 'synergids'. They contain finger like projections called 'filiform apparatus'. They help in directing the movement of pollen tube towards the embryo sac by secreting some chemicals and also help in absorption and conduction of food materials.
2. **Antipodals**: The three cells arranged on the posterior side of the embryo sac nearer to the chalaza are called 'antipodals'. They remain ephemeral and degenerate before or after fertilisation.
3. **Central cell***:* It is the largest cell of the embryo sac which has centrally located vacuole and polar nuclei. The polar nuclei fuse to form a diploid nucleus. It is called 'secondary nucleus'.

7.2 POLLINATION:

The process of transfer of pollen grains from anthers to stigma is called pollination. In all flowering plants it occurs invariably prior to the fertilisation. In angiosperms as the ovules are embedded inside the ovary, the pollen grains fall on the stigma. This type of pollination is called 'indirect pollination'. In gymnosperms, ovary is absent, hence the ovules are naked. The pollen grains fall directly on ovule. Such a mode of pollination is termed as "direct pollination".

The flowers which do not open are called cleistogamous flowers and the pollination in them is called cleistogamy.

The flowers which open are called chasmogamous flowers and the pollination in them is called chasmogamy.

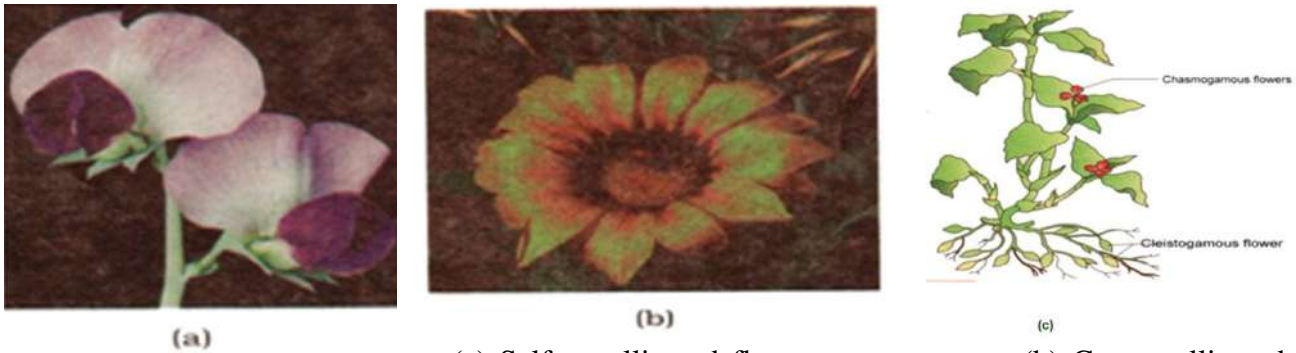
The pollination in angiosperms is classified into two types: 1. Self pollination 2.Cross pollination .

1. **Self pollination or autogamy** : The transfer of pollen grains from the anthers to stigma of the same flower is called 'self pollination'(7.9 a).This type of pollination is possible only in bisexual flowers. It is found in both **cleistogamous** and **chasmogamous** flowers (7.9c).
2. **Cross pollination or Allogamy** : The transfer of pollen grains from the anthers of one flower to the stigma of another flower of the same species is called ' cross pollination' (Figure 7.9 b). It occurs in **chasmogamous** flowers. It also seen in some closed flowers in which the mature anthers and stigmas protrude from the flowers. The cross pollination is of two types.

   i) Geitonogamy: It is a type of cross pollination that occurs between two flowers present on the same plant. That means the pollen grains of one flower fall on the stigma of another flower present on the same plant.

   ii) **Xenogamy**: If the pollen grains of one flower reach the stigma of another flower of another plant belonging to the same species it is called Xenogamy.

Figure 7.9



(a) Self – pollinated flowers (b) Cross pollinated flowers (c) Cleistogamous flowers

7.2.1 Agents of pollination: As the pollen grains are not capable of reaching stigmas spontaneously, they take the help of some external agents to get pollinated. The relationship between the agent and the structure of the flower reveals the pollination mechanism. Pollination requires an abiotic and a biotic agent. Abiotic agents include wind and biotic agents are animals (insects, birds, bats and snails).

Abiotic	Wind	Anemophily

	Water	Hydrophily
Biotic		
Animals	Birds	Ornithophily
	Bats	Chiropterophily
	Insects	Entamophily
	Snails	Malacophily
	Squirrels	Therophily
	Reptiles	Ophiophily

Table 7.1 Agents of cross pollination

ABITIC AGENTS: **I. Anemophily** : The pollination that occurs through wind is called anemophily. E.g. *Oryza* (paddy)

II. Hydrophily : The cross pollination that takes place through water is called hydrophily. It occurs in hydrophtes. The hydrophily is of two types.

i) **Epihydrophily** : The pollination that occurs on the surface of water is called epihydrophily. eg: *Vallisneria* (Figure 7.10*).*

ii) **Hypohydrophily** : The pollination that occurs beneath the surface of water is called hypohydrophily. e.g: *Zostera*

BIOTIC AGENTS

III . Zoophily: The cross pollination favoured by animals is called zoophily. Depending upon the type of animals which act as an agent the zoophily is of different types.

I) **Ornithophily**: It takes place with the help of birds. Eg. *Bignonia.*

II) **Chiropterophily**: It is favoured by bats. e.g: *Kigelia pinnata* (sausage tree).

III) **Entomophil**y: It takes place by insects Figure 7.10 b. This is the most common type of zoophily. e.g: *Cestrum nocturnum.*

IV) **Malacophily**: Pollination favoured by slugs and snails. e.g: Archids.

V) **Therophily** : Pollination by squirrels.

VI) Ophiophily: Pollination by arboreal (tree dwelling) rodents, and reptiles (snakes).

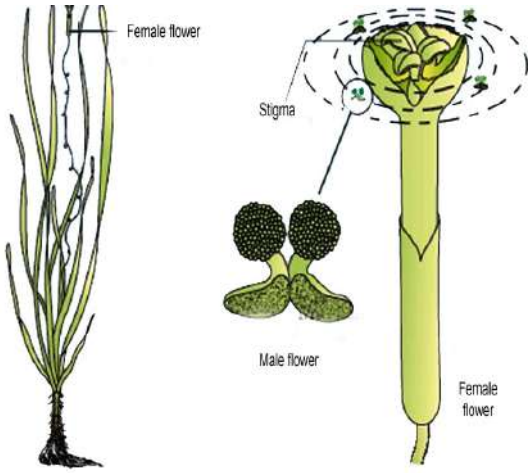


Figure 7.10 (a) Pollination by water in Vallisneria (b) Insect Pollination

7.2.2 OUT BREEDING DEVICES (CONTRIVANCES FOR CROSS POLLINATION)

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. Some of the devices for cross pollination are as follows :

1.Dichogamy: In this type the androecium and gynoecium of a bisexual flower mature at different times. It is of two types:

a)Protandry : In a bisexual flower if the androecium matures earlier than gynoecium, by the time of gynoecium matures, the entire pollen fall off from the stamens and hence self pollination does not occur. e.g: *Gossypium* and *Helianthus.*

b)Protogyny : In a bisexual flower if the gynoecium matures earlier than the stamens. By the time the gynoecium matures, the stamens remain immature in condition. E.g: *Solanum* and *Datura.*

2. Herkogamy: The arrangement of male and female reproductive organs at different levels in a bisexual Flower is called 'herkogamy'. In some flowers stigmas project beyond the stamens. E.g*: Hibiscus*. (Figure 17.11 a)

3. Heterostyly: The presence of styles in different lengths in the flowers of the same species is called heterostyly (Figure 7.11b). It is of two types.

i) **Diheterostyly**: Arrangement of styles in two different heights in flowers of the same species. In these flowers cross pollination takes place between the flowers having styles and stamens of same height. e.g: *Primula* and *Oldenlandia.*

ii) **Triheterostyly**: In some plants three forms of flowers are present. In these flowers the styles and stamens are arranged in three different lengths (short, long and medium sizes). In these flowers cross pollination occurs between the flowers in which styles and stamens are in the same height. E.g: *Lythrum* and some species of *Oxalis.*

Figure 7.11 (a) Herkogamy in Hibiscus

Figure 7.11 (b) Heterostyly

4. Self sterility: In some bisexual flowers if the pollen grains fall o the stigma of the same flower, germination does not occur. But the same pollen grains germinate, when they fall on the stigma of the other flowers of the same species. e.g: *Abutilon* and *passiflora.*

5. Dicliny or unisexuality: In some species, the flowers contain either of the essential organs i.e. androecium or gynoecium. These flowers are called 'unisexual flowers', production of unisexual flowers are called 'dicliny'. e.g. *Vallisneria.*

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 pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma (Figure 7.13 a) or the pollen tube growth in the style. All these events from pollen deposition on the stigma until pollen tube enter the ovule are together referred to as pollen-pistil interaction.

7.4 FERTILISATION

The fusion of male and female gametes is called fertilisation. In angiosperms the female gametophyte (embryo sac) is embedded in the ovule. The male gametophytes (pollen grains) at two celled stage reach the stigma by pollination. They germinate on the stigma and produce pollen tubes. These pollen tubes grow into the style, reach the ovule and release male gametes into the embryo sac.

7.4.1 Process of fertilisation

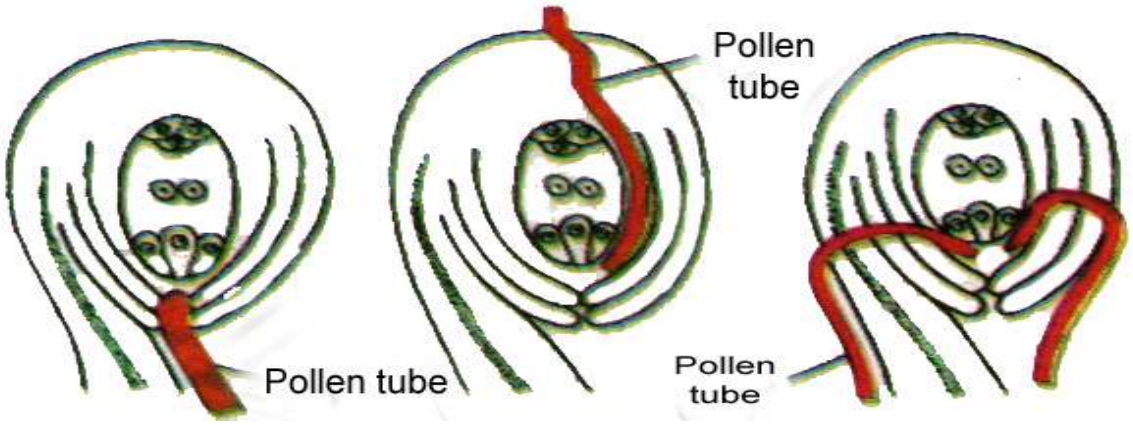
The process of fertilization in angiosperms is described under the following five steps:

a. Entry of pollen tube into the ovule: The pollen tube enters into the ovule by any one of following three ways.

i) **Porogamy:** The entry of the pollen tube into the ovule through the micropyle is called **porogamy**. This is the most common type found in many plants. E.g: *ottelia* and *Hibiscus*. (Figure 7.12a*)*

ii) **Chalazogamy**: In some plants pollen tube enters the ovule through chalaza. E.g: *Casuarina.* (Figure 7.12b)

iii) **Mesogamy** : Sometimes the pollen tube may enter into the ovule through the integuments or Funiculus. e.g: *Cucurbita*.(Figure 7.12c*)*



(a) (b) (c)

Figure 7.12 (a) Entry of Pollen tube through Micropyle(b) Entry of Pollen tube through Chalaza (c) Entry of Pollen tube through Integuments

Entry of pollen tube into the embryo sac

The pollen tube enters into the embryo sac only through micropylar region either passing in between egg cell and synergid or penetrating through synergid cell (Figure 7.13 b). The entry of pollen tube is directed by filiform apparatus.

b. Discharge of male gametes or sperms

After the entry of pollen tube into the embryosac, the male gametes or sperms are liberated by one of the following ways. a) Tip of the pollen tube may burst out. b) Degeneration of the tip of the pollen tube c) Formation of an apical pore at the tip of the pollen tube. The pollen tube finally releases the intact male gametes (or sperms) Figure 7.13 c and vegetative nucleus.

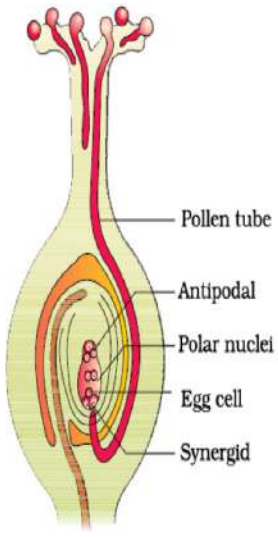
c. Gamatic fusion:

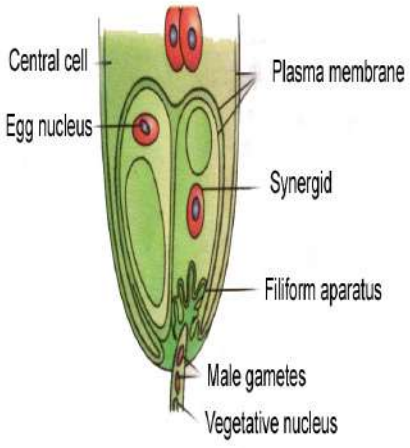
According to many scientists, only the nuclei of male gametes migrate out of them. However, in recent years, some evidence has been presented which suggests that the male cytoplasm is also sometimes involved in fertilisation. However, one of sperm nuclei (considered as first sperm) fuses with egg cell and forms a diploid **zygote** (2n). This fusion is called **Syngamy or fertilisation**. It was first discovered by **Strasburger.**

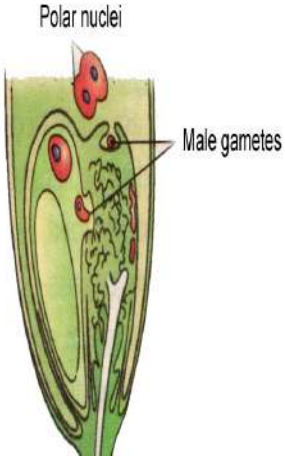
e. Triple fusion and double fertilization:

The second sperm nucleus fuses with the secondary nucleus of the embryo sac. This results in the formation of a triploid **primary endosperm nucleus (PEN).** It was first discovered by **Nawaschin** in *Lilium* and *Fritillaria.* And later found to be a universal occurrence among the angiosperms. In this fusion, haploid sperm nucleus combines with diploid secondary (it is formed by the fusion of two polar nuclei). Hence it is called **triple fusion.**

In this way in angiosperms, both the male gametes released from the pollen tube take part in fertilisation. with the occurrence of two fertilisations this phenomenon is described as **double fertilisation.** i.e. Double fertilisation includes syngamy as well as triple fusion. The central cell after triple fusion becomes the **Primary endosperm cell (PEC)** and develops into the **endosperm** while zygote develops into an **embryo.**







(a) (b)

(c)

Figure 7.13 (a) Pollen grains germinating on the stigma
(b) Enlarged view of an egg apparatus showing entry of pollen tube into a synergids
(c) Discharge of male gametes

7.5 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.

7.6 POST FERTILISATION: STRUCTURES AND EVENTS

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

7.6.1 ENDOSPERM

Normally in angiosperms the endosperm is formed from primary endosperm nucleus after fertilisation. Endosperm is the nutritive tissue useful for developing embryos. It is triploid (3n) in condition. But in gymnosperms the female gametophyte which is formed before fertilisation acts as endosperm. Hence it is haploid (n) in condition.

In some plants, during its developmental stages the embryo takes food from the endosperm and completely utilised it by the time the ovule is converted into seed. At that time the ovule contains only the embryo without any endosperm. Such seeds are called **non-endospermic seeds** or **Ex-albuminous seeds**. e.g*: Dolichos, Cicer* and *Capsella.*

In some other plants as the embryo cannot utilize the endosperm completely, a little amount of endosperm is left out in the mature seeds. Such seeds are called **endospermic seeds** or **Albuminous seeds**. e.g: *Cocos, Ricinus* and *Datura*.

7.6.2 EMBRYO

Embryo develops at the micropylar end of the embryo sac where 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. The zygote gives rise to the proembryo and subsequently to the globular, heart-shaped and mature embryo.

7.6.3 Structure of 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. Within the seed coat is the embryo, consisting of an **embryonal axis** and **two cotyledons** (Figure 7.14a). 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.

7.6.4 Structure of Monocotyledonous seed

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** (Figure 7.14 b) and a short axis with a **plumule** and a **radicle** are enclosed in sheaths which are called **coleoptile** and **coleorhizae** respectively.

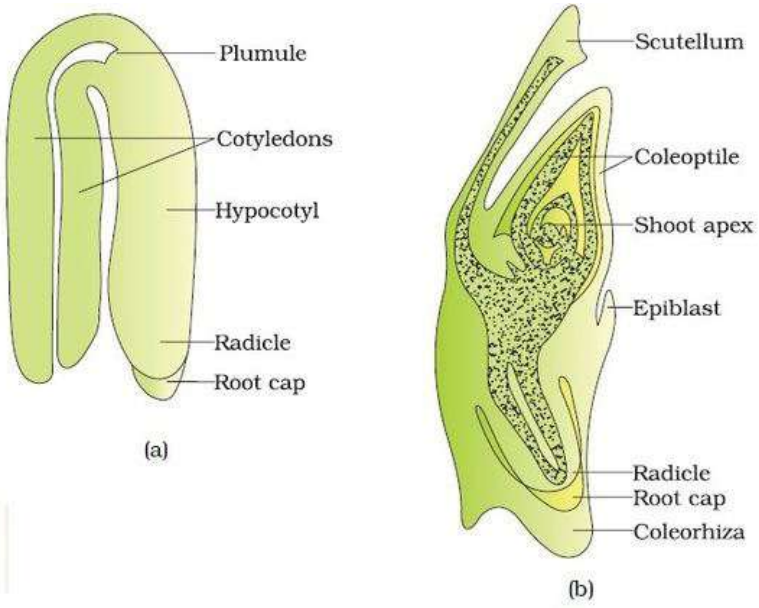


Figure 7.14 (a) A typical dicot embryo
(b) L.S of an embryo of grass (Monocot)

7.7 APOMIXIS, PARTHENOCARPY AND POLYEMBRYONY

APOMIXIS: 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.

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

POLYEMBRYONY: 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. 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?

SUMMARY

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

A typical anther is bilobed, dithecous tetrasporangiate. Pollen grains develop inside the microsporangia. Four wall layers, 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 represent 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 cells (a vegetative cell and a 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 megaspore forms the embryosac (the female gametophyte). The mature embryosac 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 a 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 grains germinates on the stigma and the resulting pollen tube grows through style, enters the ovule and finally discharges two male gametes into embryosac. Angiosperms exhibit double fertilization 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 embyryo. 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 fertilization, ovary develops into fruit and ovules develop into seeds.

A phenomenon called apomixes is found in some angiosperms, particularly in grasses. It results in the formation of seeds without fertilization. Apomixis 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 pollen grains from one flower to another.

Autogamy: Transfer of pollen grains within in the same flower.

Antipodals: Three cells present in the embryosac towards chalaza.

Apomixis: production of seeds without fertilization**.**

Chasmogamy: Pollination occurring in an opened flowers.

Cleistogamy: Pollination occurring in a closed flower.

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

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

Double fertilization: Two fusion processes (a) one male gamete + eggcell (b) second male gamete + secondary nucleus: characteristic feature of angiosperms.

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.

Floriculture: Cultivation of flower yielding plants.

Funicle : Stalk of the ovule.

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

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.

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

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

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

Pericarp: The outer wall of the fruit.

Pollinators: Agents which help in pollination.

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

Polyembryony: Development of morethan one embryo, in the same **seed.**

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

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

Scutellum: Cotyledon of monocots (Grass family).

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

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

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: Innermost 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. What is the dominant phase in the life cycle of an angiosperm?
2. Mention the modes of reproduction in algae and fungi.
3. How do Liver worts reproduce vegetatively?
4. Between an annual and a perinneal plant, which one has a short juvenile phase?
5. what the following parts of a flower develop into after fertilisation?
   a) Ovary b) Ovules
6. Define vivipary. Give an example.
7. Name the component cells of the 'egg apparatus' in an embryosac.
8. Name the parts of pistil which develop into fruit and seeds.
9. What is self-incompatability?
10. Which is the triploid tissue in a fertilised ovule?
11. How is pollination carried out in water plants?
12. Mention two strategies evolved to prevent self pollination in flowers.

SHORT ANSWER TYPE QUESTIONS

1. "Fertilisation is not an obligatory event for fruit production in certain plants." Explain the statement.
2. Why is vegetative reproduction also considered as a type of asexual reproduction.
3. Give a brief account on the phases of the life cycle of an angiosperm plant.
4. Give two suitable examples showing vegetative propagation in plants.
5. Write a brief account on agents of pollination.
6. What is Apomixis? What is its importance.

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.

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 heterogenous group of plants individually. But yet possible using specific apporoach. 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 from criteria apart from morphological features. Taxonomy includes four basic components viz., characterization, identification, nomenclature and classification. You have learnt about the detailed morphological characteristics of flowering plants in chapter-5. In the following pages of this chapter, Identification, Nomenclature and classification, Taxonomic categories, Taxonomic aids and semi-technical description of a typical flowering plant and of selected families are dealt with.

8.1: IDENTIFICATION

Identification is to determine whether a collected organism is entirely new or already known. The plant identification can be done by directly comparing the characters with an authentic herbarium specimen or indirectly with the help of keys in floras.

8.2: NOMENCLATURE:

Providing a correct scientific name to an identified plant is called 'nomenclature'. It is necessary for proper communication and identification of taxa. 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 standard is 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. The system of providing a name with two components is called Binomial nomenclature. The naming system given by **Carolus Linnaeus** is being followed by biologist all over.

For plants, scientific names are based on agreed principles laid down by **International Code For Botanical Nomenclature (ICBN).** These rules are framed at the periodical meetings of **International Botanical Congress held once in every six years**. The first meeting was held at Paris **in 1867 which result in Paris code.** The latest meeting was held at **Shenzhetn in china (XIX International Botanical Congress-2017).** According to **'ICBN'** the following rules must be followed while naming the plants:

1. The scientific name must be Latin.
2. Binomial nomenclature system must be used for naming the plants.
3. The scientific name should be either underlined or published in italics**.**
4. Every plant should have only one correct scientific name.
5. The first word denoting the genus starts with a capital letter while the specific epithet starts with a small letter.
6. The authors name may be given in abbreviated form at the end of scientific name. e.g: *Pisum sativum* L. (L stands for Linnaeus)

   If the generic name and specific name are exactly same it is known as Tautonymy. e.g: *Malus malus.* They are not valid in Plant nomenclature.

8.3 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.

1**. Artificial system:** These are the systems based on one or few comparable characters like morphology or natural habits.

e.g: Classification of plant**s** on the basis of form into herbs, shrubs, trees etc., by Theophrastus in his book "Historia plantarum".

Linnaeus 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", so his system is called sexual system.

2. Natural system: These are the systems in which plants are grouped on the basis of their natural relationships taking into consideration all possible morphological characters. e.g: Bentham& Hooker's (1862-1893) system of classification of plants as proposed in their book "Genera plantarum".

Bentham & Hooker divided the flowering plants into three classes namely Dicotyledonae, Gymnospermae and Monocotyledonae. Dicotyledonae was divided into three sub classes namely polypetalae, Gamopetalae and Monochlamydae. Polypetalae was divided into three series namely Thalamiflorae (with 6 coharts or orders) Disciflorae (with 4 coharts) and Calyciflorae (with 5 coharts). Gamopetalae was divided into three series viz., Inferae (with 3 coharts),

Heteromerae (with 3 coharts) and Bicarpellatae (with 4 coharts). Monochlamydae was divided into eight series (not divided into cohorts). Monocotyledonae was divided into seven series (not divided into cohorts). The other 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 belongs to monocotyledonae. .

3. Phylogenetic system: The classification 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.

E.g: The system proposed by **Engler and Prantl in their book "Die Naturlichen Planzen familien" (1887-1893) and J.Hutchinson (1954)** in his book "Families of flowering Plants". The latest phylogenetic classification is APG (Angiospermic Phylogenetic Group) system.

8.4 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 represents a unit of classification.

'Species' is the basic unit of classification. All those plants which are identical in all respects are regarded as one species. Different species with related characters are grouped into a 'genus.' Different genera with common characters are put into a 'family.' Different families with similar characters are grouped into an 'order'. Different orders which are related to each other are grouped into a 'Series'. A group of related series is considered as a 'class'. Diffrerent classes with similarities are grouped into a 'Division'. A group of divisions constitute the 'Kingdom' which is the largest taxon occupying the top most position in the taxonomic hierarchy. Every unit of classification can be subdivided as sub-class, sub-order etc.

Kingdom

↑

Division

↑

Class

↑

Order

↑

Family

↑

Genus

↑

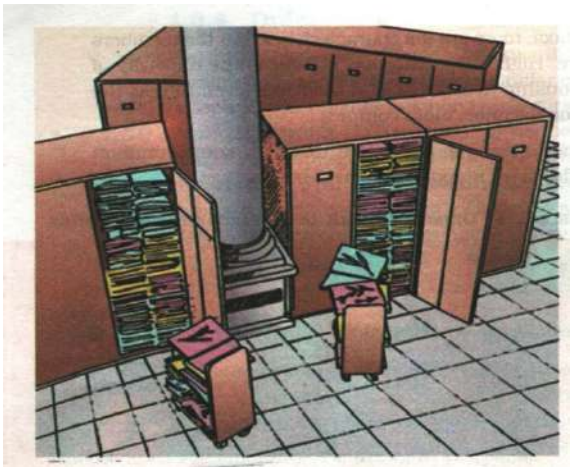
species

8.5 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 diversity. These studies would require correct classification and 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.

8.5.1 HERBARIUM:

It is store house of collected plant specimens that are dried, pressed and preserved on sheets



(Figure8.1). Further, these sheets are arranged according to a universally accepted system of classification. The herbarium sheets also carry a label providing information about date and place of collection. It is used for quick referral systems in taxonomical studies.

Fig 8.1 Herbarium showing stored specimens

Royal Botanical 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 related information is preserved and published on Internet for wider use.

8.5.2 BOTANICAL GARDENS:

These specialized 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 scientific name and its family. The famous botanical gardens are at Kew (England), **Indian Botanical garden, Howrah (India) and National Botanical Research Institute, Lucknow (India)**.

8.5.3 Musem :

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.

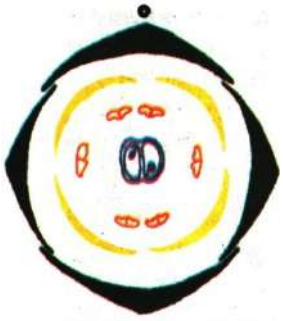


Figure 8.2 Floral diagram with floral formula

Ebr Ebrl ♀ $K_{2+2}C_4A_{2+4}G_{(2)}$

8.6 SEMITECHNICAL DESCRIPTION OF A TYPICAL FLOWERING PLANT

Description of various morphological features of a flowering plant presented in Unit-2 form the basis for characterisation, 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 floral formula are presented. The floral formula is represented by some symbols of floral parts. In the floral formula, Br stands for bracteate, Ebr stands for ebracteate (bracts absent); Brl stands for bracteolate, Ebrl stands for Ebracteolate (bracteoles absent); stands for actinomorphic, % for zygomorphic: for male, Female, 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 $\underline{G}$ 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 among 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 8.2). 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 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 8.2 represent those of the mustard family (Brassicaceae).

8.7 DESCRIPTION OF SOME IMPORTANT FAMILIES

8.7.1 FABACEAE

This family was earlier called as Papilionoideae, a sub-family of Leguminosae in Bentham and Hooker's system of classification, later it was raised to the status of a separate family.

Distribution: There are about 452 genera and 8500 species in this family, which are worldwide in distribution. Mostly they grow in tropical and sub-tropical regions.

Important plants

1. *Arachis hypogea* (Ground nut)
2. *Abrus precatorius* (Crab's eye, Guruvinda)
3. *Butea monosperma* (*B. frondosa*) (Flame of the forest)
4. *Cajanus cajan* (Red gram, pegion pea)
5. *Cicer arietinum* (Bengal gram, chick pea)
6. *Crotalaria juncea* (Sun hemp)
7. *Dolichos lablab* (Chikkudu, Bean)
8. *Dalbergia latifolia* (Indian rose wood)
9. *Glycine max* (Soya bean)
10. *Indigofera tinctorea* (Blue dye plant)
11. *Derris indica* (Pongamia pinnata) (kanuga)
12. *Phaseolus mungo* (*Vigna mungo*) (black gram)
13. *Phaseolus aureus* (*Vigna aureus*) (greengram)
14. *Pisum sativum* (Garden pea)
15. *Lathyrus sativus* (wild Pea)

16. *Pterocarpus santalinus* (Red sanders)
17. *Trigonella foenum-graecum* (Fenugreek,Menthulu)
18. *Tephrosea purpurea* (Vempali)
19. *Sesbania sesban* (Avisa)
20. Ulex

Vegetative characters

Habitat: Most of the members of this family are mesophytes. Exceptionally xerophytic adaptations are seen in *Ulex.*

Habit: There is a great diversity in the habit. Many of the plants are annual herbs, some are shrubs, some others are trees. some are weak stemmed that climb as twinners (*Dolichos*) or with Tendrils (*Pisum, Lathyrus*).

Root system: Plants are characterised by tap root system. The roots bear root nodules in which the symbiotic nitrogen fixing bacteria, *Rhizobium* are present.

Stem: It is aerial erect and herbaceous or woody. In Some plants stem is weak and prostrate or twinner (*Dolichos*) or tendrilar climber (*Pisum, Lathyrus*).

Leaf: Leaves are cauline, alternate, stipulate, petiolte and dorsiventral. The leaf base is Pulvinous. They are simple, pinnately compound or trifoliate, venation is reticulate.

Floral characters

Inflorescence: It is usually an axillary or terminal raceme (*Crotalaria*).

Flower: Flowers are bracteates, bracteoles may be present or absent, Pedicillate, complete, zygomorphic, bisexual, pentamerous and perigynous.

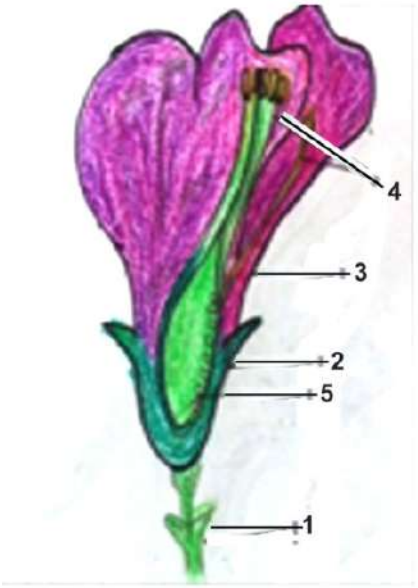
Calyx: Sepals five, gamosepalous, aestivation is volvate, odd sepal is anterior in position.

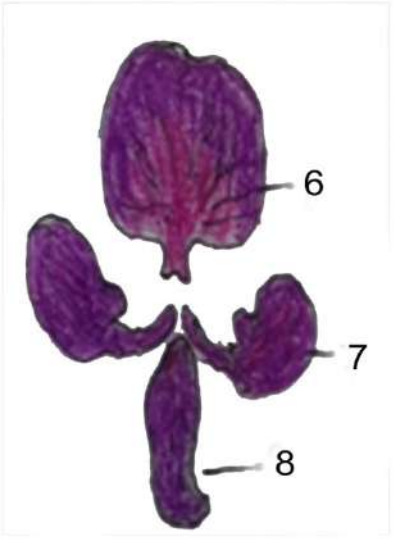
Corolla: The corolla is Papilinaceous. It consists of five petals which are free. The posterior petal is the largest and is called 'Vexillum or Standard petal'. The two lateral petals are called 'Wings or Alae'. The two boat shaped petals beneath the wings on the anterior side are called 'Keel or Carina'. The keel petals are fused and encloses the essential organs. The aestivation is 'descendingly imbricate'.

Androecium: Stamens ten diadelphous (9+1) as in *Pisum* or monoadelphous as in *Arachis, Crotalaria*. Anthers are dithecous, introrse and dehisce longitudinally.

Gynoecium: It is monocarpellary with unilocular and half-inferior ovary. Usually many ovules on marginal placentation. Style is long curved at the apex. Stigma is simple, nectar gland is present at the base of the ovary.

(c)





(a)

(b)

(d)

e)

(f)

Figure 8.3 ***Tephrosia purpurea***

A) Twig B) L.S of Flower C) Papalionaceous Coralla D) Diadelphous stamens E) T.S of Ovary F) Floral diagram 1. Bracteoles 2. Calyx 3. Coralla 4. Stamens 5. Ovary 6. Standard petal 7. Wings 8. Keel

Floral Formula: $Br, Brl, \%, \female, K_{(5)}, C_{1+2+(2)}, A_{(9)+1}, G_{1}^{-}$

Pollination: Flowers are protandrous usually entamophilous, cross pollination with piston mechanism. In *Lathyrus* and *Pisum*, there is self pollination.

Fruit: Mostly the fruit is a legume or Pod (*Pisum, Cajanus, Dolichos*). While in *Arachis* the pods are indehiscent and Geocarpic.

Seed: It is non endospermic and dicotyledonous. The cotyledons store proteins in large quantities.

Economic Importance

Fabaceae is economically very important family.

1. Pulses like red gram, black gram, green gram, bengal gram are a rich source of proteins. 2. Pods of *Dolichos, Glycine* are used as vegetables.

3. Seeds of *Pisum* and *Arachis* are edible.

4. Groundnut oil from *Arachis hypogea* seeds and Soyabean oil from seeds of *Glycine max* are used in cooking.

5. The oil cake from *Arachis hypogea* is used as fodder.

6. The oil from the seeds of *Derries indica* is used in the making of medicines.

7. Fibre from *Crotalaria* (Sun-hemp) is used in the making ropes.

8. *Sesbania* and *Tephrosia* are used as Green manure.

9. Wood from *Dalbergia* is used for making furniture.

10. Wood from Red sanders is used for making musical instruments.

11. *Indigofera* yields blue dye. Which is used for fabric whitener.

8.7.2 SOLANACEAE

DISTRIBUTION

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 habit of tropics, subtropics and even temperate zones.

Important Plants

1. *Atropa belladonna* (Belladona)
2. *Capsicum frutiscens* (Chilly)
3. *Cestrum nocturnum* (Night Queen)
4. *Cestrum diurnum* (Day king)
5. *Datura metel* (Thorn apple)
6. *Lycopersicon esculentum* (Tomato)
7. *Nicotiana tabacum* (Tobacco)
8. *Petunia alba* (Petunia)
9. *Physalis minima* (Sun berry)
10. *Solanum melongina* (Brinjal)
11. *Solanum tuberosum* (Potato)
12. *Solanum surattense* (vaakudu)
13. *Solanum nigrum* (Kamanchi)
14. *Withania somnifera* (Aswagandha)

Vegetative Characters

Habitat: Members of this family are mostly mesophytes and a few are xerophytes *(Solanum surattence*)

Habit: Plants are annual or perennial herbs. Some are shrubs (*Cestrum*) and rarely trees.

Root system: It is tap root system.

Stem: The stem is aerial, erect and mostly herbaceous. It is covered either by hairs or prickles. In *Solanum tuberosum* (potato) the stem is underground tuber. The petiole commonly shows adnation with stem. Bicollateral vascular bundles are present.

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

Floral Characters

Inflorescence: It is usually cymose type. It may be terminal or axillary in position. Terminal solitary cyme in *Datura*, axillary as in *Solanum* and panicle in Tobacco.

Flower: The flowers are bracteate or ebracteate, ebracteolate, pedicillate, actinomorphic, complete, bisexual, pentamerous and hypogynous.

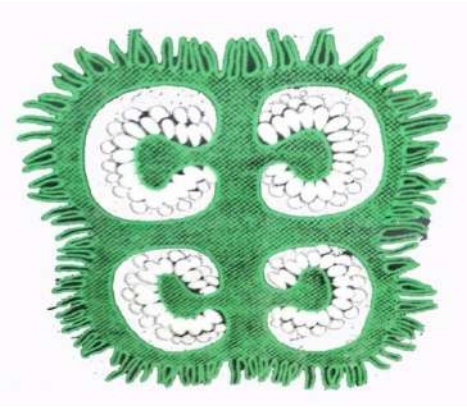
Calyx: It consists of 5 sepals which are fused (Gamosepalous), persistent in *Solanum* and *Capsicum*. The aestivation is volvate.

Corolla: The corolla consists of 5 petals and is gamosepalous. The aestivation is volvate or twisted.

Androecium: There are five epipetalous stamens alternating with the petals. The anther lobes are large, dithecous, basifixed and introrse. The dehiscence may be longitudinal (*Datura)* or Porous (*Solanum*).

Gynoecium: Bicarpellary, syncarpous, bilocular superior ovary, but rarely unilocular e.g: Chillies, it becomes tetralocular due to the development of a false septum in *Datura.* Carpels are arranged obliquely at 45^{o} Placenta swollen with many ovules on axile placentation. style is terminal and stigma is capitate.

(a) **(b)**



(c) **(d)**

Figure 8.4 Datura metel

(a) Twig with Inflorescence

(B) L.S of Flower

(c) T.S of Ovary

(d)Floral Diagram

Floral Formula $\text{Ebr, Ebrl, } \oplus, \text{♂, } K_{(5)}, \overset{\frown}{C_{(5)}}, A_5, \underline{G}_{(2)}$ **:**

Pollination: Flowers are usually protrandrous. Some species of *Solanum* are Protogynous. Cross pollination through insects is common. Occasionally, self pollination also occur in *Nicotiana.*

Fruit: The fruit is mostly berry (*Capsicum, Solanum, Lycopersicon*), capsule (*Datura, Nicotiana).*

Seed: Seeds are endospermic and dicotyledonous.

Economic importance

1. Stem tubers of *solanum tuberosum* (potato), berries of *S. melongina, Lycopersicon, Capsicum* are used as vegetables.
2. *Capsicum fruitiscens* contain an alkaloid called 'Capsine' and the powder of dry fruits is used as condiment in the preparation of pickles and in cooking.
3. *Nicotiana* is a commercial crop and leaves are used to prepare cigars and cigarettes etc.
4. Leaves of *Solanum surattence* and *Datura stromonium* are useful for curing asthma.
5. Fruits of *Solanum nigrum* are edible and are of great medicinal value.
6. *Atropa belladonna* contains an alkaloid called 'atropine' and is useful in making medicines.

7. Root extract of *Withania somnifera* is used as a rejuvenating tonic.
8. The fruits of *Physalis* are edible
9. Species of *Cestrum* and *Petunia* are ornamental plants

8.7.3 LILIACEAE

Distribution: The family commonly called the 'Lily family'. There are about 254 genera and 4074 species in this family. Although they are cosmopolitan in distribution, majority of them are found in tropical regions.

Important Plants

1. *Allium cepa* (onion)
2. *Allium sativum* (Garlic)
3. *Aloe barbadensis* (Aloe, Kalabanda)
4. *Asparagus racemosus* (Asparagus, Satamuli)
5. *Colchicum autumnale (*Meadow saffron*)*
6. *Dracaena angustifolia* (Red Dragon)
7. *Gloriosa superba* (Glory Lily-Nabhi)
8. *Ruscus aculeate* (Butcher's broom)
9. *Scilla hyacinthiana* (Squill)
10. *Smilax zeylanica* (Sarasaparilla)
11. *Lilium candidum* (Lily)
12. *Yucca gloriosa* (Spanish dagger)

Vegetative characters

Habitat: Both mesophytes (*Allium, Lilium*) as well as xerophytes (*Asparagus*, *Ruscus, Aloe*) are found in this family.

Habit: Plants are mostly perennial herbs, shrubs or trees are found in some species of *Dracaena, Yucca* and *Aloe*. Few are climbers (*Gloriosa, Smilax*).

Root: The roots are adventitious. Fasciculated tuberous roots are present in *Asparagus.*

Stem: In majority of the species the stem is underground and perennial. It may be bulb (Allium, Lilium), Corm (*Colchicum*), Rhizome (*Gloriosa).* Some are aerial, weak, tendrilar climbers (*Gloriosa, Smilax*), branches modified into Cladophylls (*Ruscus, Asparagus*).

Leaves: The leaves are Radicle (*Allium, Lilium*),Cauline (*Smilax,Gloriosa*), Leaves are petiolate and simple, alternate, linear, exstipulate, parallel venation or exceptionally reticulate in *Smilax.* Leaves in *Yucca* and *Aloe* are succulent. They are reduced to scales in *Asparagus* and *Ruscus***.**

Floral characters

Inflorescence: The inflorescence is mainly of racemose type. It is terminal or axillary in position and may be a simple raceme (*Asparagus*) or Panicle (*Yucca, Aloe*) or Umbel (*Allium, smilax*). Solitary terminal flowers are found in *Lilium* and axillary in *Gloriosa.*

Flower: The flowers are usually bracteate, ebracteolate, pedicillate, actinomorphic, complete, bisexual, homochlamydeous Trimerous and hypogynous. Exceptionally flowers are unisexual in Smilax and Ruscus.

Perianth: It consists of six tepals arranged in two whorls of three each. They may be polyphyllous (*Lilium*) or gamophyllous (*Aloe)* and are petalloid. The odd tepal of outer whorl is anterior in position and odd tepal of inner whorl is posterior in position. The aestivation is volvate.

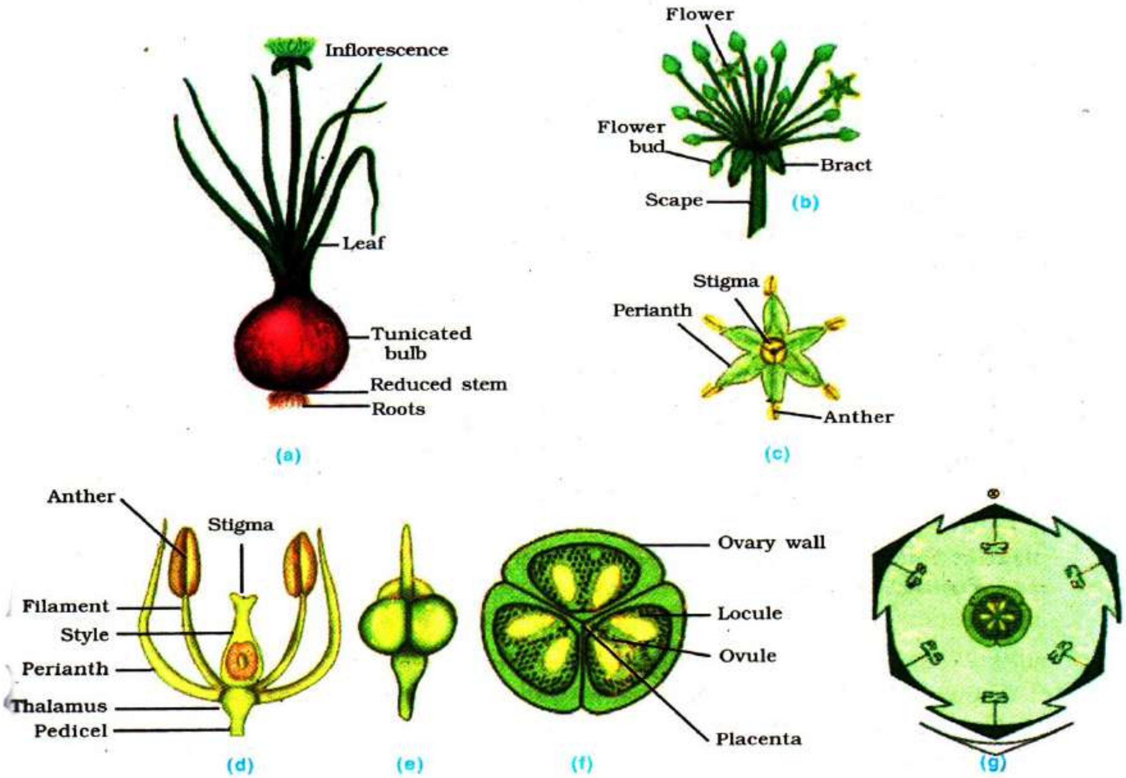


Figure 8.5 *Allium cepa* (onion) (a) Plant (b) Inflorescence (c) Flower (d) L.S of flower (e) Pistil (f) T.S of ovary (g) Floral diagram

Floral Formula: Br Ebrl ⊕ ⚥ $P_{\widehat{(3+3)}} A_{3+3} \underline{G}_{(3)}$

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

Androecium: Stamens are six, arranged in two whorls of three each. They are free or epiphyllous, anthers dithecous, basifixed, introrse and dehiscence is longitudinally.

Gynoecium: It is tricarpellary and syncarpous. The ovary is superior and trilocular with several ovules on axile placentation.The style is terminal and stigma is trifid and capitates. The ovary has septal nectaries, one on each septum.

Pollination: It is of entamophilous type. Flowers may be Protrandrous (*Allium) or* protogynous (*Clochicum).* In *Gloriosa* flowers show herkogamy.

Fruit: It may be berry *(Asparagus),* capsule (*Lilium, Gloriosa*).

Seed: It is endospermic, monocotyledonous. Polyembryony is seen in some members (*Allium*).

Economic Importance

1. The bulbs of *Allium cepa* are edible and have bactericidal properties.
2. The cloves of *Allium sativum* (Garlic) are used as spice. It is a good medicine for gastric and heart problems.
3. The tuberous roots of *Asparagus* are edible.
4. *Aloe* is valuable for treating piles.
5. "Sarasaparilla" is a medicine obtained from the roots of *Smilax*.
6. Useful drugs are obtained from *Gloriosa, Scilla* and *Colchicum.*
7. *Gloriosa, Lilium, Asparagus* and *Dracaena* are grown as ornamental plants.
8. Colchine (a chemical mutagen) is obtained from the seeds of *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, artificial 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 Prantal. 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'. Based on resemblances and distinct differences, each organism is identified and assigned correct scientific name comprising two words generic name (Genus) and specific name (Species). Herbaria and museums contain dead but preserved in specimens.

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 diagrammatic representation of floral parts and their arrangement. Family Fabaceae of polypetalae and Dicots is represented by *Tephrosia purpurea*, family Solanaceae of gamopetalae and Dicots is represented by *Datura metal* and *Allium cepa* is an example for Liliaceae of Monocots where described in semi-technical terms.

GLOSSARY

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

Artificial system: Classification based on a few easily comparable morphological characters.

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

Complete flower: A flower with all four floral parts- calyx, coralla, 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.

Geocarpic: The development of fruit below the soil.

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

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

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

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.

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.

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.

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

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 stands for?
2. Which is the largest botanical garden in the world?
3. Name the well known botanical garden in India?
4. What is the basic unit of classification.
5. Give the scientific name of mango?

6. What is natural system of plant classification?
7. Name the scientists who followed Natural system of classification.
8. What is geocarpy?
9. What is Flora?
10. Name the plant which exhibits geocarpy phenomenon.
11. Name the type of pollination mechanism found in members of Fabaceae.
12. Write the floral formula of *Solanum*?
13. Give the technical description of anthers of *Aliium cepa.*

SHORT ANSWER TYPE QUESTIONS

1. Explain binomial nomenclature.
2. What are taxonomic aids? Give the importance of herbaria and Botanical gardens.
3. Give economic importance of plants belonging to Fabaceae.
4. Describe the essential organs of Liliaceae.

EXERCISES

1. When all root nodules of a ground nut plant are removed, which process is affected?
2. How Can you identify a plant of solanaceae with reference to the characters of gynoecium?
3. Give two reasons by which a plant of Liliaceae differs from a plant of Solanaceae with reference to characters of perianth.

1. *Petunia , Datura and Nicotiana* belong to family
   (A) Fabaceae (B)Poaceae (C) Solanaceae (D) Liliaceae
2. In floral formula, (K) denotes
   (A) Polysepalous (B) Gamosepalous (C) Polypetalous (D) Gamopetalous
3. Monocarpellary ovary, diadelphous androecium and marginal placentation occur in -----

CHAPTER 9

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. The study of cells is called **cytology**. In recent times concentration is focused upon different aspects of the cell, therefore the study of cells in a broad sense is referred to as **" Cell Biology** " in place of **"cytology".**

9.1 What is a cell?

Unicellular organisms are capable of (i) independent existence and (ii) Performing the essential functions of life. Cell is the fundamental structural and functional unit of all living organisms.

Anton Von Leeuwenhoek first saw and described a living 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

It was proposed by **M.J.Schleiden (1838)** and **T.Schwann (1839**). The cell theory states that i) Cell is the structural unit of all living organisms.

ii) Cell is the functional unit of all living organisms.

This theory do not explain how new cells were formed. **Rudolf Virchow** (1885) first explained that new cells are formed from pre-existing cells by division (Omnis cellula-e cellula). He modified 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 observed cells in an onion peel and or human cheek cells under the microscope. Let us recollect their structure. The onion cell in 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,** where as cells that lack a membrane bound nucleus are **prokaryotic.** In both prokaryotic and eukaryotic cells, semi- fluid matrix called **cytoplasm** occupies the volume of the cell. Various chemical reactions occur in it to keep the cell in the 'living state'.

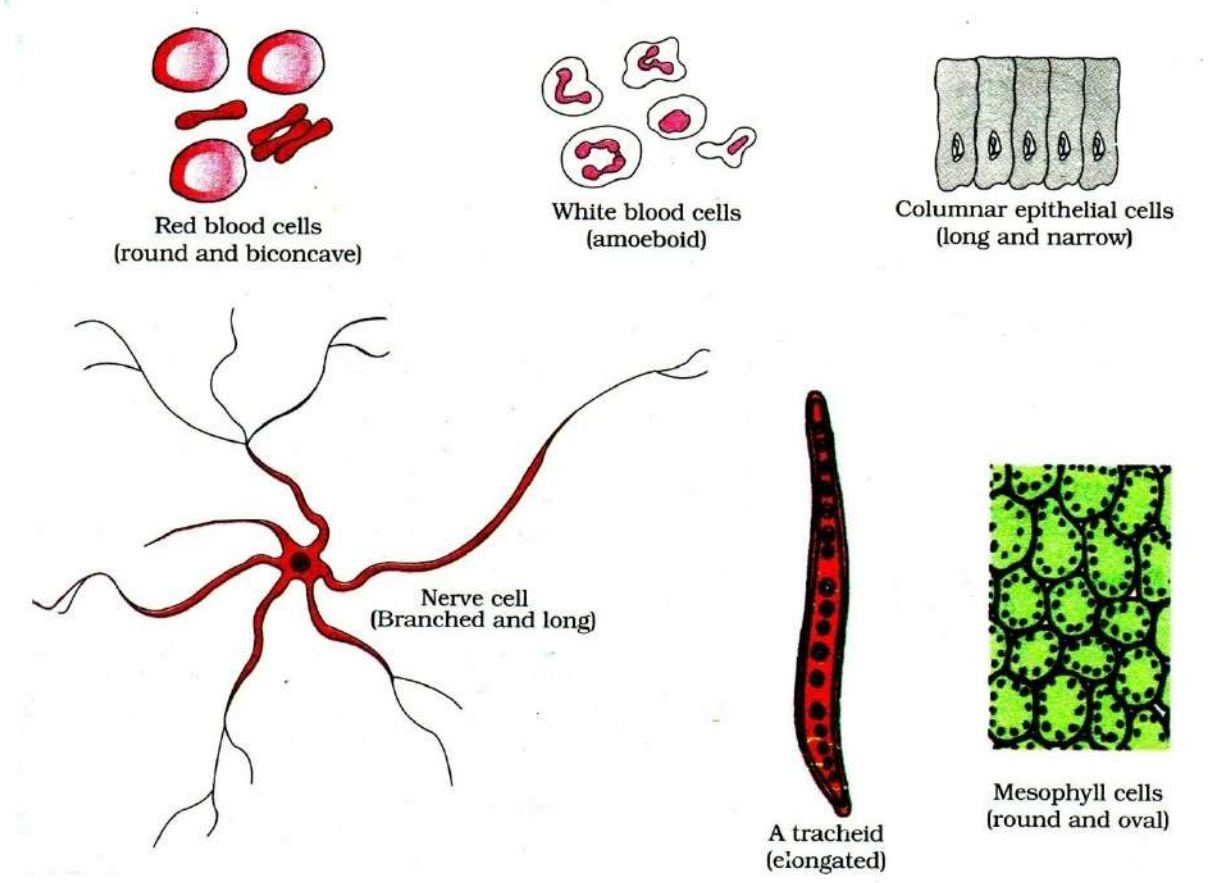


Figure 9.1 Diagram showing different shapes of the cells

Besides the nucleus the eukaryotic cells have other membrane bound structures called organelles like the

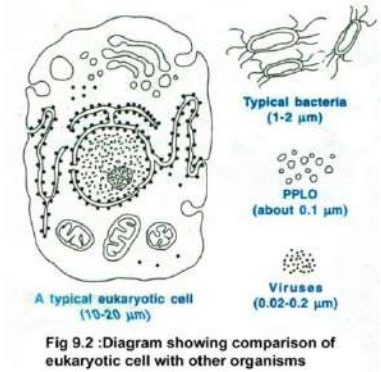


Fig 9.2 :Diagram showing comparison of eukaryotic cell with other organisms

endoplasmic reticulum (ER), 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 and prokaryotic and also within the two organelles – chloroplast (in plastids) and mitochondria and on rough ER. 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. 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, they may greatly in shape and size. The four basic shapes of bacteria are bacillus (rod like), coccus (spherical), Vibrio (comma shaped) and Spirillum (spiral). 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, many bacteria have small circular DNA outside the genomic DNA. These smaller DNAs are called Plasmids. In higher classes you will learnt that this plasmid DNA is used to monitor bacterial transformation with foreign DNA. 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 envelop. The cell envelop consists of a tightly bound three layered structure i.e., the outermost glycocalyx followed by the cell wall and then the plasma membrane. Bacteria can be classified into two groups on the basis of the differences in the chemical composition of cell envelopes and 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 do not are called **Gram negative** bacteria.

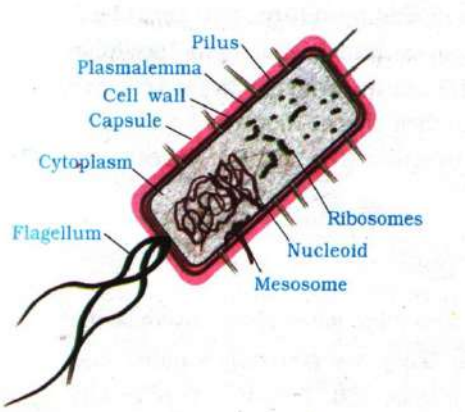


Fig 9.2 a : Typical prokaryotic cell

A special membranous structure is the mesosome which is formed by the extensions of plasma membrane into the cell. They help in cell wall formation, DNA replication, respiration, secretion processes, to increase the surface area of the plasma membrane.

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. Besides flagella, Pili and Fimbriae are also surface structures of the

bacteria but do not play a role in motility. In, some bacteria they are known to help attach the bacteria to rocks in streams and also to the host tissue.

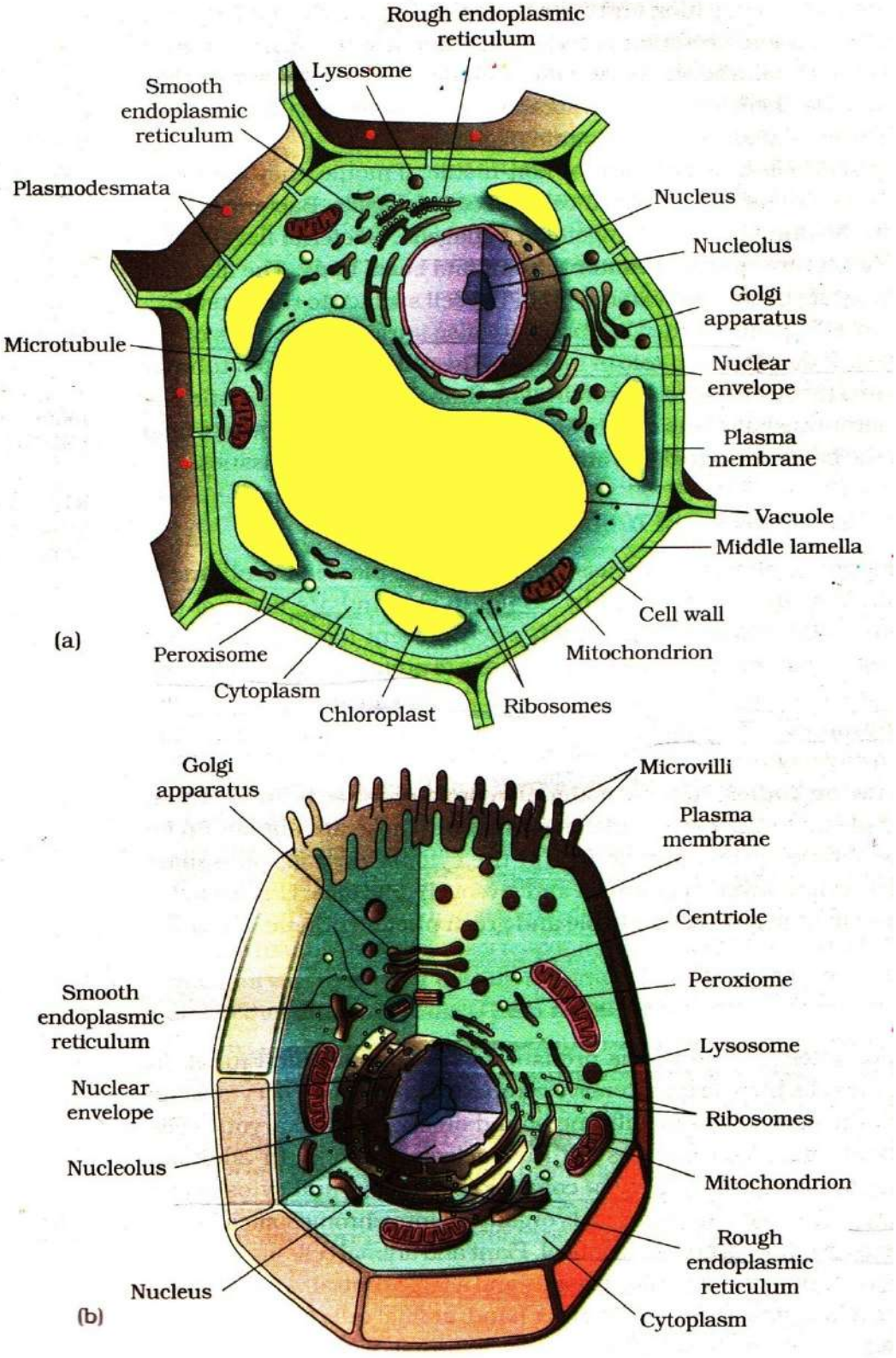


Figure 9.3 Diagram showing: (a) Plant cell (b) Animal cell

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 sub units – 50S and 30Sunits which when present together form 70S prokaryotic ribosomes. Ribosomes are the sites of protein synthesis. Several ribosomes attached to a single mRNA and form a chain called **polyribosomes or polysome.** The ribosomes of a polysome translate the mRNA into proteins.

Inclusion bodies: The reserve food materials in prokaryotic cells are stored in the cytoplasm in the form of inclusion bodies i.e., Phosphate granules, cyanophycean granules and glycogen granules. Gas vacuoles are found in purple, green and blue green photosynthetic bacteria. (Figure 9.2)

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 envelop. 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 other hand, animal cells have centrioles which are absent in almost all plant cells (Figure 9.3).

9.5.1 Cell membrane or Plasma membrane

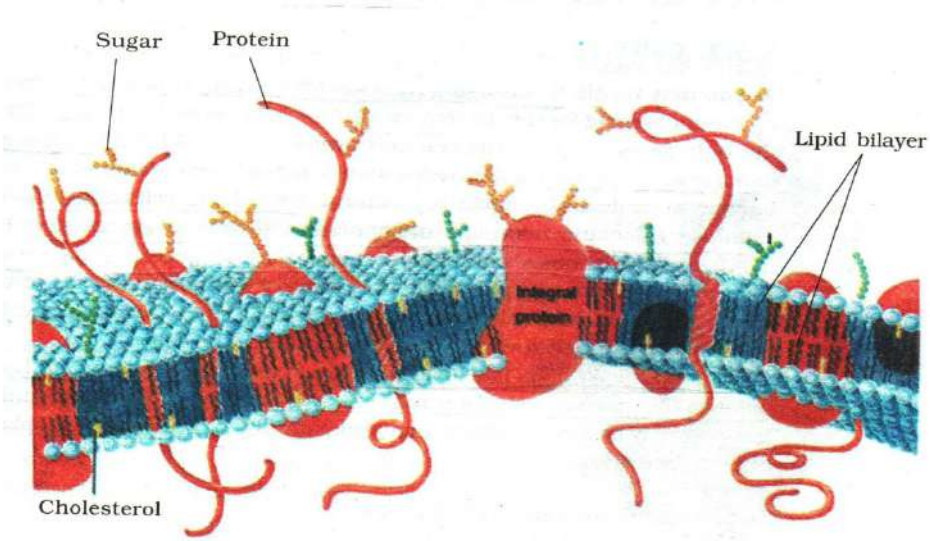


Figure 9.4 Fluid mosaic model of plasma membrane

The detailed structure of the membrane was studied only after the advent of the electron microscope in the 1950s. 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.

An improved model of the structure of cell membrane was proposed by **Singer and Nicolson** (1972) widely accepted as **fluid mosaic model** (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 if intercellular junctions, secretion, endocytosis, cell division etc.

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 across the membrane by simple diffusion along the concentration, i.e., from higher concentration to lower. Water may also move across the membrane from higher to lower concentration. Movement of water by diffusion across the membrane is called **osmosis.** 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 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

It was first observed by Robert Hooke (1665) in cork tissue of oak tree. Plants cells can be distinguished from animal cells by the presence of 'cell wall'. Cell wall is non-living rigid structure and forms an outer covering for the plasma membrane of fungi and plants. Cell wall not only gives the shape to the cell and protects the cell from mechanical damage and infection. The cell wall of young plant cell is the primary wall. It is made up of cellulose, hemicellulose, pectin and proteins. 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 inter fibrillar spaces. In some cell types like in xylem, the secondary wall exhibits thickened areas called pits to support intercellular transport.

The middle lamella is first formed layer of cell wall and develops from the cell plate during the cell division. It is mainly composed of calcium pectate and holds or glues the different neighbouring cells together.

9.5.3 Endomembrane system

A group of cell organelles with coordinated functions is called an endomembrane system. This system includes endoplasmic reticulum (ER), golgi complex, lysosomes and vacuoles. Since the functions of 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

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 endoplasmic reticulum (ER) (figure 9.5). **K.R. Porter (1953)** first coined the term to describe thread like structures in the cell. The ER often shows ribosomes attached to their outer surface is called **Rough endoplasmic reticulum (RER)**. RER is frequently observed in the cells actively involved in protein synthesis and secretion. The ribosomes are absent on the membrane, they appear smooth and are called **smooth Endoplasmic**

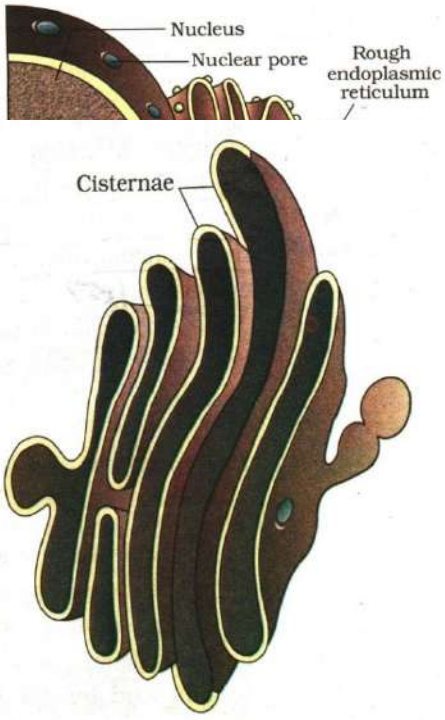


Figure 9.6 Golgi apparatus

Reticulum (SER). It is the major for synthesis of lipids. In animals cells, lipid - like Steriodal hormones are synthesized in SER.

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 consists of many flat, disc- shaped sacs or cisternae of 0.5 um to 1.0 um diameter (Figure 9.6). These are stacked parallel to each other. The golgi apparatus principally performs the function of packaging materials to be delivered either to the intra-cellular targets or secreted outside the cell. It 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 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 hydrolysing 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, vacuole sap also contains some pigments like anthocyanin which import colour to the plant parts. The vacuole is bounded by a single membrane called tonoplast. In plants, tonoplast facilitates the transport of a number of ions and other materials against concentration gradients into the vacuole.

9.5.4 Mitochondira

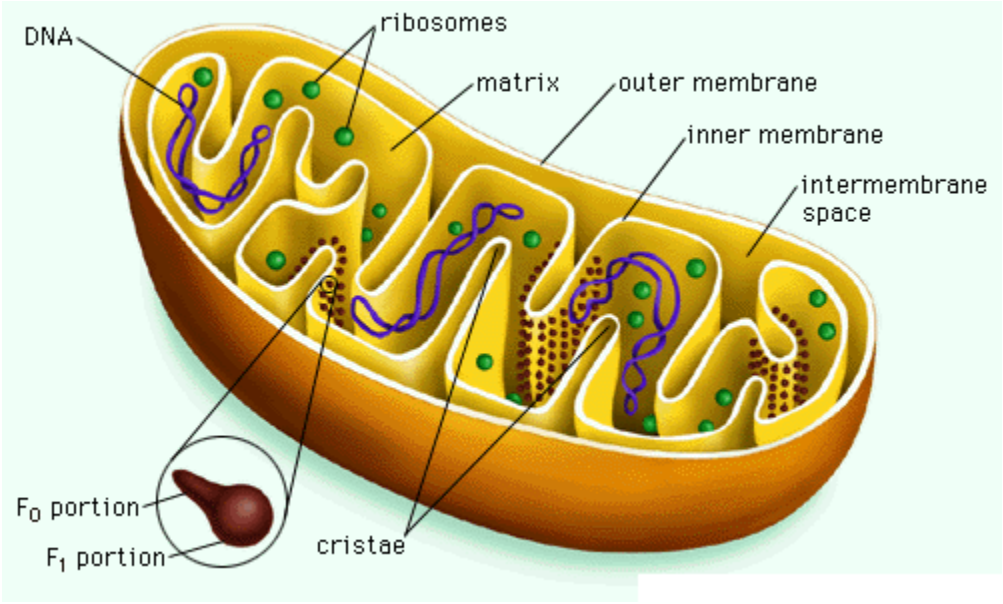


Fig : 9.7 Structure of Mitochondrion (Transverse section)

Mitochondia (sing: Mitochondrion) were first reported by **Kollikar. Altmann** called them as BIoplast. **Benda** (1897) coined the term **Mitochondria.** They are present in all eukaryotic cells. Based on physiological function that is carried out in the cell, the number of mitochondria varies from cell to cell and from organism to organism. These are rod shaped or spherical shaped organelles.

Each mitochondrion consists of a fluid filled space surrounded by double membrane envelope. The space present between the two membranes of the envelope is called **perimitochondrial space or intermembrane space**. The outer membrane is smooth and it is more permeable to small molecules. The inner membrane is folded or projected into number of finger like structures called **cristae or mitochondrial crests.** The mitochondrial matrix contains 70s type of ribosomes, circular DNA and RNA. The matrix is rich in oxidative enzymes, useful for aerobic respiration. The surface of cristae is studded tiny stalked particles known as **F_0 . F_1 particles**. Each mitochondrion posses their own DNA and are of self duplicating. Hence they are also called **semi-autonomous organelles** like chloroplast.

Functions: Mitochondria are concerned with oxidation of food materials by aerobic respiration. They convert potential energy into kinetic energy and store it in the form of ATP. Hence mitochondria are called **Power houses of the cell.**

9.5.5 Plastids

Plastids are found in all plants cells and in euglenoids. Based on the type of pigments plastids, can be classified into chloroplasts, chromoplasts and leucoplasts. Chloroplast contain chlorophyll and carotenoid pigments, chromoplast contain carotene, xanthophylls and others are present, they give a yellow, orange or red colour to the plant parts. The leucoplast are the colourless plastids with stored nutrients.

Chloroplast: Chloroplast are found in the mesophyll cells of the leaves. These are lense shaped, oval, spherical, discoid or even ribbon-like organelles having variable length (5-10 um) and width (2-4 um). It is surrounded by two membranes i.e., outer membrane and inner membrane that are separated by **periplastidial space** of about 10nm wide. The space limited by the inner membrane of the chloroplast is called **stroma**. It consists of several photosynthetic enzymes that useful in carbon fixation or calvin cycle. The stroma also contains circular DNA molecule and 70s type of ribosomes. 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) in addition, there are flat membranous tubules called the **stroma lamellae** connecting the thylakoids of the different grana. The space within a thylakoids is called lumen. Photosynthetic pigments such as chlorophylls and carotenoids are present in the thylakoid membranes.

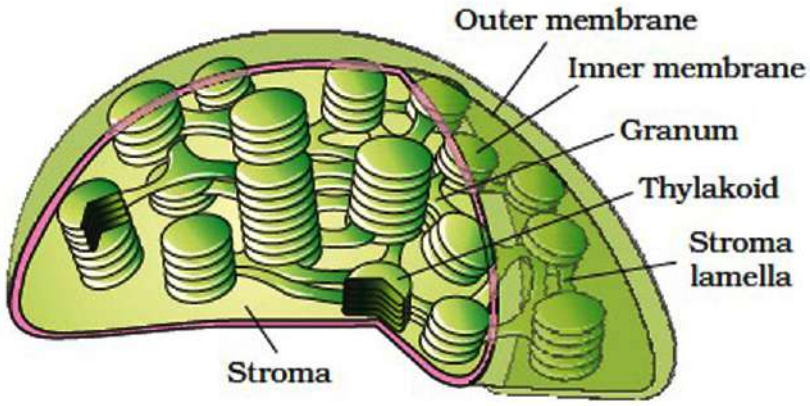


Figure 9.8 Sectional view of chloroplast

The presence of DNA in the chloroplast helps in self duplication.Hence chloroplasts are called semi-autonomous organelles.

Functions: Chloroplast are chiefly concerned with assimilation of food materials by photosynthesis which occur in two phases (a) light reaction takes place in grana (b) Carbon fixation takes places in stroma region.

9.5.6 Ribosomes

These are granular structures first observed 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 prokaryotic ribosomes are 70s. Here 'S' stands for the

sedimentation coefficient (expressed in Svedberg unit): It is indirectly a measure of density and size. Ribosomes provide space as well as enzymes for the synthesis of proteins.

9.5.7 Nucleus

Nucleus was first described by **Robert Brown** in 1831. Electron microscopy has revealed that the nuclear envelop, which consists of two parallel membranes with a space between (10 to 50 nm) called **perinuclear space.** The outer membrane usually remains continuous with the endoplasmic reticulum and also bears ribosomes on it. The fluid inside the nucleus is called **nucleoplasm,** contains nucleolus and chromatin material. The **nucleoli** are spherical structures present in the nucleoplasm. It is a site for active ribosomal RNA synthesis. The interphase nucleus has a loose and indistinct network of nucleoprotein fibres called **chromatin**. Chromatin contains DNA and some basic proteins called **histones,** some non-histones and also RNA. During different stages of cell division, cells show structured **chromosomes** in place of the nucleus.

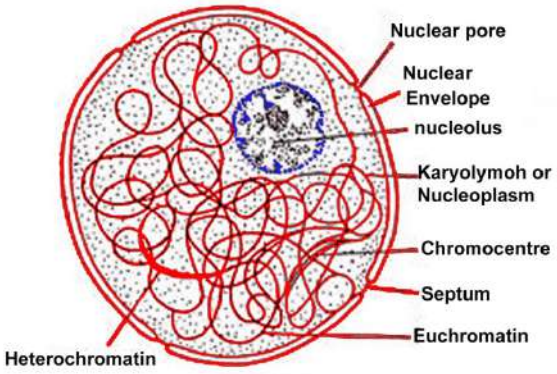


Fig. 9.9 Structure of nucleus

9.5.8 Chromosomes

Hofmeister (1848) identified deeply stained dark structures in a dividing nucleus of pollen mother cells of Tradescantia. **Waldeyer** (1888) named them as Chromosomes (chroma= colour; soma=dody) because of their affinity for basic dyes. They are chiefly concerned with the transfer of genetic traits from one generation to the next and hence referred to as **'Physical basis of heredity'.** 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. (9.12). The **metacentric** chromosome has middle centromere forming two equal arms of the centromere. The **sub-metacentric** chromosome has centromere nearer to one end of the chromosome resulting into one shorter are and

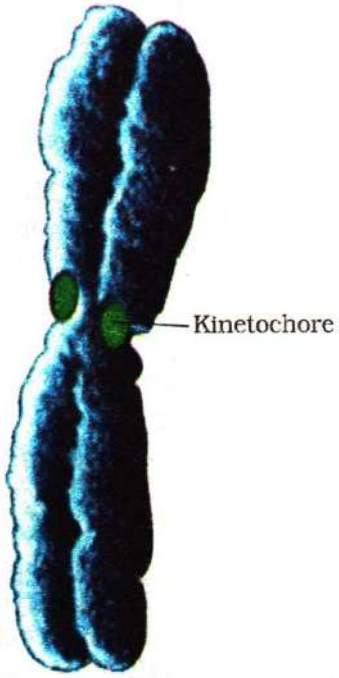


Figure 9.10 Chromosome with kinetochore

one longer arm. In case of **acrocentric**

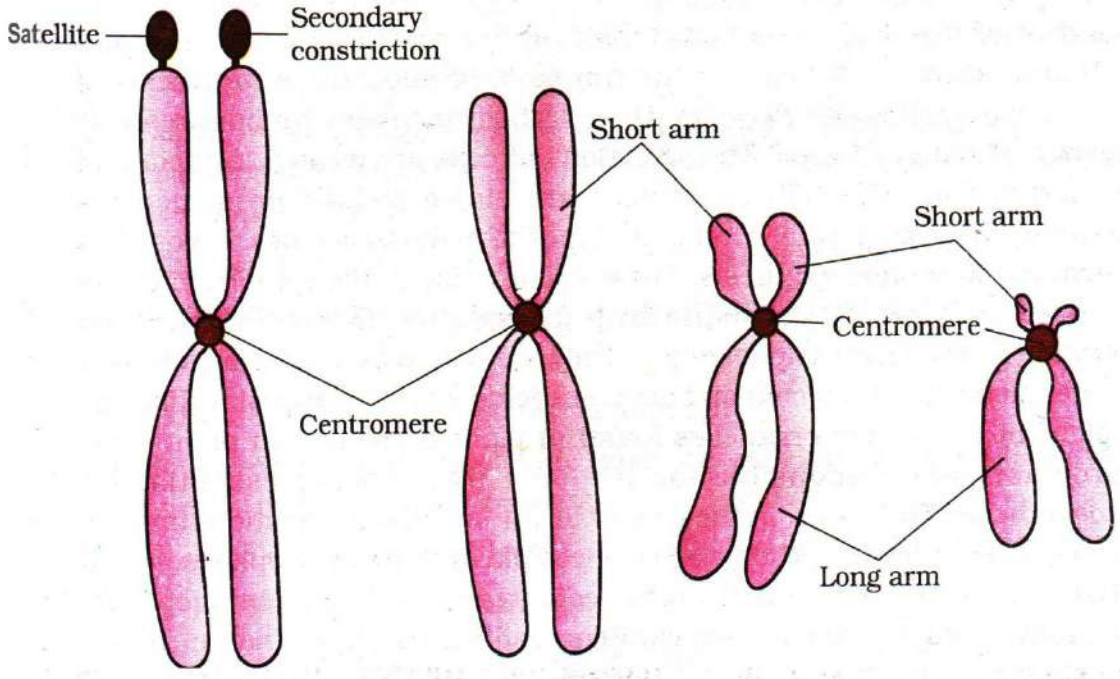


Figure 9.11 Types of chromosomes based on the position of centromere

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 'String of beads'. The beads are known as "nucleosomes". A typical nucleosome contains 200 bp of DNA double helix wrapped (two turns) around core of histone octamer having two copies of each of four types of histone octamer having two copies of each 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 continues between two successive nucleosomes is called linker DNA (Figure 9.12). The association between negatively charged DNA and positively charged histones allows for meaningful DNA packaging inside the nucleus. The string of beads structure in chromatin is packaged to form chromatin fibres that are further coiled and condensed to form chromosomes.

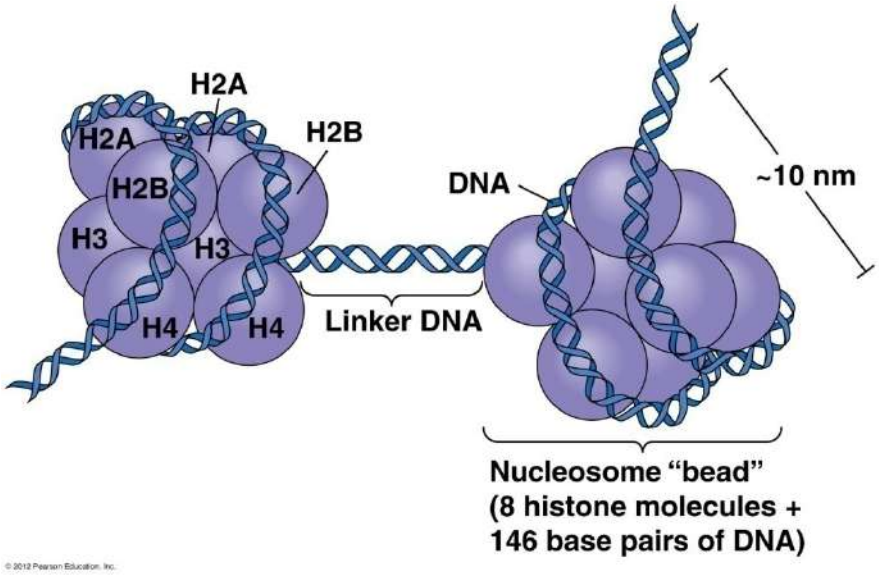


Figure 9.12 Nucleosome model

9.5.9 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 play an important role in the synthesis of Phospholipids and Photorespiration. Glyoxysomes contain the enzymes of glyoxylate cycle which convert stored lipids to carbohydrates.

SUMMARY

All organisms are made of cells and aggregates of cells. Cells vary in their shape, size and activities / functions. Based on the presence of 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. All the cell organelles perform different but specific functions. Nucleus contains nucleoli and chromatin network. It not only controls the activities of organelles but also plays a major role in heredity.

Endoplamic 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 secretion of cells are packed in them and transported from the cell. Lysosomes are single membrane structures containing enzymes for digestion all types of macromolecules. Ribosomes are involved in protein synthesis. These are 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, the green coloured plastids are chloroplasts, which contain chlorophyll. Chloroplast are responsible for trapping light energy essential for photosynthesis reticulum contains tubules or cisternae. They are of two types: rough and. The grana, in the plastids, is the site of light reactions and the stroma for biosynthetic phase of photosynthesis. Another type of plastids are called chromoplast, 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.

Carotenoids: Terpenoid pigments abundant in chloroplasts 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 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. who discovered Nucleus ?
2. What is the significance of vacuole in a plant cell ?
3. what does 'S' refer in a 70S & and 80S ribosome ?
4. Mention a single membrane bound organelle which is the rich in hydrolytic enzymes.
5. What is the feature of a metacentric chromosome ?
6. What is middle lamella made of ?
7. What is osmosis?
8. What is the function of polysome ?
9. Which part of the bacterial cell is targeted in gram's staining ?

SHORT ANSWER TYPE QUESTIONS (4 Marks)

1. Describe the cell organelle which contains chlorophyll pigments.
2. Describe the structure and functions of power houses of cell.
3. Differentiate between Rough endoplasmic Reticulum (RER) and Smooth Endoplasmic Reticulum (SER).
4. Describe the structure of nucleus.
5. What are nucleosomes ? What are they made of ?

EXERCISES

1. Cell is the basic unit of life. Discuss in brief.
2. What are the characteristics of prokaryotic cells.
3. What is a mesosome in a prokaryotic cell ? Mention the functions that it performs.
4. Energy releasing reaction in a cell occurs in
   (A) Cell wall (B) Ribosomes (C) Mitochondria (D) Plastids
5. Which is a part of endomembrane system of eukaryotic cells ?
   (A) Mitochondria (B) peroxisomes (C) Chloroplasts (D) Golgi bodies

CHAPTER-10 BIOMOLECULES

There is a wide diversity in living organisms in our biosphere. Now a question that arises in our minds is: Are all living organisms made of the same chemicals. i.e., elements and compounds? You have learnt in chemistry how elemental analysis is performed. If we perform such an analysis on a plant tissue, animal tissue or a microbial paste, we obtain a list of elements like carbon, hydrogen, oxygen and several others and their respective content per unit mass of a living tissue. If the same analysis is performed in a earth's crust as an example of non-living matter, we obtain a similar list. what are the differences between the two lists? In absolute terms, no such differences could be made out. All the elements present in a sample of earth's crust are also present in a sample of living tissue. However, a closer examination reveals that the relative abundance of carbon and hydrogen with respect to the other elements is higher in any living organism than earth's crust (Table 10.1).

Table 10.1 A comparison of elements present in non- living and living matter

Element	**% weight of Earth's crust**	**Human body**
Hydrogen (H)	0.14	0.5
Carbon (C)	0.03	18.5
Oxygen (O)	46.6	65.0
Nitrigen (N)	Very little	3.3
Sulphur (S)	0.03	0.3
Sodium (Na)	2.8	0.2
Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (Si)	27.7	Negligible

Adopted from CNR RAO, understanding chemistry,university press.Hyderabad.

10.1 How To Analyse Chemical Composition?

When we continue asking in the same way, what type of organic compounds are found in the living organisms? How does one go about finding the answer? To get an answer, one has to

perform a chemical analysis. We can take any living tissue (a vegetable or a piece of liver, etc.) and grind it in trichloroacetic acid (Cl_3CCOOH) using a mortar and a pestle. We obtain a thick slurry. If we were to strain this through a cheese cloth or cotton, we would obtain two fractions. One is called the filtrate or more technically, the acid-soluble pool, and the second, the retentive or the acid-insoluble fraction. Scientists have found thousands of organic compounds in the acid-soluble pool.

Component	% of the total cellular mass
Water	70-90
proteins	10-15
Carbohydrates	3
lipids	2
Nucleic acids	5-7
Ions	1

In higher classes you will learn about how to analyse a living tissue sample and identify a particular organic compound.

Lipids are generally water soluble. They could be simple fatty acids. A fatty acid has a carboxyl group attached to an R group. The R group could be a methyl (-CH_3), or ethyl (-C_2H_5) or higher number of –CH2 groups (1 carbon to 19 carbons). For example, palmatic acid has 16 carbons including carboxyl carbon.

Table 10.2 Average Composition of Cells

10.2 PROTEINS

Proteins are polypeptides. They are linear chains of aminoacids linked by peptide bonds. Each protein is a polymer of amino acids. As there are 21 types of aminoacids e.g., alanine, cysteine, proline, tryptophan, lysine, etc., a protein is a heteropolymer and not a homopolymer. A homo polymer has only one type of monomer repeating ‘n’ number of times. This information about the amino acid content is important. Certain amino acids are essential for our health and they have to be supplied through our diet. Hence, dietary proteins are the source of essential

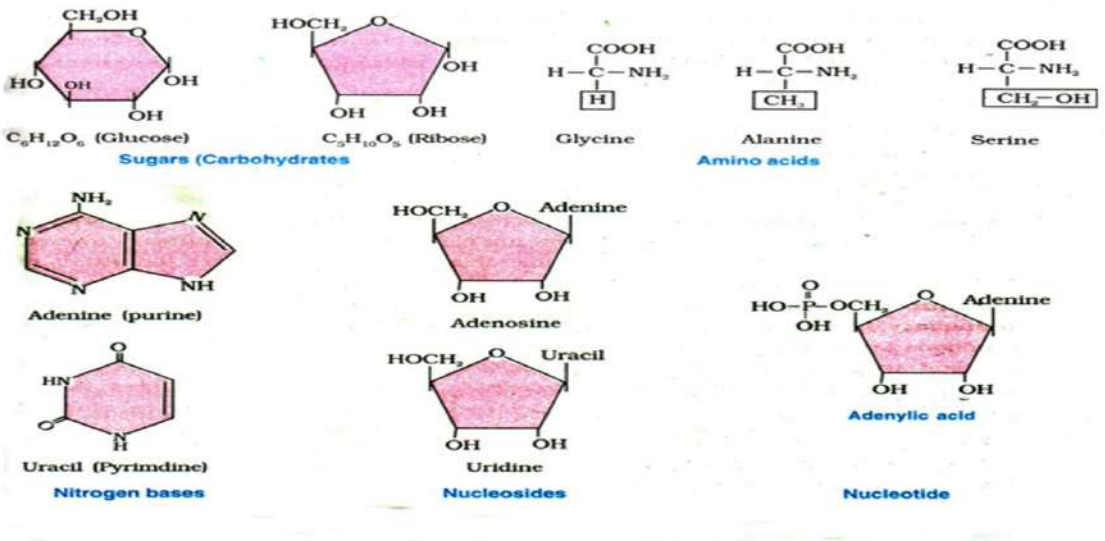
aminoacids. Therefore, amino acids can be essential or non essential. The later are those which our body can make. while we get essential amino acids through our diet/food. Proteins carryout many functions in living organisms, some important nutrients across cell membrane, some flight infectious organisms, some hormones, some are enzymes etc., (Table10.3). Collagen is the most abundant protein in animal world and Ribulose bisphosphate Carboxylase Oxygenase (Rubisco) is the most abundant protein in the whole of the biosphere.

Table 10.3 Some proteins and their functions

Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception
GLUT-4	Enables glucose transport into cells

10.3 POLYSACCHARIDES

The acid insoluble pellet also has polysaccharides



des (carbohydrates) as another class of macromolecules. polysaccharides are long chain of sugars. They are threads (literally a cotton thread) containing different monosaccharides as building blocks. For example, cellulose is a polymer polysaccharide consisting of only one type of a monosaccharide i.e., glucose. Glucose is a homoplymer. Starch is a variant of this but present as a store house of energy in plant tissues. Animals have another variant called glycogen. Insulin is a polymer of fructose. Plant cell walls are made of cellulose, Paper made from plant pulp is cellulose. Cotton fibre is cellulose. Exoskeletons of arthropods and cell wall of Fungi, for example, have a complex polysaccharide called Chitin. These complex polysaccharides are hetero polymer.

Figure 10.1 Diagrammatic representation of small molecular weight organic compounds in living tissues

10.4 NUCLEIC ACIDS

The other type of macromolecule that one would find in the acid insoluble fraction of any living tissue is the nucleic acid. These are polynucleotides. Together with polysaccharides and polypeptides these comprise the true macromolecular fraction of any living tissue or cell. For nucleic acids, the building block is a nucleotide. A nucleotide has three chemically distinct components. One is a heterocyclic compound, the second is a monosaccharide and the third is a phosphoric acid or phosphate. e.g: Adynelic acid, thymidylic acid, guanylic acid, uridylic acid and cytidylic acid. Sugar is attached to nitrogen bases is called Nucleoside. e.g: Adenosine, guanosine. thymidine, uridine and cytidine.

As you notice in figure 10.1 the heterocyclic compounds in nucleic acids are nitrogen bases named adenine, guanine, uracil, cytosine and thymine. Adenine and Guanine are substituted purines while rest are substituted pyrimidines. The skeletal heterocyclic ring is called as purine and pyrimidine respectively. The sugar found in polynucleotides is either ribose (a monosaccharide pentose) or 2' deoxyribose. A nucleic acid containing deoxyribose is called deoxy ribonucleic acid (DNA) while that which contains ribose is called Ribo nucleic acid (RNA).

SUMMARY

Although there is a bewildering diversity of living organisms, their chemical composition and metabolic reactions appears to be remarkably similar. The elemental composition of living tissue and non living matter appear also to be similar when analysed qualitatively. However, a closer examination reveals that the relative abundance of carbon, hydrogen and oxygen is higher in living systems when compared to the inanimate matter. The most abundant chemical in living organisms is water. There are thousands of small molecular weight (<1000Da) biomolecules. Amino acids, monosaccharide and Disaccharide sugars, nucleotides, nucleosides and nitrogen

bases are some of the organic compounds seen in living organisms. There are 21 amino acids and 5 types of nucleotides.

Only three types of macromolecules, i.e., proteins, nucleic acids and polysaccharides are found in living systems. Proteins are hetero polymers made of amino acids. Nucleic acids (DNA and RNA) are composed of nucleotides. Nucleic acids serve as genetic materal. Poly saccharides are components of cell wall in plants, fungi and also exoskeleton of arthropods. They are also storage form of energy (e.g., starch and glycogen). Proteins serve as variety of cellular functions. Many of them are enzymes, some are antibodies, some are receptors, some are hormones and some other are structural proteins. Collagen is the most abundant protein in animal world and Ribulose bis phosphate carboxylase and oxygenase (Rubisco) is the most abundant protein in the whole of Biosphere.

GLOSSARY

Bioenergitics: Subject dealing with energy conversions in living cells.

Bio macromolecules: Acid soluble, high molecular weight substances of the living tissue.

Essential amino acids: Amino acids that have to be supplied through diet and essential for our health.

Nucleic acids: Polymer of Nucleotides.

Peptide bond: Bond between amino acids in a protein.

Polysaccharide: Long chain biopolymer of sugar molecules.

VERY SHORT ANSWER TYPE QUESTATIONS

1. What are biomolecules.
2. Give one example to amino acids and sugars.
3. what are the components of nucleotide.
4. Give two examples to nucleotides.
5. What are the bonds present between amino acids.
6. Expand DNA.

SHORT ANSWER TYPE QUESTATIONS

1. what is the difference between a Nucleotide and Nucleoside? Give two examples of each with their structure.
2. what are proteins? Name three proteins and their functions.

EXCERCISES

1. What are macromolecules? Give examples.
2. Number of carbons in a ring of deoxyribose sugar is
   (A) Three (B) Four (C) Five (D) Six
3. Can you describe what happens when milk is converted into curd. Based on your understanding of proteins.
4. Name the abundant protein in animal world.
5. Cotton fibre is made of what type of polysaccharide.

CHAPTER 11
CELL CYCLE AND CELL DIVISION

Are you aware that all organisms, even the largest, start their life from a single cell? You may wonder how a single cell then goes on to form such large organisms. Growth and reproduction are characteristics of cells, indeed of all living organisms. All cells reproduce by dividing into two, with each parental cell giving rise to two daughter cells each time they divide. These newly formed daughter cells can themselves grow and divide, giving rise to a new cell population that is formed by the growth and division of a single parental cell and its progeny. In other words, such cycles of growth and division allow a single cell to form a structure consisting of millions of cells.

11.1 CELL CYCLE

Cell division is a very important process in all living organisms. During the division of a cell, DNA replication and cell growth also take place. All these processes i.e., cell division, DNA replication, and cell growth, hence, have to take place in a coordinated way to ensure correct division and formation of progeny cells containing intact genomes. The sequence of events by which a cell duplicates its genome, synthesis the other constituents of the cell and eventually divides into two daughter cells is termed cell cycle. Although cell growth (in terms of cytoplasmic increase) is a continuous process, DNA synthesis occurs only during one specific stage in the cell cycle. The replicated chromosomes (DNA) are then distributed to daughter nuclei by a complex series of events during cell division. These events are themselves under genetic control.

11. 1. 1 Phases of cell cycle

A typical eukaryotic cell cycle is illustrated by human cells in culture. These cells divide once in approximately every 24 hours (Figure 11.1). However, the duration of cell cycle can vary from organism to organism and also from cell to cell. Yeast for example, can progress through the cell cycle in only about 90 minutes.

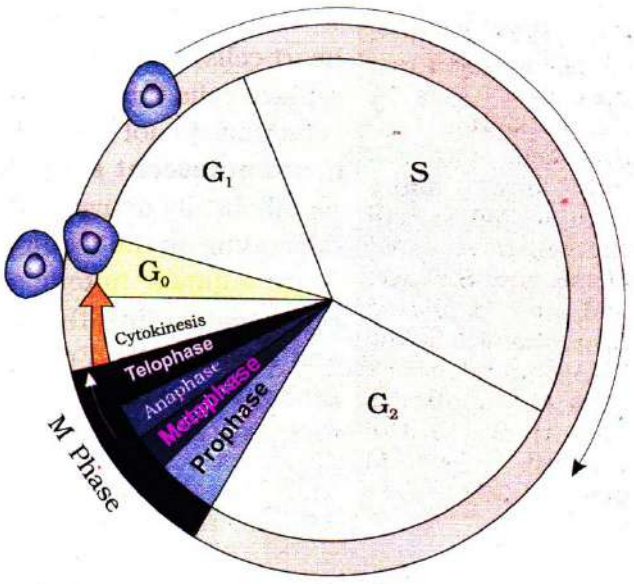


Figure 11.1 A diagrammatic view of cell cycle indicating formation of two cells from one cell

The cell cycle is divided into two basic phases

(A) Interphase

(B) Mitosis phase (M phase)

A. **Interphase** : The stage of cell cycle at which the nucleus is not in a state of division called 'Interphase'. It is the stage that occurs between two successive cell divisions. The interphase, though called the resting phase, is the time during which the cell is preparing for division by undergoing both cell growth and DNA replication in an orderly manner. The interphase is divided into three further phases or sub stages: (1) G1 phase (Gap 1) (2) S phase (synthesis) (3) G2 phase (Gap2).

(1) G1 Phase:

G1 phase corresponds to the interval between mitosis phase and initiation of DNA replication. During G1 phase the cell is metabolically active and continuously grows but does not replicate its DNA. The events that occur during G1 phase include:

- Increase in size of the cell
- Synthesis of RNA and proteins

(2) S Phase :

This phase marks the period during which DNA replication takes place. During this time the amount of DNA per cell doubles. If the initial amount of DNA is denoted as 2C then it increases to 4C. However, there is no increase in the chromosome number. If the cell had diploid or 2n number of chromosomes at G1, even after S phase the number of chromosomes remains the same i.e., 2n.

(3) G2 phase:

During G2 phase, the synthesis of proteins and RNA is continued. Various cell organelles are newly synthesised. Energy sources (ATP) required for spindle formation and movement of chromosomes is synthesised.

B. Mitosis Phase (M Phase): The M phase represents the phase when actual cell division occurs and as already mentioned the interphase represents the phase between two successive M phases.

There are two major kinds of cell division. 1) Mitosis and 2) Meiosis.

11.2 MITOSIS

This is the most dramatic period of the cell cycle, involving a major reorganisation of virtually all components of the cell. Since the number of chromosomes in the parent and progeny cells is the same, it is called equational division. Though for convenience mitosis has been divided into four stages of nuclear division (karyokinesis) and followed by cytoplasm (cytokinesis) it is very essential to understand that cell division is a progressive process and very clear cut lines can not be drawn between various stages:

- Prophase
- Metaphase
- Anaphase
- Telophase

11.2.1 Prophase

Prophase which is the first stage of mitosis followed by the S and G2 phases of interphase. In the S and G2 phases the new DNA molecules are formed are not distinct but interwined. Prophase is marked by the initiation of condensation of chromosomal material. The chromosomes gradually become short, thick and stout by condensation of chromatin (Fig 11.2a). The completion of prophase can thus be marked by the following characteristics events:

- Chromatin material condenses and organises to form compact mitotic chromosomes. Chromosomes are seen to be composed of two chromatids attached together at the centromere.
- Initiation of the assembly of mitotic spindle the microtubules, the proteinaceous components of the cell cytoplasm help in the process.

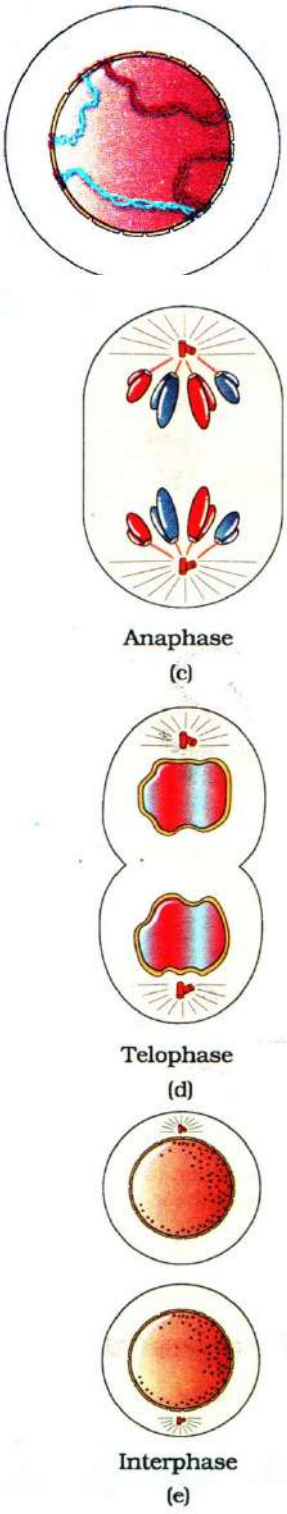


Figure 11.2 c to e : A diagrammatic view of stages in Mitosis

Cells at the end of prophase, when viewed under microscope, do not show golgi complexes, endoplasmic reticulum, nucleolus and the nuclear envelope.

11.2.2 Metaphase

The complete disintegration of the nuclear envelope marks the start of the second phase of mitosis, hence the chromosomes are spread through the cytoplasm of the cell. By this stage, condensa- tion of chromosomes is completed and they can be observed clearly under the microscope. This then, is the stage, at which morphology of chromosomes is most easily studied. At this stage, metaphase chromosome is made up of two sister chromatids, which are held together by the centromere (11.2 b). Small disc - shaped structures at the surface of the centromere are called Kinetochores. These structures serve as the sites of attachment of spindle fibres (formed by the centrioles in animal cells and by the cytoplasm in plant cells) to the chromosomes that are moved into position at the centre of the cell. Hence, the metaphase is characterised by all chromosomes coming to lie at the equater with one chromatid of each chromo-some connected by its kinetochore to spindle fibres from one pole and its sister chromatid connected by its kinetochore to spindle fibres from the opposite pole (Figure11.2b).The plane of alignment of the chromosomes at metaphase is referred to as the metaphase plate. The key features of meta phase are:

- Spindle fibres attach to kinetochores of chromosomes.
- Chromosoms are moved to spindle eqator and get aligned along metaphase plate through spindle fibres to both poles.

11.2.3 Anaphase

At the set of anaphase, each chromosome arranged at the metaphase plate is split simultane - ously and the two daughter chromatids, now referred to as chromosomes of the future daughter nuclei, begin their migration towards the opposite poles. As each chromosome moves away from the equatorial plate, the centromere of each chromosome is towards the pole and hence at the leading edge, with the arms of the chromosome is trailing behind (Figure 11.2c). Thus, anaphase stage is characterised by the following key events:

- Centromere split and chromatids separate.
- Chromatids move to opposite poles.

11.2.4 Telophase

At the beginning of the final stage of mitosis, i.e., telophase, the chromosomes that have reached their respective poles decondense and loose their individuality. The individual chromosomes can no longer be seen and chromatin material tends to collect in a mass in the poles (Figure 11.2 d). This is the stage which shows the following key events:

- Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.
- Nuclear envelope assembles around the chromosome clusters.
- Nucleolus, golgi complex and ER reform.

11.2.5 Cytokinesis

Mitosis accomplishes not only the segregation of duplicated chromosomes into daughter nuclei (karyokinesis), but the cell itself is divided into two daughter cells by a separate process called cytokinesis, at the end of which cell division is complete (Figure 11.2 e). In an animal cell, this is achieved by the appearance of a furrow in the plasma membrane. The furrow gradually deepens and ultimately joins in the centre dividing the cell cytoplasm into two. Plant cells however, are enclosed by a relatively inextensible (rigid) cell wall, therefore they undergo cytokinesis by a different mechanism. In plant cells, wall formation starts in the centre of the new cell wall begins with the formation of a simple precursor, called the cell- plate that represents the middle lamella between the walls of two adjacent cells. At the time of cytoplasmic division, organelles like mitochondria and plastids get distributed between the two daughter cells. In some organisms karyokinesis is not followed by cytokinesis as a result of which multinucleate condition arises leading to the formation of syncytium (e.g., liquid endosperm in coconut).

11.3 SIGNIFICANCE OF MITOSIS

Mitosis or the equational division is usually restricted to the diploid cells only. However, in some lower plants and in some social insects haploid cells also divide by mitosis. It is very essential to understand the significance of this division in the life of an organism is due to mitosis. Cell growth results in disturbing the ratio between the nucleus and the cytoplasm. It therefore becomes essential for the cell to divide to restore the nucleo - cytoplasmic ratio. A very significant contribution of mitosis is cell repair. The cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are being constantly replaced. Mitotic divisions in the meristamatic tissues the apical and the lateral meristems, result in a continuous growth of plants throughout their life.

11.4 MEIOSIS

The production of offspring by sexual reproduction includes the fusion of two gametes, each with a complete haploid set of chromosomes. Gametes are formed from specialised diploid cells. These specialised cells undergo division that reduces the chromosome number by half and results in the production of haploid daughter cells. This kind of division is called meiosis. Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilisation restores the diploid phase. We come across the meiosis

during gametogenesis in plants and animals. This leads to the formation of haploid gametes. The key features of meiosis are:

- Meiosis involves two sequential cycles of nuclear and cell division called meiosis I and meiosis II but only a single cycle of DNA replication.
- Meiosis I is initiated after the parental chromosomes have replicated to produce identical sister chromatids at the S phase.
- Meiosis involves pairing of homologous chromosomes and recombination between them.
- Four haploid cells are formed at the end of meiosis II.

Meiotic events can be grouped under the following phases:

Meiosis I	**Meiosis II**
Prophase I	Prophase II
Metaphas I	Metaphase II
Anaphase I	Anaphase II
Telophase I	Telophase II

11. 4. 1 Meiosis I

Prophase I: Prophase of the first meiotic division is typically longer and more complex when compared to prophase of mitosis. It has been further subdivided into the following five phases based on chromosomal behaviour, i.e., Leptptene, Zygotene, Pachytene, Diplotene and Diakinesis.

A) Leptotene : In this phase, the chromosomes become gradually visible under the light microscope. They are long and slender and the nucleus enlarges in size**.**

B) Zygotene: It is characterised by pairing of chromosomes and this process of association is called **synapsis.** Such Paired chromosomes are called homologous chromosomes**.** The pairs of homologous chromosomes are called **bivalents.** The pairing is brought about in a zipper like fashion due to a protein called synaptonemal complex and may start at centromere (procentric synapsis) or chromosome ends (Proterminal synapsis) or at any other position (Random synapsis). Zygotene is also characterised by the enlargement of nucleolus and initiation of spindle formation.

C) Pachytene : It is most significant sub-stage. During this stage, bivalent chromosomes now clearly appears as tetrads. This stage is characterised by the appearance of recombination nodules, the sites at which crossing over occurs between two homologous chromosomes. Crossing over is the exchange of genetic material between 'X' shaped structures called Chaismata. Crossing over is also an enzyme - mediated process and the

enzyme involved is called recombinase. Crossing over leads to recombination of genetic material on the two chromosomes. Recombination between homologous chromosomes is completed by the end of pachytene, leaving the chromosomes linked at the sites of crossing over.

D) Diplotene : The beginning of diplotene can be recognised by the dissolution of the synaptonemal complex by the repulsion activity between homologous chromosomes. As a result, the bivalents of the homologous chromosomes are separated from each other except at the sites of the chaismata regions. Diplotene is also characterised by the considerable condensation or despiralisation of chromosomes.

E) Diakinesis : In this stage, the chaismata begin to move towards the chromosomes ends. This displacement of chaismata towards the terminal position is called terminalisation. The bivalents become very thick and short and migrate to the periphery of the nucleus. The nucleolus begins to disappear, the nuclear membrane disrupts and the chromosomes are released into the cytoplasm.

Metaphase I: The bivalent chromosomes align on the equatorial plate (Figure 11.3). The microtubules from the opposite poles of the spindle attach to the pair of homologous chromosomes.

Anaphase I: The homologous chromosomes separate, while sister chromatids remain associated at their centromeres (Figure 11.3).

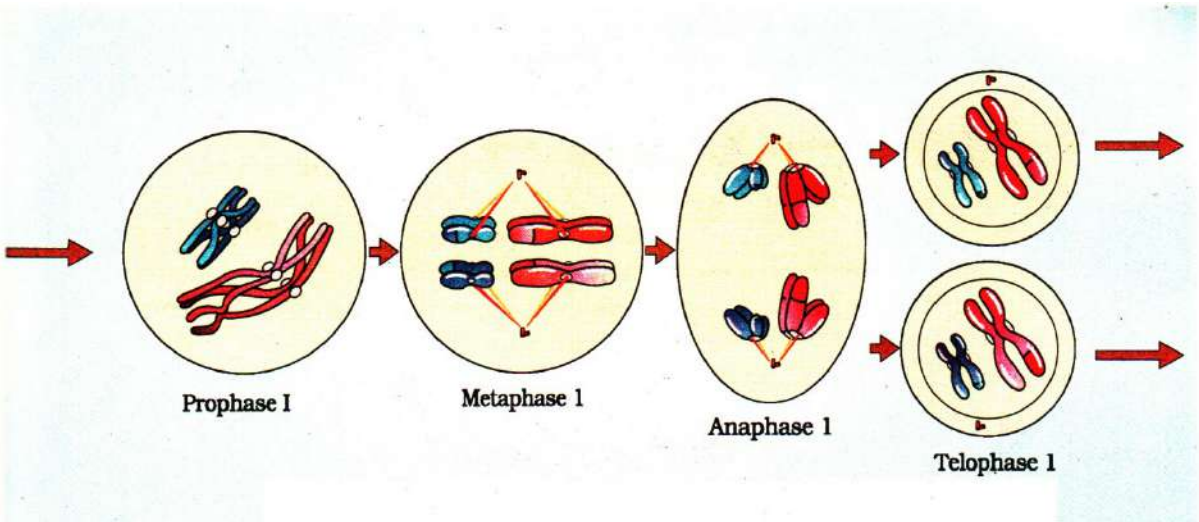


Figure 11.3 Stages of Meiosis I

Telophase I: The nuclear membrane and nucleolus reappear, cytokinesis follows and this is called as diad of cells (Figure 11.3). Although in many cases the chromosomes do undergo some dispersion, they do not reach the extremely extended state of the interphase nucleus. The

stage between the two meiotic divisions is called interkinesis and is generally short lived. Interkinesis is followed by prophase II, a much simpler prophase than prophase I (Figure 11.3).

11.4.2 Meiosis II

ProphaseII: Meiosis II is initiated immediately after cytokinesis, usually before the chromosomes have fully elongated. In contrast to meiosis I, resembles a normal mitosis. The nuclear membrane disaapears by the end of prophase II (Figure 11.4). The chromosomes again become compact.

Metaphase II: At this stage, the chromosomes align at the eqator and the microtubules from opposite poles of the spindle get attached to the kinetochores (Figure 11.4) of sister chromatids.

Anaphase II: It begins with the simultaneous splitting of the centromere of each chromosome (which was holding the sister chromatids together), allowing them to move toward opposite poles of the cell (Figure 11.4).

Telophase II: Meiosis ends with telophase II, in which the two groups of chromosomes once again get enclosed by a nuclear envelope; cytokinesis follows resulting in the formation of tetrads of cells i.e., four haploid daughter cells (11.4).

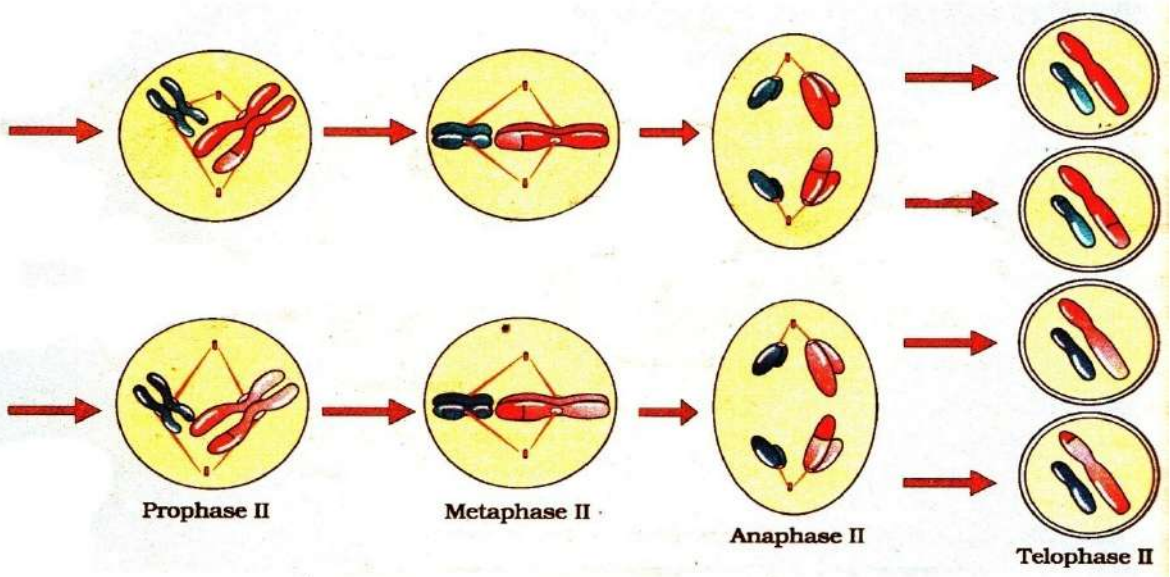


Figure 11.4 Stages of Meiosis II

11.5 Significance of Meiosis

Meiosis is the mechanism, by which conservation of specific chromosome number of each species is achieved across generations in sexually repdroducing organisms. It results in the reduction of chromosome number half. It also increases the genetic variability in the population of organisms from one generation to the next. Variations are very important for the process of evolution.

SUMMARY

According to the cell theory, cells arise from pre-existing cells. The process by which this occur is called cell division. Any sexually reproducing organism starts its life cycle from a single- celled zygote. Cell division does not stop with the formation of the mature organism but continues throughout its life cycle.

The stages though which a cell passes from one division to the next is called the cell cycle. Cell cycle is divided into two phases called (I) Interphase - a period of preparation for cell division and (ii) Mitosis (M Phase) - the actual period of cell division. Interphase is further subdivided into G1, S and G2. G1 phase is the period when the cell grows and carries out normal metabolism.

Most of the organelle duplication also occurs during this phase. S Phase marks the phase of DNA replication and chromosome replication. G2 phase is the period of cytoplasmic growth. Mitosis is divided into four stages namely prophase, metaphase, anaphase and telophase. Chromosome condensation occurs during prophase. Simultaneously, the centrioles when present move to the opposite poles. The nuclear envelope and the nucleolus disappear and the spindle fibres start appearing. Metaphase is marked by the alignment of chromosomes at the equatorial plate. During Anaphase the centromeres divide and the chromatids start moving towards opposite poles. Once the chromatids reach the two poles, the chromosomal elongation starts, nucleolous and the nuclear membrane reappear. This stage is called telophase. Nuclear division is then followed by the cytoplasmic division and is called cytokinesis. Mitosis thus, is the equational division in which the chromosome number of the parent is conserved in the daughter cell.

In contrast to mitosis, meiosis occurs in the diploid cells, which are destined to form gametes. It is called the reduction division since it reduces the chromosome number by half while making the gametes. In sexual reproduction when the two gametes fuse the chromosome number is restored to the value in the parent. Meiosis is divided into two phases – meiosis I and meiosis II. Meiosis I has a long prophase, which is divided further into five sub-phases. These are leptotene, zygotene, pachytene, diplotene and diakinesis. In the first meiotic division the homologous chromosomes pair to form bivalents, and undergo crossing over. During metaphase I the bivalents are arranged on the equatorial plate. This is followed by anaphase I in which

homologous move to the opposite poles with both their chromatids. Each pole receives half the chromosome number of the parent cell. In telophase I, the nuclear membrane and nucleolus reappear. Meiosis II is similar to mitosis. During anaphase II, the sister chromatids separate. Thus at the end of meiosis four haploid cells are formed.

GLOSSARY

Bivalent: A pair of homologous chromosomes in synopsis.

Cell cycle : Cyclic sequence of events by which the cell duplicates its genome and eventually divides.

Cell plate: Precursor of cell wall, formed during cytokinesis in plant cells.

Chaismata: X- shaped structures formed as a consequence of crossing over.

Chromatid : Longitudinal half of a metaphase chromosome.

Cytokinesis: Division of cytoplasm.

Diplotene: Stage of prophase I of meiosis where paired chromosomes start to separate.

Interphase: A preparatory stage which intervences between two successive divisions.

Karyokinesis: Division of nucleus.

Pachytene: Thick thread stage in which exchange of chromosomal material between homologoues takes place.

Quiescent stage (G_o): An inactive stage of the cell cycle for cells that no longer divide.

Synaptonemal Complex: A proteinaceous complex in which the homologous chromosomes are held together during prophase - I of meiosis.

VERY SHORT ANSWER TYPE QUESTIONS

1. Which tissue of animals and plants exhibits meiosis ?
2. If a tissue has at a given time 1024 cells. How many cycles of mitosis ha the original parental single cell undergone ?
3. Name the stage of meiosis in which actual reduction in chromosome number occurs.
4. An Anther has 1200 pollen Grains. How many Pollen Mother Cells must have been there to produce them ?

SHORT ANSWER QUESTIONS

1. Explain prophase I of meiosis.
2. Which division is necessary to maintain constant chromosome number in all body cells of multicellular organism and why ?
3. Though redundantly described as a resting phase, Interphase does not really involve rest. Comment ?

EXCERCISES

1. Name a stain commonly used to colour chromosome.
2. Name the pathological condition when uncontrolled cell division occurs.
3. G1, S and G2 are stages of
   (A) Interphase (B) Prophase (C) Metaphase (D) Anaphase

CHAPTER 12

HISTOLOGY AND ANATOMY OF FLOWERING PLANTS

12.1 THE TISSUES

A tissue is defined as a group of similar or dissimilar cells that have a common origin and perform a common function. In plants two major types of tissues are identified. They are A. Meristematic tissues and B. Permanent tissues.

12.2.1 Meristematic Tissues

During embryonic stages of the plant body, all the cells undergo division. But at the time of further growth addition of new cells through embryonic tissues is restricted to certain parts of the plant body. These persistent embryonic tissues in the plant body are called meristems (GK. *Meristos*: divided). The term meristem was coined by **K. Nageli** (1858). The cells in a meristem divide actively and produce new cells there by promoting the growth of the plant body. Plants have different kinds of meristems. The meristems which occur at the tips of roots and shoos and produce primary tissues are called **apical meristems** (Figure 12.1).

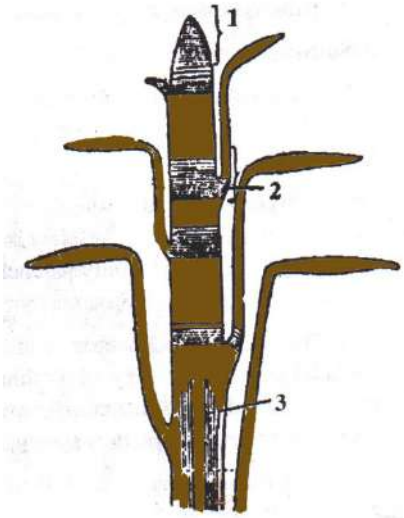


Fig 12.1 Position of meristems in the L.S. of plant axis
1. Apical 2. Intercalary 3. Lateral

Root apical meristem occupies the tip of a root while the shoot apical meristem occupies the distant most region of the stem axis. During the formation of leaves and elongation of stem, some cells 'left behind' from shoot apical meristem, constitute the axillary bud. Such buds are present in the axils leaves and are capable of forming a branch or a flower. The meristem which occurs between mature tissues is known as **intercalary meristems**. They occur in grasses and regenerate parts removed by the grazing herbivores. Both apical meristems and intercalary meristems are **primary meristems** because they appear early in life of a plant and contribute to the formation of the primary plant body.

The meristem that occurs in the mature regions of roots and shoots of many plants, particularly those that produce woody axis and appear later than primary meristem is called **secondary or lateral meristem.** They are cylindrical meristems. Fascicular vascular cambium,

interfascicular cambium and cork- cambium are examples of lateral meristems. These are responsible for producing the secondary tissues.

Following divisions of cells in both primary and secondary meristems, the newly formed cells become structurally and functionally specialised and lose the ability to divide. Such cells are termed permanent or mature cells and constitute the permanent tissues. During the formation of the primary plant body, specific regions of the apical meristem produce dermal tissues, ground tissues and vascular tissues.

12.1.2 Permanent Tissues

A group of mature or differentiated cells which have lost the capacity of cell division either temporarily or permanently and perform a specific function is known as permanent tissue. The permanent tissues constitute the major bulk of the plant body and perform different functions in relation to their location in the plant organs.

Permanent tissues having all cells similar in structure and function are called **Simple tissues.**Permanent tissues having many different types of cells are called **Complex tissues.**

12.2.2.1 Simple tissues

A simple tissue is made of only one type of cells. The various simple tissues in plants are parenchyma, collenchymas and sclerenchyma (Figure 12.2).

Parenchyma:parenchyma forms the major component within organs. The cells of the parenchyma are generally isodiametric. They may be spherical, oval, round, polygonal or elongated in shape. Their walls are thin and made up of cellulose. They may either be closely packed or have small intercellular space.

Functions: The parenchyma performs various functions like photosynthesis, storage and secretion.

Collenchyma: The collenchymas occurs in layers below the epidermis in dicotyledonous plants. It is found either as a homogeneous layer or in patches. It consists of cells which are much thickened at the corners due to a deposition of cellulose, hemicelluloses and pectin. Collenchyma cells may be oval, spherical or polygonal and often contain chloroplasts. Intercellular spaces are absent.

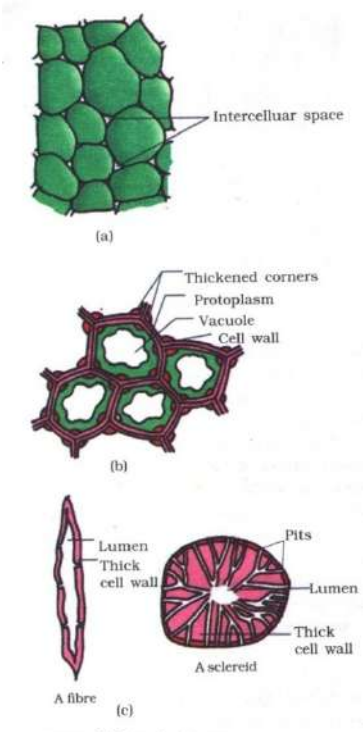


Figure 12.2 Simple tissues :
(a) Parenchyma
(b) Collenchyma
(c) Sclerenchyma

Functions: They provide mechanical support to the growing parts of the plant such as young stem and petiole of leaf.

Sclerenchyma : Sclerenchyma consists of long, narrow cells with thick and lignified cell walls having a few or numerous pits. They are usually dead and without protoplasts. On the basis of variation in form, structure, origin and development, sclerenchyma may be either fibres or sclereids. The fibres are thick-walled, elongated and pointed cells, oval or cylindrical, highly thickened dead cells with very narrow cavities (lumen). These are commonly found in the fruit walls of nuts; pulp of fruits like guava, pear and sapota, seed coats of legumes and leaves of tea.

Functions: Sclerenchyma provides mechanical support to organs.

12.1.2.2 Complex tissues

The complex tissues are made of more than one type of cells and these work together as a unit. Xylem and Phloem constitute the complex tissues in plants (Figure 12.3).

A) Xylem

It is composed of four different kinds of elements, namely, tracheids, vessels, Xylem fibres and xylem parenchyma. Gymnosperms lack vessels in their xylem. The presence of vessels is a characteristic feature of angiosperms. Tracheids are elongated or tube like cells with thick and lignified walls and tapering ends. These are dead and are without protoplasm. The inner layers of the cell walls have thickenings which vary in form. In flowering plants, tracheids and vessels are the main water conducting elements. Vessel is a long cylindrical tube- like structure made up of many cells called vessel members, each with lignified walls and a large central cavity, these cells are also devoid of protoplasm. Xylem fibres have highly thickened walls and with central leumen. Xylem parenchyma cells are living and thin- walled, and their cell walls are made up of cellulose. They store food materials and also used for conduction of water.

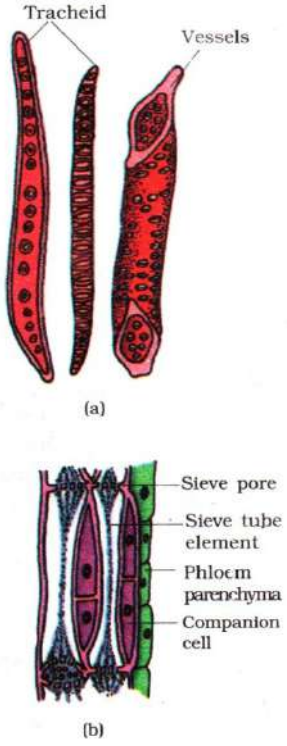


Figure 12.3 (a) Xylem (b) Phloem

Primary xylem is of two types-protoxylem and metaxylem. The first formed primary xylem elements are called protoxylem and the later formed primary xylem is called metaxylem. In stems, the protoxylem lies towards the centre (Pith) and meta xylem lies towards the periphery of the organ. This type of primary xylem is called **endarch.** In roots, the protoxylem lies periphery and

metaxylem lies towards centre. Such arrangement of primary xylem is called **exarch.**

B) PHLOEM

Phloem transports food materials, usually from leaves to other parts of the plants. Phloem in angiosperms is composed of sieve elements, companion cells, phloem parenchyma and phloem fibres. Gymnosperms have albuminous cells and sieve cells. They lack sieve tubes and companion cells. Sieve tube elements are long, tube- like structures, arranged longitudinally and are associated with the companion cells. Their end walls are perforated in a sieve-like manner to form the sieve plates. A mature sieve element possesses a peripheral cytoplasm and a large vacuole but lacks a nucleus. The functions of the sieve tubes are controlled by the nucleus of companion cells. The companion cells are specialised parenchymatous cells, which are closely associated with sieve tube elements. Phloem parenchyma is made up of elongated, tapering cylindrical cells which have dense cytoplasm and nucleus. It stores food material and other substances like resins, latex and mucilage. Phloem parenchyma is absent in most of the monocotyledons. Phloem fibres (bast fibres) are made up of sclerenchymatous cells. These are much elongated, unbranched and have pointed, needle like apices. The cell walls of the phloem fibres is quite thick. At maturity, these fibres lose their protoplasm and become dead. The phloem fibres of jute, flax and hemp are used commercially. The first formed primary phloem consists of narrow sieve tubes and is reffered to as protophloem and the later formed phloem has bigger sieve tubes and is referred to as metaphloem.

12.2 THE TISSUE SYSTEMS

We have discussed the types of tissues based on the types of cells present. Let us now consider how tissues vary depending on their location in the plant body. Their structure and function would also be dependent on location. On basis of their structure and location, there are three types of tissue systems. They are 1. Epidermal tissue system 2. Ground or Fundamental tissue system 3. Vascular or Conducting tissue system.

12.2.1 Epidermal tissue system

The epidermal tissue system forms the outer-most covering of the whole plant body and comprises epidermal cells, stomata and the epidermal appendages - the trichomes and hairs.The epidermis is the outermost layer of the primary plant body. It is made up of elongated, compactly arranged cells, which form a continuous layer. Epidermis is usually single-layered. Epidermal cells are parenchymatous with a small amount of cytoplasm lining the cell wall and a large vacuole.

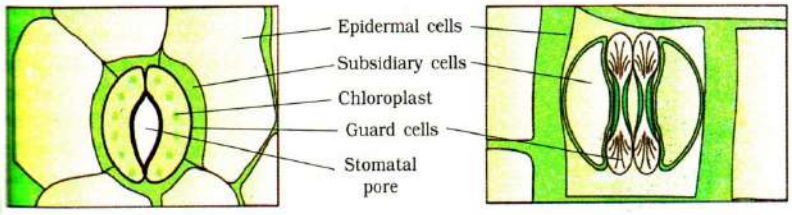


Figure 12.4 Diagrammatic representation: (a) stomata with bean-shaped guard cells (b) stomata with dumb-bell shaped guard cell

The outside of the epidermis is often covered with a waxy thick layer called cuticle which prevents the loss of water. Cuticle is absent in roots. Stomata are structures present in the epidermis of leaves. Stomata regulate the process of transpiration and gaseous enchange. Each stoma is composed of two bean- shaped cells known as guard cells. In grasses the guard cells are dumb-bell shaped. The outer walls of guard cells (away from the stomatal pore) are thin and the inner walls (towards the stomatal pore) are highly thickened. The guard cells possess chloroplast and regulate the opening and closing of stomata. Sometimes, a few epidermal cells, in the vicinity of the guard cells become specialised in their shape and size and are known as subsidiary cells. The stomatal aperture, guard cells and the surrounding subsidiary cells are together called stomatal apparatus (Figure 12.4).

The cells of epidermis bear a number of hairs. The root hairs are unicellular elongations of the epidermal cells and help absorb water from the soil. On the stem, the epidermal hairs are called trichomes. The trichomes in the shoot system are usually multicellular. They may be branched or unbranched and soft or stiff. They may even be secretory. The trichomes help in preventing water loss due to transpiration.

12.2.2 The Ground Tissue System

All tissues except epidermis and vascular bundles constitute the ground tissue. It consists of simple tissues such as arenchyma, collenchyma and sclerenchyma. Parenchymatous cells are usually present in cortex, pericycle, pith and medullary rays, in the primary stems and roots. In leaves, the ground tissue consists of thin- walled chloroplast containing cells and is called mesophyll.

12.2.3 The Vascular Tissue System

The vascular system consists of complex tissues, the phloem and the xylem. The xylem and phloem together called constitute vascular bundles (Figure 12.5). In dicotyledonous stems, cambium is present between phloem and xylem. Such vascular bundles, because of the presence of cambium, possess the ability to form secondary xylem and phloem tissues, and hence are called **open** vascular bundles. In the monocotyledons, the vascular bundles have no cambium present in them. Hence, since they do not form secondary tissues, they are referred to as **closed.** When xylem and phloem within a vascular bundle are arranged in an alternate manner on different radii, the arrangement is called **radial** such as in roots. In *conjoint* type of vascular bundles, the xylem and phloem are situated at the same radius of vascular

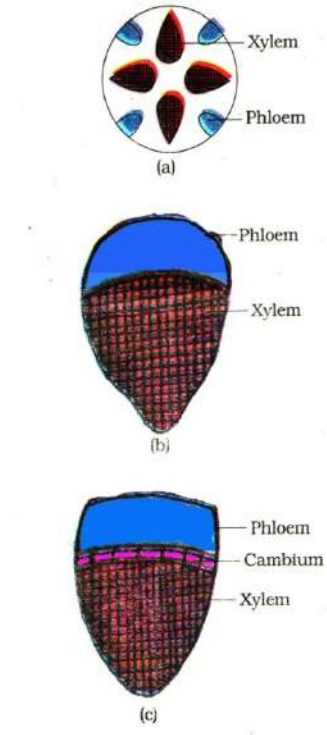
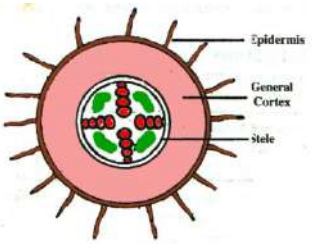


Figure 12.5 Various types of vascular bundles : (a) radial (b) conjoint closed (c) conjoint open

bundles, such vascular bundles are common in stems and leaves. The conjoint vascular bundles usually have the phloem located only on the outer side of xylem. In **bicollateral** vascular bundles phloem present on either side of the xylem separated by cambia. E.g: Cucurbita.

12.3 ANATOMY OF DICOTYLEDONOUS AND MONOCOTYLEDONOUS PLANT



For better understanding of tissue organisation of roots, stems and leaves, it is convenient to study the transverse section (T.S) of the zones of these organs.

12.3.1 Dicotyledonous Root

Look at Figure 12.6 (a), it shows an enlarged view of a sector of the transverse section of young primary root of dicotyledonous plants. It shows three zones - Epidermis, Cortex and Stele.

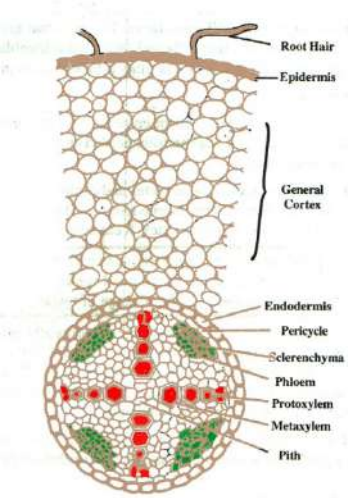
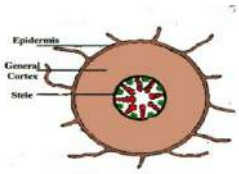


Fig : 12.6 (a) T.S of Dicot root (Primary)

Epidermis

This is the outermost layer of thin walled cells. Some epidermal cells show tubular extensions called root hairs. Root hairs grow into the soil spaces and absorb water. The epidermis also gives protection to the inner tissues.

Cortex



It is present below the epidermis. It consists of undifferentiated parenchyma. Intercellular spaces are present between them. Innermost layer of cortex is the endodermis. The radial and transverse walls show Casparian stripes. They are called passage cells.

Stele

It is present in the centre of the root. It is surrounded by pericycle. The xylem and phloem are present on the different radii. So vascular

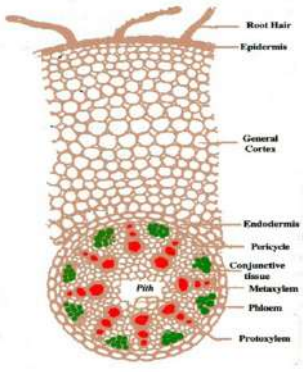


Fig : 12.6 (b) T.S of Monocot Root

bundles are called **'radial vascular bundles.** Xylem is **exarch** showing protoxylem elements present towards the pericycle and metaxylem elements towards the medulla. It is **tetrarch** because it has four xylem strands. Conjunctive tissue is present between xylem and phloem. Center of the stele is occupied by a small parenchymatous pith or medulla.

12.3.2 Monocotyledonous Root

The anatomy of the monocot root is similar to the dicot root in many respects (Figure 12.6 b). It has epidermis, cortex, endodermis, pericycle, vascular bundles and pith. As compared to the dicot root which has fewer xylem bundles, there are usually more than six (polyarch) xylem bundles in the monocot root. Pith is large and well developed. Monocotyledonous roots do not undergo any secondary growth.

12.3.3 Dicotyledonous stem

The transverse section of a typical young dicotyledonous stem shows epidermis, cortex and stele (figure 12.7 a).

Epidermis

This is the outermost layer of single row of cells. It is covered by thin layer of cuticle. It may bear **trichomes** and a few stomata.

Cortex

It lies

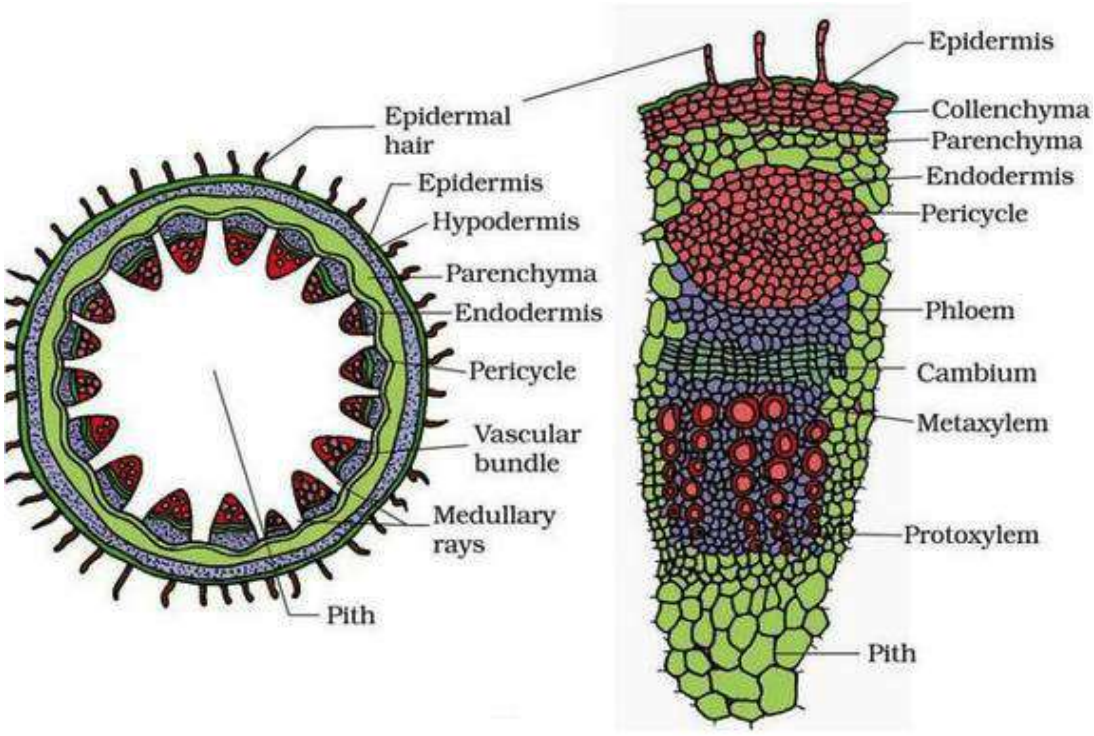


Fig : 12.7(a) Dicot Stem (T.S)

between the epidermis and stele. The cortex is smaller than the stele. The cortex is differentiated into three parts such as hypodermis, general cortex and endodermis. **Hypodermis** is the outermost part of the cortex and composed of 3-6 rows of collenchymatous cells. It is found beneath the epidermis. **General cortex** is present beneath the hypodermis and is made of parenchymatous cells. **Endodermis** is the innermost layer of cortex. The radial and transverse walls show casparian bands. The cells show starch grains.

Stele

It lies in the centre of the stem. It is differentiated into pericycle, vascular bundles, pith (Medulla) and medullary rays. **Pericycle** is present between the endodermis and the vascular bundles. It is represented by patches of sclerenchyma alternating with patches of parenchyma. Each **vascular bundle** is top shaped. Limited number of vascular bundles are arranged in the form of a circular ring (Eustele). Vascular bundles are **conjoint** (because each bundle contains both xylem and phloem), **collateral** (because xylem and phloem are present side by side on the same radius) and **open** (because of the presence of cambium between xylem and phloem). Xylem is **endarch** because protoxylem elements are present towards the centre and metaxylem towards the pericycle. The central part of the stele is made of **medulla** or **pith** having parenchymatous cells with intercellular spaces. In between two vascular bundles are present radially elongated **medurally rays**.

12. 3. 4. Monocotyledonous stem

The transverse section of monocot stem shows epidermis, hypodermis, ground tissue and vascular bundles (Figure 12.7b).

Epidermis

This is the outermost layer of single row of cells. It is covered by thin cuticle. Few stomata are present and multicellular epidermal hairs are absent.

Hypodermis

It lies below the epidermis. Hypodermis is two or three layers thick and is made of sclerenchymatous cells.

Ground tissue

It extends from hypodermis to the centre of the axis. The cells are parenchymatous and intercellular spaces are absent. cortex and endodermis was not differentiated.

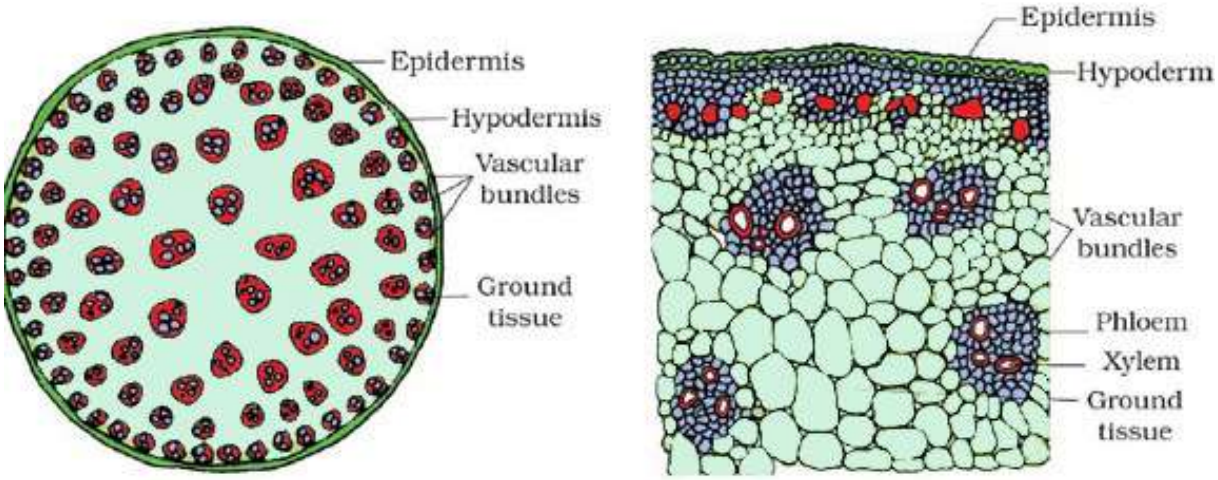


Fig: 12.7 (b) Monocot Stem (T.S)

Vascular bundles

Numerous vascular bundles are scattered in the ground tissue (Atactostele). They are oval in shape. The vascular bundles nearer the periphery are smaller than those centre. Vascular bundles are **conjoint** (because each bundle contains both xylem and phloem), **collateral** (because xylem and phloem are present side by side on the same radius) and **closed** (because of the abscence of fascicular cambium in between xylem and phloem). Each vascular bundle is surrounded by sclerenchymatous bundle sheath. Hence vascular bundles are called **firo-vascular dundles**. Xylem is endarch because the metaxylem elements are towards the peicycle (Periphery) and protoxylem towars the centre. In the xylem, vessels are arranged in the shape of 'Y'. **Protoxylem lacunae** (lysigenous cavities) are present. Medulla (pith), medullary rays and pericycle are absent.

12.3.5 Dorsiventral (Dicotyledonous) leaf

The transverse section of dorsiventral leaf shows three main parts called epidermis, mesophyll and vascular bundles (12.8 a).

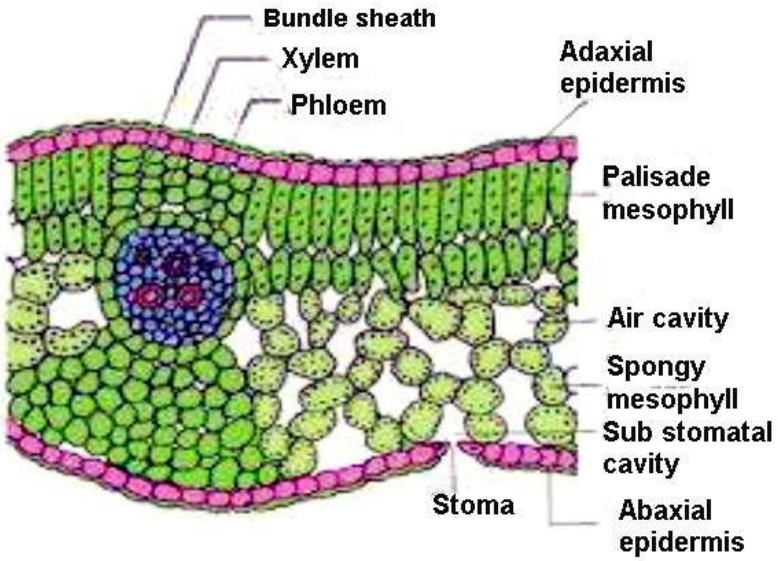


Fig : 12.8(a) T.S of Dicot leaf

Epidermis

The epidermis which covers both the upper surface (adaxial epidermis) and lower surface(abaxialepidermis) of the leaf has a conspicuous cuticle. The abaxial epidermis generally bears more somata than the adaxial epidermis. The epidermis also show multicellular hairs which are uniseriate.

Mesophyll

The tissue between the upper and the lower surfaces is called mesophyll. Mesophyll which possesses chloroplasts and carry out photosynthesis, is made up of parenchyma. It has two types of cells the palisade parenchyma and the spongy parenchyma. The adaxially placed palisade parenchyma is made up of elongated cells, which are arranged vertically and parallel to each other. The oval or round and loosely arranged spongy parenchyma is situated below the palisade cells and extends to the lower epidemis. There are numerous large spaces and air cavities between these cells.

Vascular bundles

Vascular system include vascular bundles, which can be seen in the veins and the midrib. The size of the vascular bundles is dependent on the size of the veins. The veins vary in thickness in the reiculate venation of the dicot leaves. The vascular bundles are surrounded by a layer of thick walled bundle sheath cells.

12.3.6 Isobilateral (Monocotyledonous) leaf

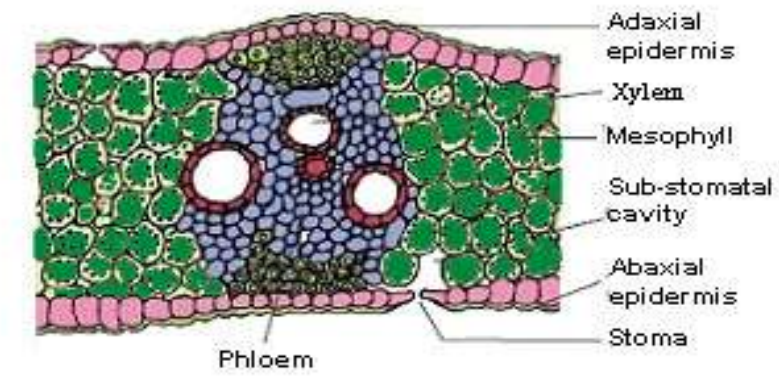


Fig : 12.8(b) T.S of monocot leaf

The anatomy of monocotyledonous leaf is similar to that of the docoyledonous leaf in many ways. It shows the following characteristic differences. In an isobilateral leaf, the stomata are present on both the surfaces of the epidermis: and the mesophyll is not differentiated into palisade and spongy parenchyma (Figure 12.8 b).

In grasses, certain adaxial epidermal cells along the veins modify themselves into large, empty, colourless cells. These are called **bulliform cells**. When the bulliformcells in the leaves have absorbed water and are turgid, the leaf surface is exposed. When they are flaccid due to water stress, they make the leaves curl inwards to minimise water loss.

The parallel venation in monocot leaves is reflected in the near similar sizes of vascular bundles (except in main veins).

12.4 SECONDARY GROWTH

The growth of the roots and stems in length with the help of apical meristem is called primary growth. Apart from primary growth, most dicotyledonous plants exhibit an increase in girth. This increase is called the secondary growth. The tissues involved in secondary growth are the two lateral meristems: Vascular cambium and cork cambium.

12.4.1 Vascular Cambium

The meristamatic layer that is responsible for cutting off vascular tissues xylem and phloem is called vascular cambium. In the young stem it is present in patches as a single layer between the xylem and phloem. Later it forms a complete ring.

12.4.1.1 Formation of cambial ring

In dicot stems, the cells of cambium present between primary xylem and primary phloem is the intrafascicular cambium. The cells of medullary cells, adjoining these intrafascicular cambia become meristamatic and form the interfascicular cambium. Thus, a continuous ring of vascicular cambium is formed.

12.4.1.2 Activity of The cambial ring

The cambial ring becomes active and begins to cut off new cells, both towards the inner and the outer sides. The cells cut off towards pith, mature into secondary xylem and the cells cut off towards periphery mature into secondary phloem. The cambium is generally more active on the inner side than the outer. As a result, the amount of secondary xylem produced is more than

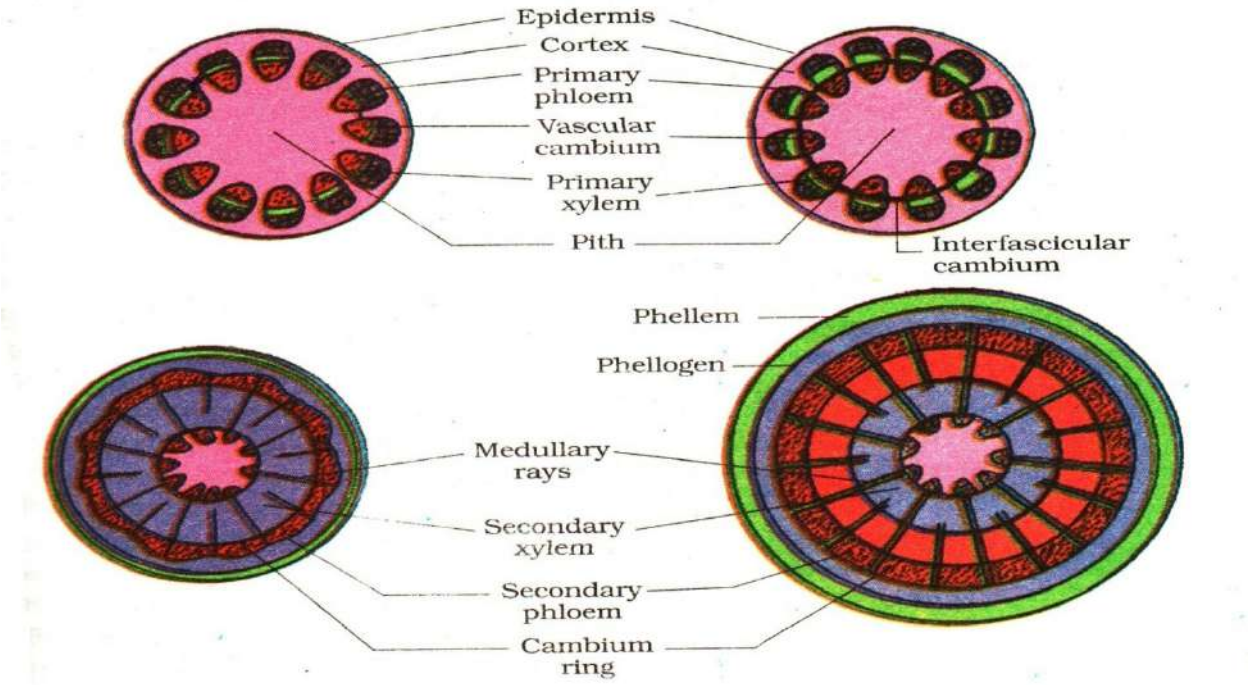


Figure 12.9 Stages of secondary growth in Dicot stem (T.S)

secondary phloem and soon forms a compact mass. The primary and secondary phloems get gradually crushed due to the continued formation and accumulation of secondary xylem. The primary xylem however remains more or less intact, in or around the centre. At some places, the cambium forms a narrow band of parenchyma, which passes through the secondary xylem and the secondary phloem in the radial directions. These are the secondary medullary rays (12.9).

12.4.1.3 Spring Wood And Autumn Wood

The activity of cambium is under the control of many physiological and environmental factors. During the favourable season for growth, i.e. in spring, when more leaves and flowers

are formed, the plant requires large amounts of water and mineral salts. Hence wood is produced in this period shows more number of xylem vessels having wider lumens. This is known as spring wood or early wood. During the unfavourable season i.e. in autumn, the plants less active and do not require more water and mineral salts. Hence the wood is produced in this period shows less number of xylem vessels having narrow lumens. This is known as autumn wood or late wood. In this way, two types of wood (secondary xylem) are produced in one year. These two kinds of woods that appear as concentric rings, constitute an annual ring or growth ring. By counting the number of annual rings the approximate age of trees can be estimated. This branch of science is known as dendrochronology.

The spring wood is lighter in colour and has a lower density where as the autumn wood is darker and has a higher density.

12.4.1.4 Heart wood and Sap wood

In old trees, the greater part of secondary xylem is dark brown due to deposition of organic compounds like tannins, resins, oils, gums, aromatic substances and essential oils in the central or innermost layers of the stem. These substances make it hard, durable and resistant to the attacks of micro organisms and insects. This region comprises dead elements with lignified walls and is called heart wood. The heart wood does not conduct water but it gives mechanical support to the stem. The peripheral region of the secondary xylem is lighter in colour and it is known as the sap wood. It is involved in the conduction of water and minerals from root to leaf.

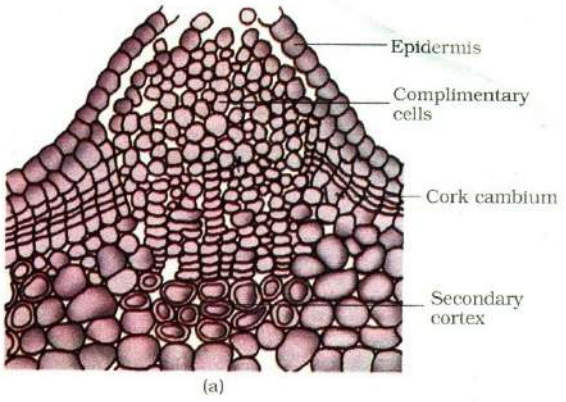


Figure 12.10 (a) Lenticel and (b) Bark

12.4.3 Cork Cambium

As the stem continues to increase in girth due to the activity of vascular cambium, the outer cortical and epidermal layers get broken and need to be replaced to provide new protective cell layers. Hence, sooner or later, another meristematic tissue called cork cambium or phellogen develops, usually in the cortical region. Phellogen is a couple of layers thick. It is made of narrow, thin-walled and nearly rectangular cells. Phellogen cuts off cells on both sides. The outer cells

differentiates into cork or phellem while the inner cells differentiate into secondary cortex or phelloderm. The cork is impervious to water due to suberin deposition in the cell wall. The cells of secondary cortex are parenchymatous. Phellogen, phellem and phelloderm are collectively known as periderm. Due to activity of the cork cambium, pressure builds up on the remaining layers peripheral to phellogen and ultimately these layers die and slough off. Bark is non-technical term that refers to all tissues exterior to the vascular cambium, viz., periderm and secondary phloem. Bark that is formed early in the season is called early or soft bark. Towards the end of the season late or hard bark is formed (Figure 12.10 a).

At certain regions, the phellogen cuts off closely arranged parenchymatous cells on the outer side instead of cork cells. These parenchymatous cells (complementary cells) soon rupture the epidermis, forming a lens - shaped openings called lenticels. Lenticels permit the exchange of gases between the outer atmosphere and the internal tissue of the stem. These occur in most woody trees (Figure 12.10 b).

12.4.3 SECONDARY GROWTH IN ROOTS

In the dicot roots, the vascular cambium is completely secondary in origin. It originates from the tissue located just below the phloem bundles, a portion of pericycle tissue, above the protoxylem forming a complete and continuous wavy ring, which later becomes circular (Figure 12.11). Further events are similar to those already described above for a dicotyledonous stem.

Secondary growth also occurs in stems and roots of gymnosperms. However, in general, secondary growth does not occur in monocotyledons.

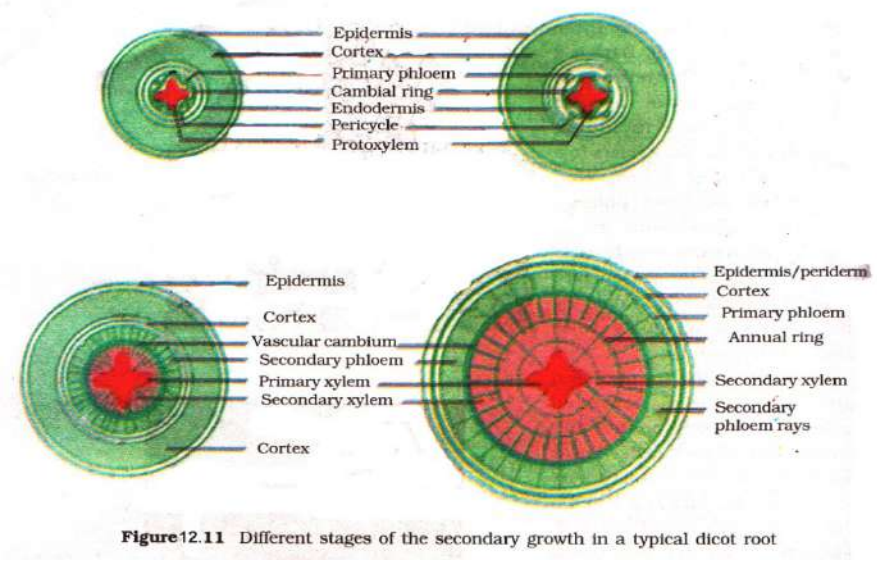


Figure 12.11 Different stages of the secondary growth in a typical dicot root

SUMMARY

Anatomically, a plant is made of different kinds of tissues. The plant tissues are broadly classified into meristematic (apical, lateral and intercalary) and permanent (simple and complex). Assimilation of food and its storage, transportation of water, minerals and photosynthates, and mechanical support are the main functions of tissues. There are three types of tissue systems - epidermal, ground and vascular. The epidermal tissue systems are made of epidermal cells, stomata and the epidermal appendages. The ground tissue system forms the main bulk of the plant. It is divided into three zones- cortex, pericycle and pith. The vascular tissue system is formed by the xylem and phloem. On the basis of presence of cambium, location of xylem and phloem, the vascular bundles are of different types. The vascular bundles form the conducting tissue and translocate water, minerals and food material.

Monocotyledonous and dicotyledonous plants show marked variation in their internal structures. They differ in type, number and location of vascular bundles. The secondary growth occurs in most of the dicotyledonous roots and stems and it increases the girth (diameter) of the organs by the activity of primary and secondary meristems namely the vascular cambium and the cork cambium. The wood is actually a secondary xylem. There are different types of wood on the basis of their composition and time of production.

GLOSSARY

Annual ring: The spring wood and autumn wood that appear in a year as concentric ring in secondary organs of dicotyledons constitute annual ring. By counting the number of annual rings, the approximate age of trees can be estimated.

Autumn wood or late wood: The wood having vessels with narrow lumens is called autumn wood. It is formed in autumn season.

Bicollateral vascular bundle: Phloem is present on either side of the xylem separated by cambia.

Bulliform cells : These are the large, empty and colourless cells present in adaxial epidermis of isobilateral leaves. They help in rolling and unrolling of the leaves.

Casparian stripes : These are water impermeable, waxy suberised bands deposited on tangential as well as radial walls of the endodermal cells.

Complex tissues: Permanent tissues having many different types of cells are called complex tissues.

Conjoint vascular bundle: This is one type of vascular bundle in which the xylem and phloem are present at the same radius of vascular bundle.

Exarch : The protoxylem lies towards periphery and metaxylem lies towards the centre. This type of arrangement of primary xylem is found in roots.

Fibres: These are thick walled elongated cells of sclerenchyma generally occuring in groups.

Heart wood : The dark brown coloured central part of secondary xylem comprising of dead elements with highly lignified walls is called heart wood. It is infiltrated with various organic compounds like tannins, resins, oils, gums, aromatic substances and essential oils.

Lenticels: Lens shaped openings in the cork of woody trees are called lenticels. They show closely arranged parenchymatous cells. The lenticels permit exchange of gases between the outer atmosphere and the internal tissues of the woody organs.

Meristems : These are specialised regions of active cell division in plants.

Periderm : Phellogen, phellem and phelloderm are collectively known as periderm.

Phellem: Cork tissue formed from the cells cut off from the phellogen.

Phelloderm: Cells formed on inner side of cork cambium constituting secondary cortex.

Phellogen : It is also called cork cambium which appears usually in cortex. This produces phellem and phelloderm.

Sap wood : The peripheral region of the secondary xylem is lighter in colour and is known as the sap wood. It conducts water and minerals from root to leaf.

Sclereids: These are spherical, oval or cylindrical, highly thickened sclerenchymatous dead cells with very narrow lumens.

Simple tissues: Permanent tissues having all cells similar in structure and function are called simple tissues.

Spring or early wood : The wood having vessels with wide lumens is known as spring wood. It is formed in spring seaon.

Starch sheath: The endodermis is called starch sheath as the cells are rich with starch grains.

Stomatal apparatus: The stomatal aperture, guard cells and the surrounding subsidiary cells are together called stomatal apparatus.

VERY SHORT ANSWER TYPE QUESTIONS

1. Why are xylem and phloem called complex tissues?
2. What is the function of phloem parenchyma?
3. How is the study of plant anatomy useful to us ?

SHORT ANSWER TYPE QUESTIONS

1. State the location and function of different types of meristems.
2. What is the difference between lenticels and stomata?
3. What are simple tissues ? Describe various types of simple tissues.
4. Describe the internal structure of dorsiventral leaf with the help of labelled diagram.
5. Described the internal structure of an isobilateral leaf with the help of labelled diagram.
6. Describe in brief the T.S of a dicot stem.
7. Describe in brief the T.S of monocot stem.
8. What is periderm? How does periderm formation takes place in the dicot stems?

EXERCISES

1. Name the various kinds of cell layers which constitute the bark.
2. Why is wood made of xylem and not of phloem?
3. Assume that you have removed the duramen part of a tree. Will the tree survive or die?

CHAPTER-13

Ecological Adaptations and Succession

13.1 Introduction:

Our Living world is fascinatingly diverse and amazingly complex. We can try to understand its complexity by investigating processes at various levels of biological organisation like protoplasm, cells, tissues, organs, individual organisms, population, communities, eco-systems and Biomes.

When we observe nature around us with a scientific frame of mind we will certainly come up with many interesting questions - How does the bee know which flower has nectar? Why does Cactus has so many spines ? Why are night blooming flowers generally white?

Ecology is an inter disciplinary branch of biology which deals with the study of distribution, structure, various aspects of life of organisms and their interaction with the environment. The Term Ecology was first used by ***Reiter*** in 1885 followed by **Earnest Haeckel** in 1886 (Greek; oikos = house, logos = study). It is generally defined as "The study of plants and animals in reciprocal relationship with their environment". The famous ecologist **Odu*m*** defined ecology as "Sturucture and function of Nature". Ecology is basically concerned with four levels of Biological organisations - organisms, populations, communities and Biomes.


Tropical Rain forest

(a)

b)

(c) **(d)**

Figure 13.1 Major Biomes of India

(a) Tropical rain forest **(b)** deciduous forest (c) Desert (d) Sea coast

Organisms are adapted to their environments in terms of not only survival but also reproduction. The rotation of our planet around the sun and the tilt of its axis cause annual variations in the intensity and duration of temperature, resulting in distinct seasons. These variations together with annual variation in precipitation (precipitation includes both rain and snow) account for the formation of major biomes such as desert, rainforest and tundra (Figure 13.1).

In this unit, a concise account of plant communities and their ecological adaptations and succession are included.

13.2 PLANT COMMUNITIES AND ECOLOGICAL ADAPTATIONS

While considering the various alternatives available to organisms for coping with extremes in their environment, we have seen that some are able to respond through certain physiological adjustments while others do so behaviourally (migrating temporarily to a less stressful habitat). These responses are also actually, their adaptations. So we can say that adaptation is any attribute of the organism (morphological, physiological, behavioural) that enables the organism to survive and reproduce in its habitat. Many desert plants have a thick cuticle on their leaf surfaces and have their stomata arranged in deep pits to minimise water loss through transpiration.

Some land plants that can tolerate the salinities of the sea are called **Halophytes**, for ex: *Rhizophora*. plants grow in direct sunlight are **heliophytes**, for example Sun flower. Where as the plants grow in shady places are called **Sciophytes** for example Mosses and ferns. **Eugen warming** classified plant communities into three major ecological groups Hydrophytes, Mesophytes and Xerophytes based on dependence and relation of plants to water.

13.2.1. HYDROPHYTES

They are the plants that grow in water or in very wet places. These are further sub divided into five categories according to their mode of living in water.

1. Free Floating Hydrophytes: They float freely in water surface. e.g: *Pistia*, *Lemna* (13.2 a).
2. Rooted Hydrophytes with Floating leaves: Their roots are fixed in mud, but leaves have long petioles which keep them floating on the water surface. e.g: Nymphaea, Nelumbo

3. **Submerged Suspended Hydrophytes***:* These plants are in contact with only water, being completely submerged and not rooted in the mud. E.g: *Hydilla, Uticularia* (13.2 b).

4. **Submerged Rooted Hydrophytes***:* These plants are completely submerged in water but they are attached by the root system to the muddy soil. e.g: *Vallisneria, Potamogeton* (13.2c).

5. **Amphibious plants:** These live partly in water and partly in air. e.g: *Limnophylla, Typha*.

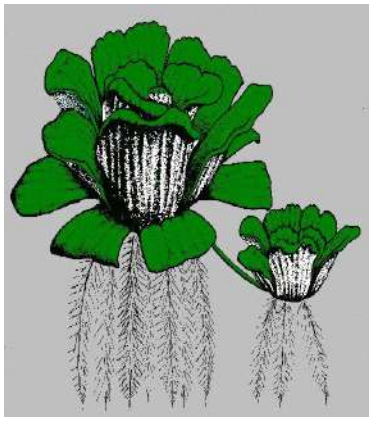


Figure 13.2 Hydrophytes

(a) Pistia **(b) Hydrilla** **(c) Vallisneria**

13.2.2 Ecological adaptations in Hydrophytes

Morphological and anatomical characteristics are mostly common to all hydrophytes but may differ only in some.

Morphological

Due to surplus of water in the habitat, the roots are of secondary importance and less significant and are very poor.

1. Roots may be absent or poorly developed. In some plants, roots caps are replaced by root pockets.
2. Stem is long, slender and flexible.
3. Leaves are thin and either long and ribbon shaped or long and linear or finely dissected and in floating leaves their upper surface is coated with wax.

Anatomical

1. Cuticle is totally absent in the submerged parts of the plants. It may be present in the form of very fine film.
2. The epidermis is composed of thin walled cells.
3. Stomata are totally absent in submerged hydrophytes. In plants with floating leaves the leaves are epistomatous.
4. All hydrophytes contain aerenchyma. It helps in gaseous exchange and buoyancy.
5. Mechanical and vascular tissues are poorly developed.

13.2.3 MESOPHYTES

Mesophytes are plants that normally grow in habitats where water is neither scarce nor not abundant. Mesophytes are very extensive on the surface of land and most crops like wheat, maize, barley, peas or sugarcane or species in grasslands, tropical and temperate forests are all mesophytes.

13.2.4 XEROPHYTES

These plants grow in habitats deficient in water supply. xerophytes are generally classified into the following categories.

I) **Ephemerals:** They are annuals, which complete their life cycle within a short period of 6-8 weeks. e.g: *Tribulus.*

II) **Succulents**: These plants absorb large quantities of water during rainy season and store it in different plant parts usually in the form of mucilage. e.g: *Aloe*, *Opuntia* (13.3 a).

III) **Non-Succulents**: These are perennial plants which can withstand prolonged period of drought. e.g: *Nerium, Casuarina* (13.3 b).

a) ***Opuntia***

b) ***Casuarina***

Figure 13.3 Xerophytes

13.2.5 Ecological adaptations xerophytes

All three major groups viz., ephemerals, succulents, non-succulents may differ in several ways but at the same time sharing certain common features.

Morphological

As these plants grow in water deficient conditions, they possess very well developed root system.

1. Roots are long with extensive branching spread over wide areas.
2. Root hairs and root caps are very well developed.
3. Stems are stunted, woody, hard and covered with thick bark.
4. Stems are usually covered by hairs and or waxy coatings.
5. Leaves are very much reduced, small, scale like and sometimes modified into spines to reduce the rate of transpiration.

Anatomical

1. Epidermis is covered with thick cuticle.
2. Epidermal cells may have silica crystals and it may be multilayered.
3. Stomata are generally confined to lower epidermis of leaves (hypostomatous) and present in pits (sunken) in some plants.
4. Mechanical and Vascular tissues are relatively well developed.

13.3 Plant succession

The gradual and fairly predictable change in the species composition of a given area is called **ecological succession**. An important characteristic of all communities is that composition and structure constantly change in response to changing environmental conditions. This change is orderly and sequential, parallel with the changes in the physical environment. These changes lead finally to a community that is in near equilibrium with the environment and that is called a **climax community**.

The entire sequence of communities that successively change in a given area are called sere(s). The present day communities in the world have come to be so because of succession that has occurred over millions of years since life started on earth. Actually succession and evolution would have been parallel processes at that time.

Succession is, hence a process that starts where no living organisms are found. These could be areas where no living organisms ever existed is called primary succession. e.g: bare rock, newly created pond or reservoir. The areas that somehow lost all the living organisms that existed here is called secondary succession. It begins in areas where natural biotic communities

have been destroyed such as in burned or cut forest, lands that have been flooded. Since some sediment is present, succession that occurs here is faster than primary succession.

Based on nature of habitat whether it is water or it is on very dry areas- succession of plants is called Hydrach or xerarch.

Hydrarch succession: It takes place in wetter areas and the successional series progress from hydric to the mesic conditions.

Xerarch succession: It takes place in dry areas and the series progress from xeric to mesic conditions. Hence, both hydrarch and xerarch successions lead to medium water conditions (mesic) – neither too dry (xeric) nor too wet (hydric).

SUMMARY

As a branch of biology, Ecology is the study of the relationships of living organisms with the abiotic (physico-chemical factors) and biotic components (other species) of their environment. It is concerned with four levels of biological organization - organisms, populations, communities and biomes.

Temperature, light, water and soil are the most important physical factors of the environment to which the organisms are adapted in various ways. A few species have evolved adaptations to avoid unfavourable conditions. A community or biotic community is an assemblage of all the populations (belonging to different species) occurring an area. The plants grow in various habitats are classified into different community groups. These communities are further classified into sub-categories based on certain criteria. They exhibit different adaptations to suit the changed environmental conditions.

The biotic community is dynamic and undergoes changes with the passage of time. These changes are sequentially ordered and constitute ecological succession. Succession begins with invasion of a bare lifeless area by pioneers which later pave way for successors and ultimately a stable climax community is formed. The climax community remains stable as long as the environment remains unchanged.

GLOSSARY

Adoptations: The dynamic process in which the behaviour and physiological mechanisms of an individual continually change to adjust to variations in living conditions.

Biomes: A major ecological community, extending over a large area and usually characterized by a dominant vegetation.

Biosphere: A biologically inhabited part of the earth consisting of all ecosystems of the world is called biosphere or ecosphere. The earth is considered as a 'Gaint Ecosystem'.

Communities: A community or biotic community is an assemblages of all the populations belonging to different species occurring in an area.

Ecosystem: A functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment. The term ecosystem was coined by A.G. Tansley.

Ecological succession: The process of change in the species structure of an ecological community over time.

Population: A group of similar individuals belonging to the same species found in an area. It is called "local population".

VERY SHORT ANSWER TYPE QUESTIONS

1. Define heliophytes
2. Define sciophytes.
3. Define population .
4. Define community.
5. Hydrophytes show reduced xylem. why?
6. Who coined the term 'Ecology'.
7. Who coined the term 'Ecosystem'.

EXCERCISES

1. Categorise the following plants into hydrophytes, halophytes, mesophytes and give reasons.
a. Salvinia b. Opuntia c. Rhizophora d. Mangifera .
2. what is the chief difference between the epidermis of hydrophytes and xerophytes in relation to their function. 3.
What will happen to pistia plant when its roots are removed?

VOCATIONAL BRIDGE COURSE
BOTANY– First Year (w.e.f. 2018-2019)
SCHEME AND WEIGHTAGE

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1. The Question paper is to be set for 40 (Forty) marks. The student has to answer for 25 (Twenty five) marks.

2. There will be 8 (Eight) Very Short Answer Questions each carrying 1 (One) Mark. The student has to answer 5 questions from this Section-A.

3. In Section-B there will be 8 (Eight) Short Answer Question each carrying 4 (Four) Marks. The student has to answer 5 questions from this Section-B.

Weightage for the Chapters included in the Syllabus is as follows:

S.No.	Unit	Number of Periods	Weightage of Marks
1	Diversity in Living Word	12	05
2	Morphology	09	09
3	Reproduction in Plants	09	08
4	Plant Systematics	04	02
5	Cell Structure and Functions	07	06
6	Anatomy	07	08
7	Plant Ecology	02	02
	Total	50	40

VOCATIONAL BRIDGE COURSE
BOTANY– First Year (w.e.f. 2018-2019)
QUESTION BANK

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UNIT - I: DIVERSITY IN THE LIVING WORLD

Very Short Answer Questions (1 Mark)

1. What does ICBN stand for?
2. Define Metabolism?
3. Which is the largest botanical garden in the world?
4. Name a well known botanical garden in India.
5. What is the basic unit of classification?
6. Give the scientific name of Mango.
7. How are Viroids different from Viruses?
8. Who proposed five kingdom classification?
9. Name two diseases caused by Mycoplasmas.
10. State 2 Economically important uses of Bacteria.
11. Who is popularly known as father of Botany?
12. Explain how the term Botany has emerged?
13. What is Palaeobotany?
14. What are the groups of plants that live as symbionts in lichens?
15. What is Playnology?
16. Which group of plants is called amphibians of plant kingdom?
17. Name the branch of Botany which deals with amphibians of plant kingdom?
18. What is the basis of classification of Algae ?
19. What are the two stages found in the gametophyte of mosses ?
20. Name the Gymnosperms which contain mycorrhiza
21. Name the corolloid roots respectively.

Short Answer Questions (4 Marks)

22. What are taxonomical aids? Give the importance of herbaria and Botanical Gardens.
23. Explain binomial nomenclature.
24. Give the salient features and importance of Chrysophytes.
25. Give a brief account of Dinoflagellates.
26. Write the role of fungi in our daily life?
27. Explain briefly scope of Botany in relation to Agriculture, Horticulture and Medicine.
28. Differentiate between red algae and brown algae
29. Differences between homosporous and heterosporous Pteridophytes with examples.
30. Draw labelled diagrams of female thallus and male thallus of a liverwort

UNIT - II: MORPHOLOGY

Very Short Answer Questions (1 Mark)

31. What types of specialized roots found in epiphytic plants?
32. Define venation.
33. How do dicots differ from monocots with respect to venation?
34. Which organ is modified to trap insects in insectivorous plants?
35. What type of inflorescence is found in fig trees?
36. Define placentation.

37. What type of placentation is found in *Dianthus*?
38. What is meant by parthenocarpic fruit?
39. Why certain fruits are called false fruits?
40. Name two examples of plants having false fruits.
41. Name any two plants having single seeded dry fruits.
42. What are aggregate fruits? Give two examples.
43. What are endospermic seeds? Give examples.

Short Answer Questions (4 Marks)

44. Explain with examples different types of phyllotaxy.
45. Describe any two special types of inflorescences.
46. Describe in brief the fleshy fruits studied by you.
47. Explain how root is modified to perform different functions. (Any Four).
48. Explain how stem is modified variously to perform different functions. (Any Four).
49. Describe any four types of placentations found in flowering plants?
50. Explain with examples different types of aestivations?

UNIT - III: REPRODUCTION IN PLANTS

Very Short Answer Questions (1 Mark)

51. What is the dominant phase in the life cycle of an angiosperm?
52. Mention the modes of reproduction in algae and fungi?
53. How do Liver worts reproduce vegetatively?
54. Between an annual and a perinneal plant, which one has a shorter juvenilephase?
55. What the following parts of a flower develop into after fertilization?
    a) Ovary b) Ovules
56. Define vivipary. Give example.
57. Name the component cells of the 'egg apparatus' in an embryo sac.
58. Name the parts of pistil which develop into fruit and seeds.
59. What is self-incompatibility ?
60. Which is the triploid tissue in a fertilized ovule ?
61. How is pollination carried out in water plants ?
62. Mention two strategies evolved to prevent self pollination in flowers.

Short Answer Questions (4 Marks)

63. "Fertilisation is not an obligatory event for fruit production in certain plants". Explain the statement.
64. Why is vegetative reproduction also considered as a type of asexual reproduction?
65. Give a brief account on the phases of the life cycle of an angiosperm plant.
66. Give two suitable examples showing vegetative propagation in plants.
67. Write a brief account on agents of pollination.
67. What is Apomixis? What is its importance?

UNIT - IV : PLANT SYSTEMATICS

Very Short Answer Questions (1 Mark)

68. What is Natural system of plant classification?
69. Name the scientists who followed Natural System of Classification.
70. What is geocarpy?
71. Name the plant which exhibits geocarpy phenomenon.
72. Name the type of pollination mechanism found in members of Fabaceae.

73. Write the floral formula of *solanum* plant.
74. Give the technical description of ovary in *Solanum nigrum*.
75. Give the technical description of anthers of *Allium cepa*.

Short Answer Questions (4 Marks)

76. Describe the essential organs of Solanaceae.
77. Give economic importance of plants belonging to Fabaceae.

UNIT - V: CELL STRUCTURE AND FUNCTIONS

Very Short Answer Questions (1 Mark)

78. Who discovered Nucleus?
79. What is the significance of vacuole in a plant cell ?
80. What does 'S' refer in a 70S & and 80S ribosome ?
81. Mention a single membrane bound organelle which is rich in hydrolytic enzymes.
82. What is the feature of a metacentric chromosome ?
83. What is middle lamella made of ?
84. What is osmosis ?
85. What is the function of Polysome ?
86. Which part of the Bacterial cell is targeted in Gram's Staining?
87. Which tissue of animals and plants exhibits meiosis?
88. If a tissue has at a given time 1024 cells. How many cycles of mitosis had the original parental single cell undergone?
89. Name the stage of meiosis in which actual reduction in chromosome number occurs.
90. An Anther has 1200 Pollen Grains. How many Pollen Mother Cells must have been there to produce them ?

Short Answer Questions (4 Marks)

91. Describe the cell organelle which contains chlorophyll pigments.
92. Describe the structure and function of power houses of cell.
93. Differentiate between Rough Endoplasmic Reticulum (RER) and Smooth Endoplasmic Reticulum (SER).
94. Describe the structure of nucleus.
95. What are the characteristics of a prokaryotic cell ?
96. What are Nucleosomes? What are they made of ?
97. Explain prophase I of meiosis.
98. Which division is necessary to maintain constant chromosome number in all body cells of multi cellular organism and why?
99. Though redundantly described as a resting phase, Interphase does not really involve rest. Comment ?

UNIT - VI: ANATOMY

Very Short Answer Questions (1 Mark)

100. Why are xylem and phloem called complex tissues?
101. What is the function of phloem parenchyma?
102. How is the study of Plant Anatomy useful to us ?

Short Answer Questions (4 Marks)

103. State the location and function of different types of meristems.
104. What is the difference between lenticels and stomata?

105. What are simple tissues ? Describe various types of simple tissues
106. Describe the internal structure of dorsiventral leaf with the help of labelled diagram.
107. Describe the internal structure of an isobilateral leaf with the help of labeled diagram.
108. Describe in brief the T.S of a dicot stem.
109. Describe in brief the T.S of monocot stem.
110. What is Periderm ? How does periderm formation takes place in the Dicot Stems ?

UNIT – VII : PLANT ECOLOGY

Very Short Answer Questions (1 Mark)

111. What are the cells that make the leaves curl in plants during water stress?
112. Define heliophytes. Give an example
113. Define sciophytes. Give an example
114. Define population.
115. Define community
116. Hydrophytes show reduced xylem. Why?

VOCATIONAL BRIDGE COURSE
BOTANY– First Year (w.e.f. 2018-2019)
MODEL QUESTION PAPER

Time: 1 ½ Hours **Max. Marks: 25**

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Section – A

5x1=5

Note: i) Answer any **five** of the questions briefly
ii) Each question carries **one** mark.

1. What does ICBN stands for?
2. What is meant by parthenocarpic fruits?
3. What is Self incompatibility?
4. Write the floral formula of Solanum plant?
5. What is natural system of classification ?
6. Which tissue of plants exhibit meiosis?
7. What does 'S' refers in 70S and 80S ribosomes ?
8. Define Halophytes ?

Section – B

5x4=20

Note: i) Answer any **five** questions
ii) Draw labelled diagrams wherever necessary
ii) Each question carries **four** marks.

9. What is heterospory? Give its significance?
10. Describe any Two special type of inflorescences ?
11. Explain any four stem modification with examples?
12. Explain Binomial Nomenclature?
13. Describe the structure and functions of Power houses of cell?
14. Explain Prophase I of meiosis?
15. Describe in briefly the internal structure of Dicot root?
16. Write briefly about different types of meristems?

BIOLOGICAL SCIENCE

ZOOLOGY BRIDGE COURSE

INDEX

Unit 1

Diversity of Living World

SUMMARY

Biology is the science of living process. The living world comprises an amazing diversity of living organisms. However, living organisms show 'Fundamental similarity in many respects. The study of life involves many of the principles of chemistry, physics and mathematics. Biological systems are most complex chemical systems on the earth. Cells of an organism are basic units of structural and functional units of life. Every level of biological organisation involves energy transactions governed by 'Laws of thermodynamics'.

Life defies simple definition although one can perceive the difference between inanimate (non-living) matter and living organisms. Cellular organisation, ordered complexity, ability to reproduce themselves, growth, utilization and transfer of energy, irritability and above all, exhibiting the ability to adapt and evolve are some of the fundamental characters of living organisms. The process of evolution is continuous and newer forms evolve continuously.

The discovery of molecular structure of DNA by Watson and Crick (1953) is the major event in the study of molecular basis of inheritance.

The five kingdom classification of Wittaker followed until a few decades ago, has given place six kingdoms viz., Bacteria, Archaea, Protista, Fungi,Plantae and Animalia.

1.1 WHAT IS LIFE ?

'Life' is an exclusive property of the various types of living organisms in the world. Recent discovery of fossils of some microscopic organisms extended the known 'history of life' on the Earth to about 3.5 billion years. **Biology** is the science dealing with the study of living organisms which are broadly classified into microorganisms, plants and animals. In spite of their wide **'diversity'** they show **'Fundamental uniformity'** in possessing protoplasm with the genetic substance, the DNA which is made up of **'nucleotides',** university. Living organisms show:

I. **Cellular organization** and **highly ordered structure:** An organism's body is made up of one to many **'Cells'**, which are the **structural** and **functional units** of the body. Each cell is isolated from the cells surrounding it by a limiting membrane the plasma membrane. This membrane controls the exchange of various substances across it. Two major kinds of cells occur in the living world - the **prokaryotic** cells (without distinct nuclei) and the **eukaryotic** cells (with distinct nuclei).

II. Complexity of organization: A fundamental feature of life is the presence of a high degree of 'order'. Living organisms show hierarchical organization such as cellular level, tissue level, organ level and organ - system level. Several organ-systems make up an organism. This type of 'ordered **complexity'** is not seen in the non-living things. The hierarchy of life can be schematically represented as follows (starting from the inorganic elements that go into the constitution of protoplasm).

ATOMS→ MOLECULES→ CELL→ TISSUE→ ORGAN→ ORGAN SYSTEM→ ORGANISM→ POPULATION→ COMMUNITY→ ECOSYSTEM→ BIOSPERE.

This representation includes both the inorganic and organic components, as living substance is made up of several inorganic constituents and life processes involves continues exchange and recycling of inorganic elements.

III. Sensitivity / Response to Environment: It is the property of showing response to external or internal stimuli received through various kinds of 'sense organs'. Living organisms show response to environmental stimuli, which could be physical, chemical or biological. Plants show sensitivity to environmental factors such as light, temperature, water, etc.

IV. Growth: Growth is one of the fundamental characters of living beings (including the unicellular organisms). Increase in mass and increase in number are twin characteristics of growth. Some non-living things also may show tendency of growth but growth in living beings is **'growth from inside'**, whereas growth in the non- living things is by accumulation of material on the surface. Higher plants show growth all their life producing new branches, leaves, etc., where as it is 'limited' (up to a certain age only) in animals. *Growth cannot be taken as a defining Property of living organisms (Ref: NCERT Text Book) as non-living structures also show growth in some respects.*

V. Energy utilisation / Energy processing/ Metabolism: The sum total of all the chemical reactions occurring in the bodies of organisms constitute metabolism and it is a defining feature of all living organisms without exception. Life activities require *'energy'* in different forms. The chief source of energy for living organisms is the sun light. It is also transferred from one organism to another organism. The life processes which build up or Store *(Conserve)* energy are called **anabolic** processes and the processes involving expenditure of energy are called **catabolic** processes. Together, they constitute - metabolism.

VI. Reproduction: Living organisms produce young ones of their kind, using molecules of heredity, the DNA molecules (genes), which are passed on to the offspring. It is important to note that **'Life comes only from life' (biogenesis)** and not from non-living substances. Reproduction, characteristic of all living organisms, occurs by *vegetative, asexual* and *sexual* methods, sexual method involves fusion of gametes forming a zygote, which through various stages of development becomes a young organism. However, some organisms do not reproduce (mules, sterile worker honey bees, infertile human couples, etc.,), **Protozoans** reproduce by asexual methods such as 'binary fission', **Sponges, hydra**, etc., reproduce by 'budding'. In **planarians,** fragmented body regenerates the lost parts of the body and becomes a new organism.

VII. Homeostasis: Maintenance of relatively constant internal conditions **(Steady state)** different from the surrounding environment is called **'homeostasis'**. It is the **dynamic constancy** of the **internal environment** of an organism within a range that the cells can tolerate. Living organisms maintain 'constant internal environment' by various physiological adaptations.

VIII. Evolution: Life is not 'static'. It constantly changes (dynamic) from simple to more complex forms. Variations in organisms arise through **'mutations'** or **'gene recombinations'**. Charles Darwin's Natural Selection theory states that living beings accumulate their 'beneficial variations' over a period of time and tend to evolve gradually into new types of organisms (species) after surviving the struggle for existence.

IX. Senescence and Mortality: Living beings are born, grow into mature forms, undergo ageing process and finally die. The process of ageing is called 'senescence'. It leads to death / mortality. Living beings are thus **'Mortal'.**

All the **Life phenomena** like nutrition, respiration, excretion, Irritability. etc., are due to **interactions** between the various components of an organism. 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 constituent of the organelle but arise as a result of interactions among the molecular components comprising the organelle. Thus, interactions result in certain properties, at a higher level of organization. This phenomenon is true in the **hierarchy of organization complexity** at all levels. **Biology is the story of life and evolution of living organisms on the Earth.** All living organisms the present, past and future are linked to one another by sharing a common **genetic material,** but to varying degrees.

1.2 NATURE, SCOPE AND MEANING OF ZOOLOGY

Biology is a science devoted to the study of living organisms. Science progressed by breaking down complex subjects into their component parts and so today there are numerous branches of biology of which BOTANY, ZOOLOGY and MICROBIOLOGY are the principal, heterogeneous and divergent groups.

Zoology (Zoon-animal; logos-knowledge / Study) or **'Animal Science'** is a part of the biological science which deals with the study of various aspects of animals, starting from the sponges (Phylum: Porifera) to mammals (Class: Mammalia). The aim of zoology is to explain the **animal world** in terms of **scientific principles.**

BRANCHES of ZOOLOGY

Lamarck (1809), French biologist coined the term **'Biology'**. Which means the 'study of living organisms'? This diverse science which deals with all aspects of animal life has several sub-branches. A few of them are listed below.

Sub branches of zoology

1. **Taxonomy** (Taxis - arrangement; nomos - rule, custom)

It is the theory and practice of identification, nomenclature and classification of organisms.

2. **Morphology** (morphos - from, logos - study)

It deals with the study of form, size, shape, colour and structure of various organisms and their tissues, organs, organ-systems, etc. It includes the following

i. **External morphology** It is study of external characters of an organism.

ii. **Internal morphology** This branch deals with the study of internal structure.

3. **Cytology** (Kytos - cells: logos - study):

Cytology deals with the study of form and structure of cells and cell organelles. cell biology is the branch of Science that deals with the study of the cell as a structural and functional unit of living organisms.

4. **Physiology** (Physis - nature of functioning; logos - study) :

It is the study of different body functions and processes.

5. **Embryology** (Embryon - embryo; logos - study) and Developmental biology

Embryology deals with the study of events that lead to fertilization, cleavages, early growth and differentation of zygote into an embryo. It is also defined as the branch of biology dealing with the formation and development of embryos. Developmental biology is the study of embryonic development and the other developmental processes after birth.

6. **Evolution** (e-out; volva - roll):

It is the study of origin of life and continuous genetic adaptations of organisms to the environment. It also deals with the gradual changes that occur in the living organisms through geological time. Evolution means 'unfolding'. **Herbert Spencer** coined the term 'Organic Evolution'.

7. **Palaeontology** (Paleo - ancient; on - being; logos - study)

Study of fossilized remains of organisms of the past geological ages is called palaeontology. This includes palaeobotany (fossils of plants) and palaeozoology (fossils of animals).

8. **Ecology** (Oikos - house; logos - study)

It is the study of living organisms in relation to the other living organisms (biotic factors) and abiotic environmental factors surrounding them. **Haeckel** coined the term **'Ecology'**.

9. **Genetics** (Gen - to grow into)

Genetics is the study of inheritance of characters from one generation to the next. It deals with **heredity** and **variations**. **Bateson** coined the term 'Genetics'.

10. Ethology (Gk. ethos - Character)

The study of the animal behaviour based on the systematic observation recording, analysis of functions of animals, with special attention to physiological, ecological and evolutionary aspects is called **ethology.**

1.3 NEED FOR CLASSIFICATION- BINOMIAL CLASSIFICATION

It is impossible to study all living organisms. So, it is necessary to devise some means to make this possible. This process is called **'classification'**. Classification is defined as the process by which anything is grouped into convenient categories based on some easily observable characters. The scientific term used for these categories is 'TAXA' (Singular; taxon). Taxa can indicate categories at different levels e.g. Animals (which includes multicellular animals). Chordata, Mammalia, etc., represent taxa at different levels.

Hence, based on characteristics, all the living organisms can be classified into different taxa. This process of classification is called **taxanomy.** External and internal structures along with the structure of cell, development processes and ecological information of organisms are essential and they form the basis of modern taxonomic studies. Hence, **Characterisation, identification, nomenclature** and **classification** are the process that are basic to taxonomy.

BIOLOGICAL CLASSIFICATION

The living organisms exhibit a great deal of diversity due to variations in their structure and function. So far, over 1.25 million animal species have been identified and described. They show diversity in structure, habits, habitats and modes of life. To understand the interrelationships among the diversified animal groups, a systematic classification is necessary.

History of Biological Classification

Carolus Linnaeus (1707 - 1788), father of Taxonomy and Founder of Modern Systematics, introduced the system of hierarchical classification. In the 19^{th} and 20^{th} centuries numerical taxonomy and phylogenetic classification emerged.

Classification

Phylogenetic (Cladistic) Classification

It is an evolutionary classification based on how a common ancestry was shared. Cladistic classification summarizes the 'genetic distance' between all species in the 'phylogenetic tree'. In cladistic classification characters such as **analogous characters** (characters shared by a pair of organisms due to convergent evolution e.g. wings in sparrows and patagia (wing like structures) in flying squirrels) and **homologous characters** (characters shared by a pair of organisms, inherited from a common ancestor e.g., wings of sparrows and finches) are followed/taken into consideration. **Ernst Haeckel** introduced the method of representing phylogeny by 'trees' or branching diagrams.

LEVELS AND HIERARCHY OF CLASSIFICATION

Human beings are not only interested in knowing more about different kinds of organisms and their diversities, but also the relationship among them. This branch of study

is referred to as **systematics**. Systematics is the branch of science that deals with the vast diversity of life. It also reveals the trends and evolutionary relationships of different groups of the organisms. These relationships establish the phylogeny of organisms. A key part of systematics is taxonomy. Taxonomic hierarchy includes **seven obligate categories** namely **kingdom, phylum, class, order, family, genus** and **species**, and other intermediate categories such as subkingdom, grade, division, subdivision, subphylum, superclass, subclass, superorder, suborder, super family, subfamily, subspecies, etc.

Linnaeus was the first taxonomist to establish a definite hierarchy of taxonomic categories called taxa (singular: taxon) like kingdom, class, order, genus and species. Haeckel (1888) introduced the taxon Phylum. A species sometimes may have more subspecies, which shows some morphological variations (intra-specific variations).

1. Kingdom: All multicelluar, non-saprobic, heterotrophs are included in the kingdom Animalia/ Metazoa.

2. Phylum: It includes one or more classes. E.g. Phylum Chordata includes the classes Cyclostomata, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia, along with the protochordates. All these are based on common features such as presece of notochord, dorsal hollow nerve cord, pharyngeal slits, post-anal tail, etc., in some stage of the life history.

3. Class: It includes one or more related orders. E.g. The class Mammalia includes the orders Rodentia (**rats**), Chiropetra (**bats**), Cetacea (**whales**), Carnivora (**dogs**) Primates (**monkeys** and **apes-gorilla, gibbon** and **man**), etc.

4. Order: It includes an assemblage of one or more related families. E.g. The families Felidae and Canidae are included in the order **Carnivora** along with Hyaenidae (**hyenas**), Ursidae (**bears**), etc.

5. Family: It includes one or more related genera and can be distinguished from the other families by important characteristic differences. Family felidae includes the genus of cat (Felis), genus of leopard (Panthera), etc. The members of Felidae can be distinguished from those of Canidae (foxes, dogs, wolves). Adding the suffix-idae to the type generic name forms the name of the family e.g. adding the suffix 'idae' to the Genetic name **'Homo'** gives the name of the Family to which man belongs - Hominidae. The name of the subfamily can be coined by adding the suffix-**inae** to the type generic name (e.g **Homininae**) and the name of the superfamily by adding the suffix-**oidea** (e.g. **Hominoidea**)

6. Genus: It is a group of related species, resembling one another in certain characters e.g. *Panthera leo* (lion), *Panthera tigris* (tiger) and *panthera pardus* (leopard) belongs to the genus panthera.

7. Species and subspecies: Species is the **basic unit** of classification in the hierarchical taxonomic system. Species is a group of similar organisms sharing a '**Common gene pool**' and interbreeding freely, producing 'fertile' offspring, A species occurs in the form of many interbreeding groups called 'populations'.

A species may include **subspecies**. Subspecies is/may be a geographically/ isolated population of a species, which shows some minor **variations** from the parent population, but are capable of interbreeding with the individuals of other subspecies of the same species? *Subspecies are probably new species in the making.*

For example, the scientific name of crow is *Corvus splendens*, Geographically the crows present in India, Pakistan, Myanmar and Sri Lanka are isolated and evolved into different subspecies. *Corvus splendens splendens* is the **subspecies** in **India** and **Pakistan**. *Corvus splendens insolens* is the subspecies in **Myanmar** and *corvus splendens protegatus* is the **subspecies** in **Sri Lanka**. In this system of nomenclature the first word refers to the 'genus', the second to the 'species' and the third to the 'subspecies'.

NOMENCLATURE

It is estimated that the number of species known and described ranges between 1.7 to 1.8 million. They are called by their local names (in regional languages), which vary from place to place and even within the same country. So there is need to standardise the naming pattern of living organisms such that a particular organism is known by the same name all over the world / universally. This process of naming of animals with distinctive (scientific) names is called **nomenclature**. *Naming of organisms is done as per the guide lines of the* **International Code of Zoological Nomenclature (ICZN)**. **Binominal nomenclature** *(orginally called Binomial nomenclature) is used in naming organisms all over the world.*

Binominal Nomenclature

Carlous Linnaeus**, a Swedish botanist, popularised the* '**binomial nomenclature**' *by using it in the 10th edition of his book* **Systema Naturae**. *It is the type of nomenclature in which each organism is provided with an appropriate scientific name consisting of two components, the **''binomen''**. The first word refers to the **'genus'** (p; : genera) and the second word is the specific epithet* (species name). The word that refers to the 'genus' is a ***'noun', *and the specific epithet that refers to the 'species' is mostly an **'adjective'**. The generic name begins with a capital letter and the specific name with a small letter. Names must be in Latin or Latinised from and are usually **'Printed'** in italic type. When '**Written'** the two words are to be underlined separately. Let us take the example of a 'lion' to understand binominal nomenclature. The scientific name of lion is **Felis leo**. In this name, the word '**Felis'** represents the genus, while the word 'leo', is the specific epithet, The name of the taxonomist follows the scientific name either in full form or in an abbreviated form e.g. **Felis leo linnaeus** or **Felis leo Linn** or **Felis Leo L.** It indicates that this species was first described by Linnaeus. The year of the discovery is written after the name of the person who discovered it - e.g. Felis leo Linnaeus, 1758**.** When the name of the genus is not the one under which the original author placed a species, or if the generic name is changed subsequently, the original author's name the year are kept in parenthesis e.g. **Panthera leo (Linnoaeus, 1758)**. It is written so, to understand that Linnaeus originally placed the species name 'Leo' under the genus 'Felis' and it was later shifted to the genus Panthera.*

TAUTONYMY: The practice of naming the animals, in which the generic name and species name are the same, is called tautonymy. So the name is called tautonym e.g. ***Axis axis*** (Spotted deer); ***Naja naja*** (the Indian cobra).

1.4 SPECIES CONCEPT

1. Species

*Species is the '**basic unit**' of classification. Species is a Latin word meaning 'kind' or 'appearance', **John Ray** in his book **'Historia Generalis Plantarum'**, used the term 'species' and described it on the basis of common descent (origin from common ancestors) as a group of morphologically similar organisms. Linnaeus considered species, in his book **'Systema***

***Naturae'**, as the basic unit of classification. Buffon, in his book **'Natural History'**, Proposed the idea of evolution of species which is the foundation for the biological concept of evolution. This biological concept of species (dynamic nature of species) became more popular with the publication of the book **''The origin of species''** by Charles Darwin.*

***Buffon's biological concept of species explains that species is an interbreeding group of similar individuals sharing the common 'gene pool', and producing fertile offspring.** Species is considered as a group of individuals which are:*

*1. Reproductively isolated from the individuals of other species - **a breeding unit.***

*2. Sharing the same ecological niche - **an ecological unit.***

*3. Showing similarity in the karyotype - **an genetic unit.***

*4. Having similar structure and functional characteristics - **an evolutionary unit.***

Let us consider the following examples

Example-1: Apis Indica, Apis dorsata, Apis mellifera** and **Apis florea

*In the above example '**Indica', 'dorsata', 'mellifera'** and **'florea'** are different species belonging to the same genus called **Apis.***

Example-2: Pheretima posthuma, periplaneta americana** and **Panthera leo.

*In the example 2 the words **'posthuma', 'americana'** and **'leo'** are names of different species belonging to different genera.*

BIODIVERSITY

What is Biodiversity?

When we observe our surroundings we find different kinds of organisms which vary in size, feeding habits, behaviour, etc. For examples there are more than 20,000 species of ants, 3, 00,000 species of beetles, 28,000 species of fishes and 20,000 species of orchids. This variation of life at various levels of biological organization is termed as biodiversity.

Reasons for greater biodiversity in the tropics:

Reason 1: Tropical latitude have remained relativity undisturbed for millions of years and thus had a long 'evolutionary time'. As long duration was available in this region for speciation, it led to the species diversification.

Reason 2: Tropical climates are relatively more constant and predictable than that of the temperate regions. Constant environment promotes niche specialization (how an organism responds, behaves with environment and other organisms of its biotic community) and this leads to greater species diversity.

Reason 3: Solar energy, resources like water etc., are available in abundance in this region. This contributed to higher productivity in terms of food production, leading to greater diversity.

Species - Area relationships

Before we learn relation between species richness and the area available to them, let us learn the term 'species richness'.

1.5 Species Richness – IUCN- red data book- conservation wild life in India

In simple terms, it is the number of species per unit area. The more the number of species in an area the more is the species richness. **Alexander von Humboldt** observed that within a region. species richness increased with increasing explored area, but only up to a limit. In fact, the relation between species richness and area for a wide variety of taxa (angiosperm plants, birds, bats, fresh water fishes) turns out to be a non-linear curve. On a logarithmic scale, the relationship is a straight line described by the equation.

log S=log C=+Z log A

Where

S = species richness

A = area

Z = slope of the line (regression coefficient)

C = Y-intercept

Ecologists have discovered that the value of Z lies in the range of 0.1 to 0.2 regardless of the taxonomic group or the region (whether it is California or New York of Britain). If you analyse species - area relationship among very large areas like entire continents the slope of the line is much steeper (Z values in the range of 0.6 to 1.2) or example for frugivorous (fruit-eating) birds and mammals in the tropical forests of the different continents, the slope is found to be **1.15.**

IUCN Red data books

International Union for the Conservation of Nature and Natural Resources (IUCN) is the world's main Authority on the issues of conservation status of species.

All the threatened species are listed in the **Red Data Books** published by the IUCN. These species are classified into different categories based on degree of risk and they are chiefly :

a) Critically endangered

b) Endangered

c) Vulnerable

Conservation of wild life in INDIA

This is through legislation preservation and organisations

Legislation : Under the provision of the **Wildlife Act of 1972,** killing endangered wild animals is strictly prohibited. Trading wildlife products (like tusks, rhino's horns, etc.) is a punishable offence.

Preservation: National Parks, Sanctuaries, Biosphere Reserves, Sacred Groves etc. are different regions which are earmarked to protect diverse fauna and flora.

Organisational Protection: Organisations which are set up to prevent destruction of India's wild life are

1. Wild life protection society of India (**Dehradun**)
2. Zoological Survey of India (**Kolkata**)

Conservation of biodiversity is a **global necessity**. It is the collective responsibility of all nations to protect the diverse living forms on the planet. One such step was in the form of 'EARTH SUMMIT (1992-Rio de Janiero) and the other being WORLD SUMMIT on sustainable development (Johannesburg-South Africa). They focussed on significant reduction in the current rate of loss of biodiversity at the global, regional and local levels. Efforts must be intensified to pass on our biological legacy to the future generations.

Threatened Species in India

The Asiatic Lion	*Panther leo persica*
The black buck	*Antelope cervicapra*
Red panda	*Ailurus ochraceus*
The lion-tailed macaque	*Macaca silenus*
Tiger	*Panthera tigris*
Kashmiri stag	*Cervus elaphus*
Elephant	*Elephas maximus*
Pygmy hog	*Sus salvanius*
Siberian crane	*Grus leucogeranus*
Slender loris	*Loris tardigradus*


Asiatic lion


Slender Loris


Kashmiri stag


Lion-tailed macaque

In conclusion-Nature is a repository of diverse life. Intrusion into nature's domain distorts its equilibrium. Preserving nature is a collective 'Global Responsibility'. Man should conserve and protect nature in his own interest and for the nature generations

GLOSSARY

Nutrition :The process by which an organism assimilates food and uses it for growth and maintenance.

Protein: **A linear chain of amino acid residues is called a polypeptide**. Building blocks of life which are polymer chains of amino acids linked together by peptide bonds.

Prokaryotes: Single cell organisms without membrane bound nucleus.

Eukaryotes: Organisms whose cells contain a membrane bound necleous, and other complex membrane bound organelles.

Glycogen: It is a type of polysaccharide found in animals analogous to starch in plants

Chordata: A phylum which includes animals showing notochord at some stage in life.

Phylogeny: The evolutionary history of an organism.

Analogous characters: They denote similarity in function without necessary anatomical similarity (wings birds and butterflies).

Tissue : An aggregation of cells similar in origin and function

Holozoic: It is a method of nutrition that involves ingestion of solid or liquid organic material

Spiral cleavage: In protostomes the plane of cell division is diagonal to the vertical axis

VERY SHORT ANSWER TYPE QUESTIONS

1. List out any four sacred grooves in India?
2. What does ICZN stands for?
3. Define species richness?
4. What is meant by Tautonemy? Give one example?
5. Define the term Histology? What is it otherwise called?
6. Write the full form of IUCN? In which book threatened species are enlisted?
7. Distinguish between Embryology and Ethology?

SHORT ANSWER TYPE QUESTIONS

1. Explain need for classification?
2. Define species? Explain varies aspects of species?
3. What are the reasons for greater biodiversity in the tropics?

Unit 2

STRUCTURAL ORGANISATION IN ANIMALS

SUMMARY

Body of an animal is formed of several kinds of cells. There are about 200 different types of specialized cells in the human body. The cells of one or more kinds are arranged together in a characteristic manner and cooperate to perform a specific role. Such a group of cells is called a tissue. The cell of a tissue may secrete between them a nonliving intercellular material. Thus, a tissue may be defined as a group of one or more types of cells having a similar origin and specialized for a specific function or functions along with the intercellular material.

Branch of biology dealing with the study of tissue is called **Histology**. The term 'tissue' was introduced by **Bichat** who is also known as the 'Father of histology'. **Mayer** coined the term 'histology' and the founder of histology is **Marcello Malpighi.** Histological study of an organ called Microscopic Anatomy. **Marcello Malpighi** is the father of microscopic anatomy. **Hertwig** introduced the term 'mesenchyme' for mesodermal tissue. The formation of tissues from germinal layer is called as histogenesis.

2.1 Symmetry

The regular arrangement of body parts in geometrical design relate to the axis of the body is called symmetry. The animals which can be cut into two equal parts or antimeres in or more planes passing through the principal axis of body are called symmetrical animals. The concept of symmetry is fundamental in understanding the organisation of animal. Symmetry in animals is balanced distribution of paired body parts. The body plan of vast majority of metazoans exhibits some kind of symmetry. However, most of the sponges and snails show asymmetry.

Types of Symmetry

2.1.1 Asymmetry: The animals which cannot be cut into two equal parts or antimeres in any plane passing through the centre of the body are called asymmetrical. e.g. most sponges(Figure 2.1) and adult snails are mostly **asymmetrical.** In the asymmetrical animals the body lacks a definite form. Asymmetry cannot said to be an adaptation or advantage to an organism. Most of the asymmetrical animals do not develop complex sensory and locomotor functions.

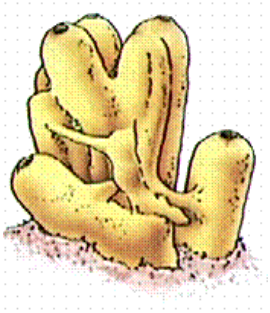


Fig 2.1 Sponge showing asymmetry

2.1.2 Spherical symmetry: **Spherical symmetry** illustrated only by the protozoan groups Radiolaria and Heliozoia, the body has the shape of a sphere and the parts are arranged concentrically around or radiate from the centre of the sphere.(Figure 2.2)

Fig 2.2

2.1.3 Radial symmetry: When any plane passing through the central axis (oro-aboral axis/ principal axis) of the body divides an organism into two identical parts, it is called **Radial symmetry**.(Figure 2.3) The animals that exhibit radial symmetry are usually either sessile or planktonic or sluggish. This symmetry is advantage to the sessile animals that live in water and receives stimuli from all the directions. All the diploblastic animals like cnidarians and ctenophores exhibits radial symmetry. Thus the radial symmetry is advantage to sessile or slow moving animals. However triploblastic animals such as echinoderms are secondarily radially symmetrical (as it is five angled, it is also called pentamerous radial symmetry).

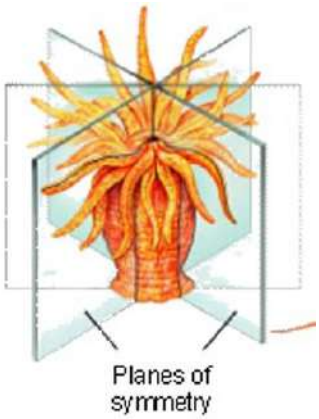


Fig 2.3 radial symmetry

2.1.4 Bilateral symmetry: When any one plane (median sagital plane) that passes through central axis and divides an organism into two identical parts, it is called **bilateral symmetry**. Triplobalstic animals exhibit this symmetry. However some gastropods are secondarily symmetrical.(Figure 2.4)

The animals that exhibit bilateral symmetry are more efficient in seeking food, locating mates and in escaping from predatory animals, because of cephalisation (concentration of nerve and sensory cells at the anterior end). As a result of cephalisation, bilateral symmetrical animals can sense new environment into which they enter and respond more efficiently and quickly.

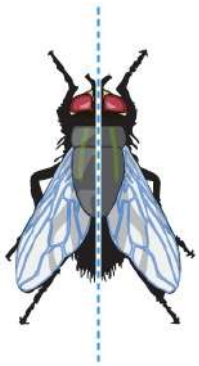


Fig 2.4 Bilateral symmetry

2.2 Coelom

The term coelom was coined by Haeckel. The body cavity, which is lined by mesoderm, is called coelom. More elaborately coelom is fluid filled space between the body wall and visceral organs and lined by mesodermal epithelium, the peritoneum. Animals possessing coelom are called coelomates/eucoelomates. Evolution of efficient organ systems was not possible until the evolution coelom, for supporting the organs and distributing material.

Types of Coelom

2.2.1 **Acoelomate Bilaterians**: The bilatarian animals in which the body cavity is absent are called acoelomates. e.g. Platyhelminthes. In these animals, the mesenchyme derived from the third germinal layer, called mesoderm, occupies entire blastocoels, between the ectoderm and endoderm, so that the adults have neither the primary cavity nor secondary cavity. As there is no body cavity, the acoelomates exhibits solid **body plan**. Problems faced by the acoelomates due to the absence of perivesceral cavity are their internal organs cannot movie freely.

2.2.2 Pseudocoelomate bilaterians : In some animals, the body cavity is not lined by mesodermal epithelia. Such animals are called **pseudocoelomates**. E.g. Phylam Nematoda. During embryonic development mesenchyme occupies only a part of blastocoel adjoining the ectoderm. The unoccupied portion of blastocoel is called **pseudocoloem,** which is filled with

pseudocoelomic fluid**.** Pseudocoelomates are the first animals to exhibit a **'tube- within-a-tube'** organisation.

As the gut wall is made up of only endodermal epithelium, diffusion of digested food material from the lumen of the gut into the surrounding pseudocoelomic fluid becomes easier and absence of circulatory system is thus compensated. Though it is called pseudopodium, it performs all the functions of regular coelom. Pseudocoelomic fluid of pseudocoelomates serves as hydrostatic skeleton and a 'shock absorber'. It allows the free movement of visceral organs, helps in the circulation of nutrients, and storage of nitrogenous waste.

2.2.3 Eucoelomate bilaterians: Coelom or true coelom is fluid filled cavity that lies between the body wall and visceral organs and is lined by mesodermal epithelium, the peritonium. The Portion of peritonium that lines the body wall is **perietal poeritoneum**. The portion of the peritoneum that covers the visceral organs is called **visceral peritoneum**. In coelomates the visceral organs are suspended in the coelom by peritoneum. A double layered peritoneum that connects some visceral organs to the body wall is called mesentery. The organs like kidneys of vertbrates are covered by parietal peritoneum only on the ventral side. Such a peritoneum is cxalled retroperitoneum and the organs lined by it are called **retroperitoneal organs.** (Figure 2.5)

Based on the mode of formation of coelom, the eucoelomates are classified into two types.

I Schizocoelomates

Animals in which the body cavity is formed by splitting of mesoderm is called schizocoelomates. Annelids, arthropods and molluscs are schizocoelomates in animal kingdom. All the schizocoelomates are protostomians and they show **holoblastic**, **spiral** and **determinate cleavage**.

II Enterocoelomates

Animals in which the body cavity is formed from the mesodermal pouches of archentron are called enterocoelomates. E.g. echinoderms, hemichordates and chordates are enterocoelomates.

All the enterocoelomates are '**deuterostomes**' and they show '**radial**' and '**indeterminate**' cleavage.

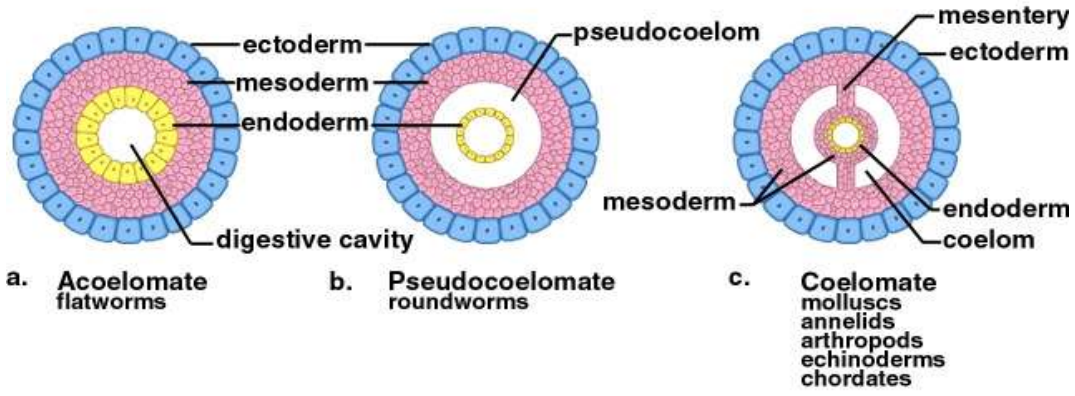


Fig 2.5 Types of coelom

Advantages of coelom over pseudocoelom:

1. Visceral organs of eucoelomates are muscular and so they can contract and relax freely independent of muscular movement of the body wall in the coelomic space, e.g peristaltic movements of the alimentary canal.
2. Gametes are released into the coelom in some invertebrates and in the female vertebrates.
3. Coelomic fluid receives excretory products and stores them temporarly before their elimination.
4. In the eucoelomates, the mesoderm comes into contact with the endoderm of the alimentary canal, and it causes regional specialization of the gut .

2.3 Animal Tissues

In acellular animals, all the functions like digestion, respiration, excretion and reproduction are performed by single cell. In multicellular animals the same basic functions are carried out by different group of cells in well organised manner.

A group cells and cell products that arise from the same region of the embryo, which also perform a specific function, constitute a ***tissue.*** *The study of tissues is called* ***histology*** *or* ***microanatomy***.

Tissues are made up of cells and extra cellular matrix. The extracellular matrix varies in composition and quantity from one tissue to other. Animal tissues are classified into four types: epithelial, connective, muscular and nervous tissues.

2.3.1 Epithelial Tissues: Epithelium (epi- upon; thelia-growing) forms outer covering of the body and lining of internal organs/cavities. Cells of epithelium are held together by an intercellular cementing substance. The specialized 'junctions' provide both structural and functional links between individual cells of an epithelium. (Figure 2.6)

There are two types of epithelial tissues namely simple 'epithelia' and 'compound epithelia' based on the number of layers or strata.

A. **Simple epithelium**

Simple epithelium is composed of a single layer of cells and forms the lining of body cavities, ducts and vessels. It helps in diffusion, absorption, filtration and secretion of substances. On the basis of shape of the cells, it is further divided into three types;

i) Simple squamous epithelium

It is composed of single layer of flat and tile like cells each with centrally located 'ovoid nucleus'.it is found in endothelium blood vessels , mesothelium of body cavities , wall of Bowman's capsule of nephron, lining of alveoli of lungs, etc.

ii) Simple cuboidal epithelium

It is composed of a single layer of cube-like cells with centrally located spherical nuclei. It is found in germinal epithelium , proximal and distal convoluted tubules of nephron. Cuboidal epithelium of proximal convoluted tubules of nephron has **microvilli.**

iii) Simple columnar epithelium

It is composed of single layer of tall and slender cells with oval nuclei located near the base.

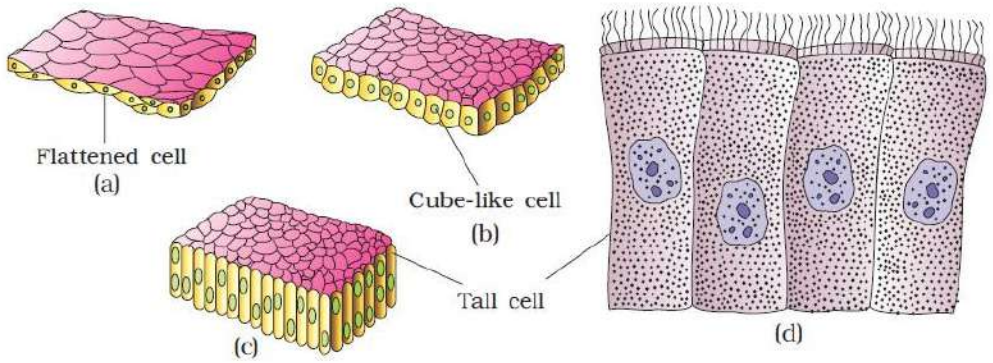


Fig 2.6 (a)Squamous epithelium (b) Cuboidal epithelium (c) columnar epithelium (d) columnar ciliated epithelium

A. Compound epithelium:

It is made up of more than one layer of cells. Its main function is to provide protection against chemical and mechanical stress. It covers dry surface of the skin.

Stratified keratinized squamous epithelium – covers moist surface of buccal cavity, pharynx, oesophagus and vagina.

Stratified non-keratinized squamous epithelium- forms the inner lining of larger ducts of salivary glands, sweat glands and pancreatic ducts.

Stratified cuboidal epithelium – forms the wall of urinary bladder as transitional epithelium.

B. Glandular epithelium:

Some of the columnar or cuboidal cells get specialised for secretion and are called **glandular epithelium.** They are mainly of two types: unicellular, consisting of isolated glandular cells (goblet cells of the alimentary canal), and multicellular, consisting of cluster of cells (Salivary gland). On the basis of the mode of pouring of their secretions, glands are divided into two categories namely **exocrine** and **endocrine** glands. Exocrine glands secrete mucus, saliva, earwax, oil, milk, digestive enzymes and other cell products. These products

are released through ducts or tubes. In contrast, endocrine glands do not have ducts. Their products called hormones are secreted directly into the fluid bathing the gland. (Figure 2.7)

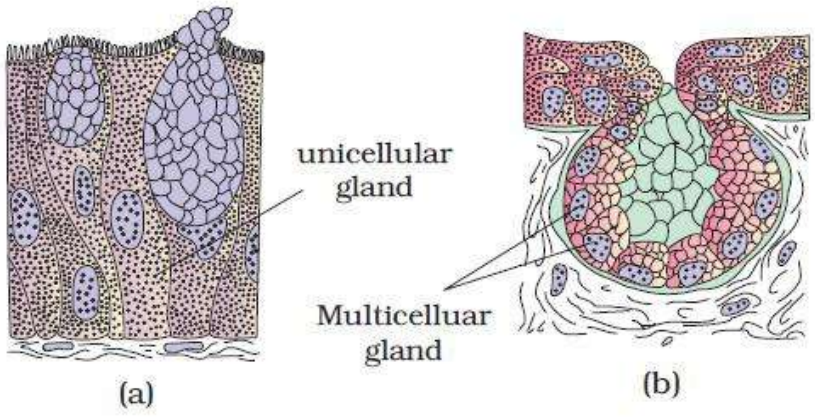


Fig 2.7 (a) Unicellular gland (b) multi cellular gland

2.3.2 Connective Tissues

Connective tissues are most abundant and widely distributed in the body of complex animals. They are named connective tissues because of their special function of linking and supporting other tissues/organs of the body. They range from soft connective tissues to specialised types, which include cartilage, bone, adipose, and blood. In all connective tissues except blood, the cells secrete fibres of structural proteins called collagen or elastin. The fibres provide strength, elasticity and flexibility to the tissue. These cells also secrete modified polysaccharides, which accumulate between cells and fibres and act as matrix (ground substance). Connective tissues are classified into three types namely connective tissue proper, skeletal tissue and fluid connective tissue based on the composition of matrix and types of cells.

2.3.2.1 Connective tissue proper: It is two types.

A) Loose connective tissue has cells and fibres loosely arranged in a semi-fluid ground substance. There are three types of loose connective tissues- areolar tissue, adipose tissue and reticular tissue.

i) **Areolar tissue**: It is the most widely distributed connective tissues in the body . It forms the packaging tissue in almost all the organs. Areolar tissue forms subcutaneous layer of skin. It has cells and fibres. Cells include fibroblasts, mast cells, macrophages, adiposities and plasma cells. Fibres are collagen, elastic and reticular fibres.

ii) **Adipose tissue**: It is specialised for fat storage. It consists of large number of adiposities and few fibres. Adipose tissue which is found beneath the skin provides thermal insulation. It forms blubber of aquatic mammals such as whales and sea cows and the hump of the camel. (Figure 2.8)

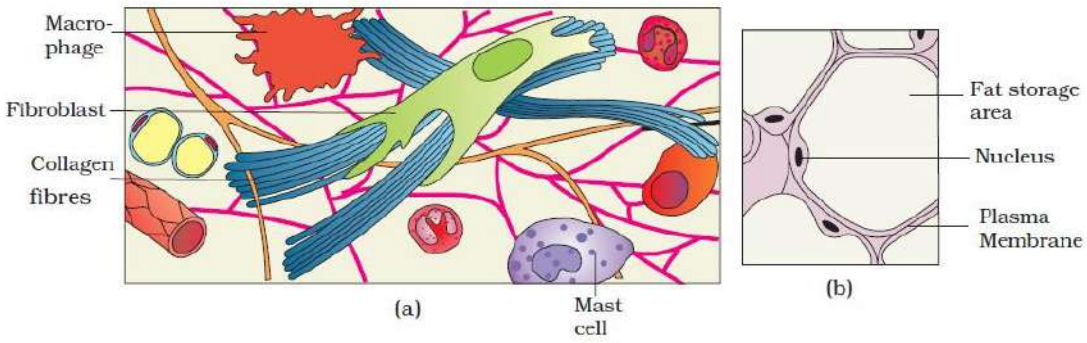


Fig 2.8 Areolar tissue (b) Aipose tissue

iii) **Reticular tissue**: It has specialised fibroblasts called reticular cells. They secrete reticular fibres that forms the inter connecting network. It forms the supporting frame work of the lymphoid organs such as bone marrow, spleen and lymph nodes and forms reticular lamina of the basement membrane.

B) **Dense connective tissue** consists of more fibres, but fewer cells. It has very little ground substance. These are three types.

i) **Dense regular connective tissue:** In this tissue collagen fibres are arranged parallel to one another in bundles. E.g. **Tendons**-which attach the skeletal muscles to bones and **ligaments**-which bone to another bone.

ii) **Dense irregular connective tissue:** In this type of connective tissue, bundles of collagen fibres are irregularly arranged. E.g. pericardium, periosteum, endosteum, heart valves.

iii) **Elastic connective tissue:** it is mainly made of yellow elastic fibres, capable of considerable extension and recoil. E.g. vocal cords, trachea, bronchi and elastic ligaments.

2.3.2.2 Skeletal tissue

It forms the endoskeleton of vertebrates. It supports the body, protects various organs, provides surface for the attachment of muscles and helps in locomotion. It is two types.

A) **Cartilage** is a solid but semi-rigid connective tissue. It resists compression. Matrix is firm, but somewhat pliable. It has collagen fibres, elastic fibres and matrix secreting cells called chondroblasts. These cells are enclosed in fluid filled spaces called **lacunae**. Cartilage is surrounded by connective tissue sheath called perichondrium. Cartilage is three types which differ from each other chiefly in the composition of matrix.

i) **Hyaline cartilage**- bluish white, translucent, and glass like cartilage. Matrix is homogenous and shows delicate collagen fibres. It is the weakest and most common type of cartilage. It forms the embryonic endoskeleton of bony vertebrates, endoskeleton of cyclostomes and cartilaginous fishes. It for **nasal septal cartilage**, cartilaginous rings of **trachea**, **bronchi** and cartilages of **larynx**.

ii) **Elastic cartilage-** it is yellowish due to the elastic fibres. Matrix has abundance of yellow elastic fibres in addition to collagen fibres. It provides strength and elasticity. Pericondrium is present. It is found in the **pinnae** of the external ears, **Eustachian tubes** and **epiglottis.**

iii) **Fibrous cartilage-** matrix has bundles of collegen fibres. Pericardium is absent. It is strongest of all cartilages. It occurs in inter-vertebral discs and pubic symphysis of the pelvis.(Figure 2.9)

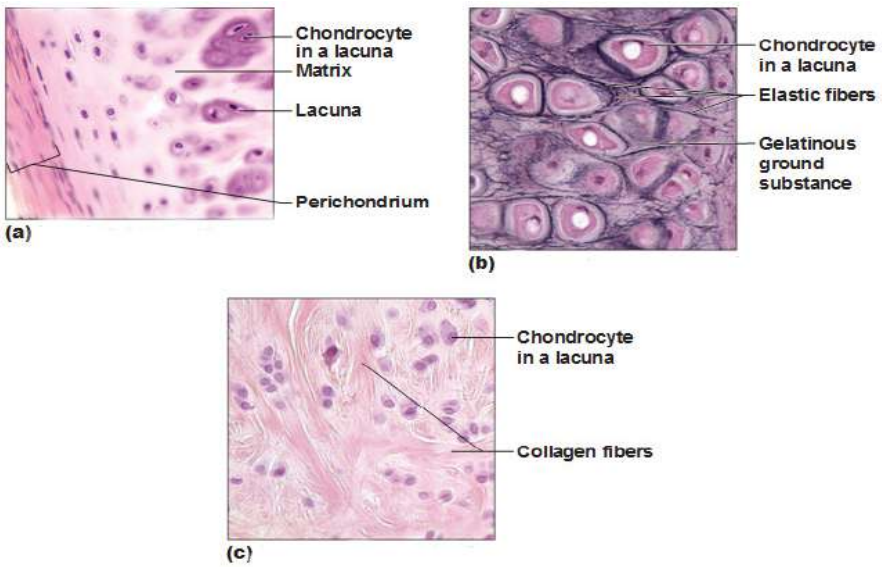


Fig 2.9 (a) Hyaline cartilage (b)Elastic cartilage (c) Fibrous cartilage

B) **Bone** has a hard and non-pliable ground substance rich in calcium salts and collagen fibres which give bone its strength . It is the main tissue that provides structural frame to the body. Bones support and protect softer tissues and organs. The bone cells (osteocytes) are present in the spaces called lacunae. Limb bones, such as the long bones of the legs, serve weight-bearing functions. They also interact with skeletal muscles attached to them to bring about movements. The bone marrow in some bones is the site of production of blood cells.

Bone has an outer fibrous connective tissue sheath called periosteum , the inner connective sheath that lines the marrow cavity called enosteum, non- living extra cellular matrix, living cells and bone marrow.

Types of bones-**cartilage bone** (formed by ossification within the cartilage, e.g. bones of limbs, girdles and vertebrae), **investing bones** (formed by ossification of embryonic mesenchyme, e.g. most of the bones of the cranium), **sesamoid bone** (formed by ossification in tendon, e.g. **Patella** (knee cap) and **visceral bones**-formed by ossification in the soft tissues, e,g. Os cordis, Os penis.

Structure of a compact bone

Diaphysis (shaft) is a part of long bone that lies between expanded ends (epiphysis). In a growing bone there is a region called metaphysis between diaphysis and epiphysis. It consists of an epiphyseal plate. Diaphysis is covered by a dense connective fibrous tissue called periosteum. Diaphysis of long bone has hollow cavity called marrow cavity which is lined or surrounded by endosteum. In between periosteum and endosteum the matrix of the bone is laid down in the form of lamellae. In between outer and inner circumferential lamellae, there are so many Heversian systems. The space between Heversian systems are filled with interstitial lamellae. Haversian system consists of a Heversian canal that runs parallel to the marrow cavity. It contains an artery, a vein, a lymphatic vessel. Heversian canal is surrounded by concentric lamellae. Small fluid filled spaces called lacunae provided with minute

canaliculi lie in between the lamellae. Canliculi connects the lacunae with one another and with Heversian canal. Each lacunae encloses one osteocyte. The cytoplasamic processes of osteocytes extend through canaliculi. A Haversian canal and surrounding lamellae and lacunae are are collectively called Haversian system or osteons (Figure 2.10). Haversian canals communicate with one another, with the periosteum and also with the bone marrow cavity by transverse canals called Volkmann's canal.

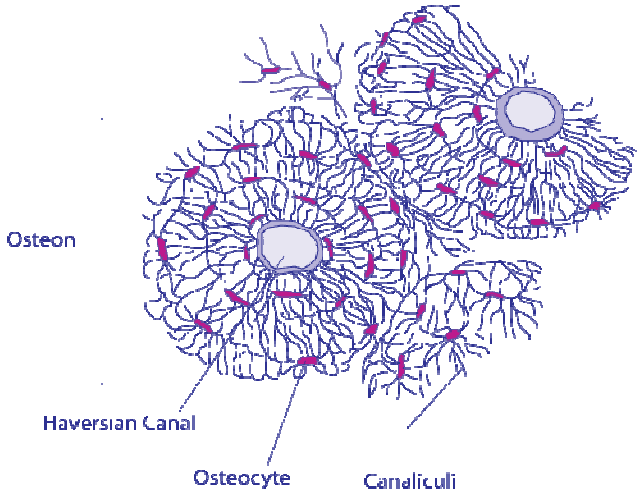


Fig 2.10 Haversian system

2.3.2.3 Fluid connective tissue

It is the tissue which consists fibre free liquid matrix called plasma and living cells that do not produce the matrix. It includes blood and lymph.

A) Blood

It is a red colour, opaque and slightly alkaline fluid. The study of blood is haematology. It is a tissue that circulates to the various parts of the body through cardiovascular system. It is composed of blood plasma and formed elements or blood cells, the RBC, WBC and platelets. The plasma constitutes about 55% and the cells around 45% of total volume of blood. The total volume of blood in an adult human being is about 5 to 6 litres. The percentage of total volume occupied by RBCs is called **haematocrit value.**

(i) **Plasma**: it is the fluid matrix of the blood. It consists of 92% of water and 8% of solutes. Solutes include plasma proteins, mineral salts, nutrients, gases, excretory waste, enzymes, hormones, etc. Plasma proteins include albumins, globulins and blood clotting proteins such as fibrinogen and prothrombin, all of which are produced by liver. Globulins are formed in the liver and lymphoid organsfall in the levels of albumin blood leads to **oedema** (accumulation of fluids in tissue). Plasma proteins act as acid base buffers maintaining the pH of blood at 7.4.

(ii) **Formed elements**: They include erythrocytes (red blood corpuscles), leucocytes (white blood corpuscles) and platelets. The process of formation of blood cells is called **haemopoiesis** or **haematopoiesis**. In the earliest stages of embryogenesis blood cells are formed from yolk sac mesoderm. Later on, the liver and spleen serve as temporary haemopoietic tissues. In final stage of embryonic development and after birth, the red bone marrow is the primary site of haemopoiesis.

(iii) **Red blood corpuscles** (Erythrocytes): Erythrocytes of mammals are circular (elliptical in camels and Llamas), biconcave and enucleate. The biconcave shape

provides a large surface area to volume ratio, thus provides more area for exchange of gases. These are 7.8 μm in diameter. The number of RBC per cubic millimetre of blood is about 5 millions in a man, and 4.5 millions in a woman. Decrease in the number of RBC is called erythrocytopenea and it leads to anaemia. An abnormal rise in RBC count is called polycythemia. Shortage of oxygen stimulates the kidneys to secrete the hormone called erythropoietin into the blood. Erythropoietin stimulates the bone marrow to increase the production of RBC. Vitamin B_{12} and folic acid are required for maturation of RBC. Mammalian RBC is surrounded by plasma membrane. Nucleus and other cell organelles are lost in the reticulocyte stage of development. Cytoplasm of RBC contains a chromoprotein, the 'haemoglobin'. Life span of RBC in humans is about 120 days. The worn out RBC are destroyed in the spleen and liver.

(iv) **White blood corpuscles (Leucocytes)**: These are nucleate colourless, complete cells. They are spherical and irregular in shape, and are capable of exhibiting amoeboid movement into the extra vascular area by **diapedesis**. They are larger than RBC in size, and less than RBC in number. The total WBC count is 6000 to 10000 per cubic millimeter of blood under normal conditions. The process of formation of WBC is called **Leucopoiesis**. Slight increase in WBC count is called **Leucocytosis** (during infection and allergy). An abnormal increase in the number of WBC is indicated in a type of cancer called **Leukemia**. WBC are of two types: Granulocytes and Agranulocytes.

Granulocytes: They possess cytoplasmic granules that may take three different types of stains, neutral or acidic or basic. Nucleus of granulocytes is divided into lobes and assumes different shapes; hence, these are called **polymorph-nuclear leucocytes**. Based on the staining properties these are three types:

Basophils

They constitute about 0.4 % of total WBC. Nucleus is divided into irregular lobes. Cytoplasmic granules are fewer and irregular in shape. They take basic stains. They produce heparin, histamine etc. They supplement the function of mast cells when needed.

Eosinophils (acidophils)

They constitute about 2.3 % of total WBC. Nucleus is distinctly bilobed. Cytoplasm has large granules which stain with acidic dyes such as **eosin**. They play a role in allergic reactions. Their number increases during allergic reactions and helminth infections. They remove antigen-antibody complexes.

Neutrophils

They constitute about 62 % of total WBC. Nucleus is many lobed. Specific cytoplasmic granules are small and abundant. They stain with neutral dyes. They are active phagocytic cells commonly described as microscopic policemen. Certain neutrophils of female mammals have sex chromatin body or drum stick body attached to the nucleus.

Agranulocytes: Cytoplasmic granule are absent in agranulocytes. Nucleus of these cells is not divided into lobes. These are of two types:

Lymphocytes

They constitute about 30 % of total WBC. They are small spherical cells with large spherical nucleus and scanty peripheral cytoplasm. There are functionally two types of

Lymphocytes- 'B' lymphocytes, which produce antibodies and 'T' lymphocytes which play the key role in immunological reactions of the body.

Monocytes

They constitute about 5.3% of the leucocytes. The nucleus is kidney shaped. These are largest, motile phagocytes. They engulf bacteria and cellular debris. They differentiate into macrophages, when they enter the connective tissues.

(v) **Blood platelets (Thrombocytes):** These are colourless non nucleated, round or oval biconvex discs. Number of platelets for cubic mm of blood is about 2, 50,000-4, 50,000. They formed from giant megakaryocytes produced in red bone marrow by fragmentation. The average life span of blood platelets is about 5 to 9 days. They secrete thromboplastin and play an important role in blood clotting. They adhere to the damaged endothelial lining of capillaries and seal minor vascular openings.(Figure 2.11)

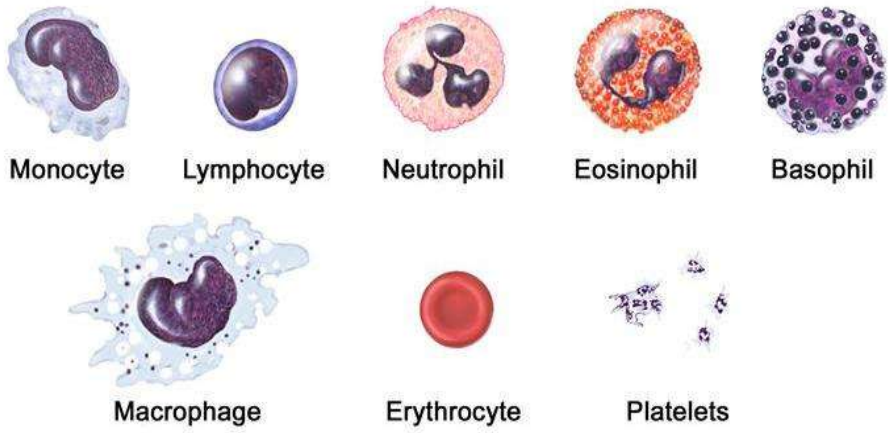


Fig 2.11 Blood cells

(B) Lymph

Lymph is colourless fluid. It lacks RBC, platelets and large plasma proteins, but has more number of leucocytes. It is chiefly composed of plasma and lymphocytes. When compared to the tissue fluid, it contains very small amounts of nutrients and oxygen, but has abundant CO_2 and other metabolites. The most important site of formation of lymph is interstitial space. As blood passes through the blood capillaries, some portion blood that include water, solutes and proteins of low molecular weight passes through the walls of capillaries, into the interstitial spaces due to hydrostatic pressure at the arteriolar ends. This fluid forms the interstitial fluid. Most of the interstitial fluid is returned directly to the capillaries due to osmotic pressure at the venular ends. Little amount of this tissue fluid passes through a system of lymphatic capillaries, vessels, ducts and finally reach the blood through the subclavien veins. The extra cellular tissue fluid that passes into the lymph capillaries and lymph vessels is called **lymph**. Lymphatic system represents an accessory route by which interstitial fluid flows from tissue spaces into blood.

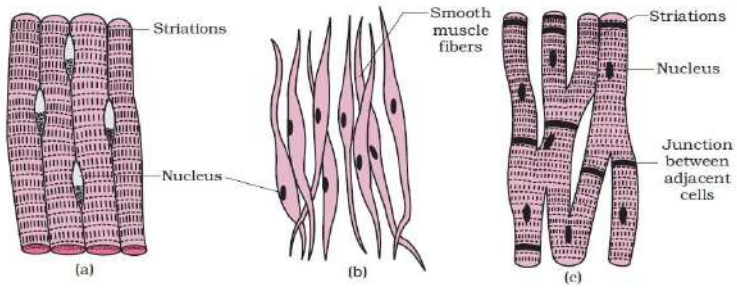
Muscle Tissue

Each muscle is made of many long, cylindrical fibres arranged in parallel arrays. These fibres are composed of numerous fine fibrils, called myofibrils. Muscle fibres contract (shorten) in response to stimulation, then relax (lengthen) and return to their uncontracted state in a coordinated fashion. Their action moves the body to adjust to the changes in the environment and to maintain the positions of the various parts of the body. In general, muscles play an active role in all the movements of the body. Muscles are of three types, skeletal, smooth, and cardiac.

Skeletal muscle tissue is closely attached to skeletal bones. In a typical muscle such as the biceps, striated (striped) skeletal muscle fibres are bundled together in a parallel fashion . A sheath of tough connective tissue encloses several bundles of muscle fibres

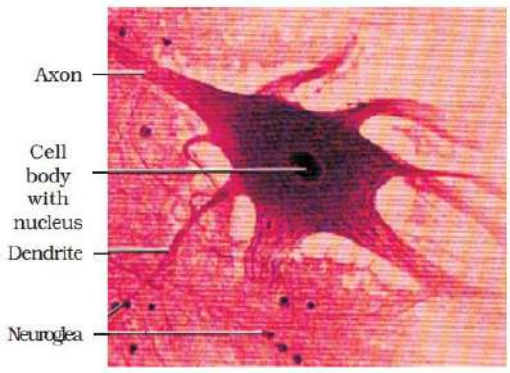
The **smooth muscle** fibres taper at both ends (fusiform) and do not show striations (Figure 7.7b). Cell junctions hold them together and they are bundled together in a connective tissue sheath. The wall of internal organs such as the blood vessels, stomach and intestine contains this type of muscle tissue. Smooth muscles are 'involuntary' as their functioning cannot be directly controlled. We usually are not able to make it contract merely by thinking about it as we can do with skeletal muscles.

Cardiac muscle tissue is a contractile tissue present only in the heart. Cell junctions fuse the plasma membranes of cardiac muscle cells and make them stick together . Communication junctions (intercalated discs) at some fusion points allow the cells to contract as a unit, i.e., when one cell receives a signal to contract, its neighbours are also stimulated to contract.



(a) Striated muscle (b) unstriated muscle (c) cardiac muscle

Neural Tissue



Neural tissue exerts the greatest control over the body's responsiveness to changing conditions. Neurons, the unit of neural system are excitable cells. The neuroglial cells which constitute the rest of the neural system protect and support neurons. Neuroglias make up more than one half the volume of neural tissue in our body. When a neuron is suitably stimulated, an electrical disturbance is generated which swiftly travels along its plasma membrane. Arrival of the disturbance at the neuron's endings, or output zone, triggers events that may cause stimulation or inhibition of adjacent neurons and other cells

GLOSSARY

Anticoagulants: these are the substances that prevent the coagulation of blood, when blood flows through blood vessels.

Articular cartilage: It is the cartilage found at the free surfaces of long bones that forms joints.

Central axis: An imaginary straight line joining the midpoint at one end or surface . It is also called the principal axis.

Diapedesis: The passage of leucocytes of blood into tyhe matrix of connective tissues through the walls of capillaries by an amoeboid movement.

Endotheliun: The simple squamous epithelium that lines the inner surface of blood vessels and heart.

Haemocoel: The functional perivisceral cavity, that lines around the visceral organs of arthropods and molluscs which is filled with thge blood.

Hydrostatic skeleton: In pseudocoelomates and eucoelomates, the body cavity is filled with a fluid which gives proper shape to the body as an endoskeleton does.

Ligament: A dense fibrous tissue strand, which connects bones to the other bones.

Median sagittal plane: The plane that runs along the anterior, posterior and sagittal axes.

Megakaryocytes: Giant cells of red bone marrow that produce blood platelets by fragmentation.

Oedema: It is an abnormal accumulation of interstitial fluid beneath the skin or in one or more cavities. Fall in levels of plasma proteins mainly serum albumin acuses a dcrese in the osmotic pressure of blood.

Osteoblasts: These are the immature cells that secrete organic matter of the matrix of a growing bone. Immature osteoblasts become mature cells, the osteocytes, in the adult stage .

Perivisceral cavity: It is the cavity taht encloses visceral organs. The perivisceral cavity of

nematodes is pseudocoelom that of annelids is eucoelom.
Plane: The flat area that runs through any axis.
Reticular cells: These are specialised cells of the fibroblasts that secrets reticular fibres of matrix.
Retroperitoneal organs: Organs those are located in between the dorsal body wall and parietal layer of peritoneum.
Sagittal axis: an imaginary straight line that joins mid dorsal and mid ventral ends.

VERY SHORT ANSWER QUESTIONS

1. What is cephalisation? How is it useful to its possessors?
2. Mention the animals that exhibited a 'tube-with-in-a-tube' organisation for the first time? Name their body?
3. Why the true coelom is considered a secondary body cavity?
4. What are retroperitoneal organs?
5. Distinguish between tendon and ligament?
6. What is the strongest cartilage?
7. What is haematocrit value?
8. Define osteon?
9. What is a sesamoid bone? Give an example?
10. What is Lymph? How does it differ from plasma?

SHORT ANSWER QUESTIONS

1. Describe the formation of schizocoelom and enterocoelom?
2. Give an account of glandular epithelium?
3. Explain haversian system?
4. Describe three types of cartilage?
5. Write short notes on lymph?

UNIT 3

ANIMAL DIVERSITY – I

Invertebrate Phyla

SUMMARY

Animalia (Metazoa) includes multi-cellular, heterotrophic (obtain nourishment by mostly ingesting and digesting the ingested food), eukaryotes with specific body plans (bauplans). Animal cells do not have cellulose cell walls, but they are held together by structural proteins, of which collagen is the most abundant protein and unique to the Kingdom Animalia.

Animals reproduce mostly sexually, by the fusion of 'gametes' resulting in the production of '**zygotes**'. Zygotes undergo different types of cleavages and pass through simple stages such as 'blastula', 'gastrula etc. and further differentiate into an adult, either 'directly' (without a larval stage), or 'indirectly' (with a larval stage). The most simple multi-cellular organisms are the 'sponges' which show 'cellular level of organisation'. The 'choano-flagellates' (mastigophores) of the kingdom 'Protista'/ 'Protoctista', are the closest living relatives of the metazoans. While sponges have 'unorganised' cells, the 'diploblastic organisms' (cnidarians and ctenophores), are the 'first true metazoans' with two germinal layers, namely 'ectoderm' and 'endoderm'. They show 'tissue level of organisation'. The diploblastic organisms show 'co-ordination' between body parts, due to the presence of 'sensory cells' and 'nerve cells'. The next higher level of organisation is reached with the development of the 'triploblastic level of organisation' (three germinal layers namely – ectoderm, endoderm and the third germinal layer, the mesoderm) - a promotion from tissue to 'organ' and 'organ-system' level of organisation. The first 'triploblasts' have a 'solid bauplan' (the space between the ectoderm and endoderm/ the perivisceral space, is filled with a tissue called 'parenchyma/mesenchyma' derived from the 'mesoderm' - the Acoelomates'). The first '**tube - within - a tube**' body organisation (outer tube- the body wall and the inner tube - the alimentary canal) arose with the evolution of the nematodes. The space between the body wall and the alimentary canal in the body of a nematode is the remnant of the 'primary body cavity' (blastocoel) and is called **pseudocoel** (false coelom). **Coelom** (perivisceral space lined by mesodermal coelomic epithelia/ peritoneal layers) arose by the splitting of the mesoderm. It is called **schizocoelom** (schizo- splitting). It is typically seen in the 'annelids', 'arthropods' and 'molluscs'. The echinoderms, hemichordates and chordates also have a true coelome (eucoelom). It arises by the confluence of the 'out-pouchings'of the archenteron (primitive gut). As such the coelom in them is described as '**enterocoelom**'.

3.1 Invertebrate Phyla

Phylum-Porifera

(Subkingdom-Parazoa)

The term Porifera (pore bearing) was coined and their animal nature was established by **Robert Grant**. Members of this phylum are commonly called **sponges**. They are generally marine (with the exception of families *Potamolepidae* and *Spongillidae*, which include fresh water sponges e.g. *Spongilla*). They are either radially symmetrical or asymmetrical animals (Figure 3.1). These are primitive, multicellular and sessile animals and have cellular level of organisation. The body wall is composed of two layers (outer epidermis/ pinacoderm and inner choanoderm) separated by a gelatinous matrix called **mesohyl**. Sponges have a water transport system or **canal system** that constantly conducts water. Water enters through minute pores called **ostia** in the body wall into a central cavity, the spongocoel, from where it goes out through the **osculum**. This transport of water is helpful in gathering food (nutrition-filter feeders), respiratory exchange of gases (respiration) and removal of wastes (excretion). Choanocytes or collar cells line the spongocoel and the canals. Nutrition is holozoic and digestion is 'intracelluiar. Nerve cells and sensory cells are absent and so they do not show much co-ordination between the functioning of various parts of the body. The body is supported by a skeleton made up of calcareous or siliceous spicules or sponging fibres or both. Sexes are not separate (hermaphroditic or monoecious), i.e. egg cells and sperms are produced by the same individual. Sponges reproduce asexually by fragmentation and sexually by formation of gametes. Fertilisation is internal. Cleavage is holoblastic and development is indirect involving different types of larval stages such as parenchymula, trichimella and amphiblastula which are morphologically different from the adult. Power of regeneration is well developed. They are considered an evolutionary blind offshoot.

Examples: *Sycon, Euplectella, Spongilla and Euspongia*. (Figure 3.2)

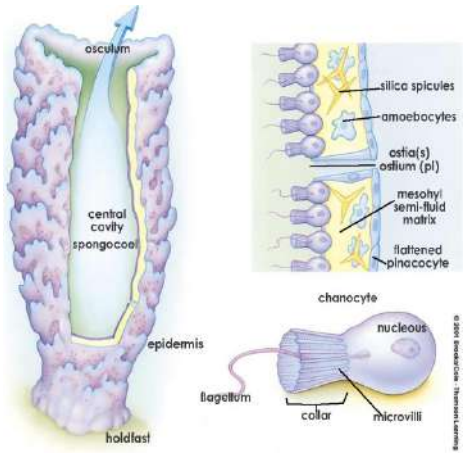


Fig 3.1 A model sponge

(a) (b) (c)

Fig 3.2 Examples for Porifera: (a) *Sycon* (b) *Euspongia* (c) *Spongilla*

Classification of the phylum Porifera

Phylum Porifera is classified into three classes

1. **Calcarea 2. Hexactinellida** and **3. Demospongiae**

Phylum-Cnidaria

(coelenterata)

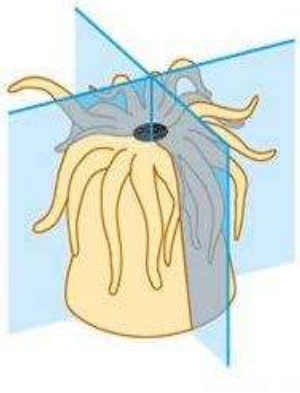


Fig 3.3 Sea anemone showing biradial symmetry

Cnidarians (previously called coelenterates) are aquatic, mostly marine, solitary or colonial, sessile or free-swimming, radially symmetrical animals (sea anemones are biradially symmetrical) (Figure 3.3). The recent name Cnidaria is derived from the 'stinging cells' called cnidoblasts or cnidocytes present mostly on the tentacles and the body. Cnidoblasts are used for anchorage, defence and capture of prey (Figure 3.4) Cnidarians are the first metazoans to exhibit tissue level of organisation' and are diploblastic. They have a central

gastro-vascular cavity or coelenteron (serves both digestive and circulatory functions), hence the earlier name coelenterata, with a single opening, the mouth serving the purpose of ingestion and egestion, there being no anus. Digestion is both extracellular and intracellular. Nervous system is of primitive type formed of diffuse 'nerve net'. Sense organs such as statocysts occur in the 'medusoid forms'. Some of the cnidarians, e.g., 'coral forming' cnidarians have an exoskeleton composed of calcium carbonate. Cnidarians show two basic body forms called **polyp** and **medusa** (Figure 3.5). The former is a sessile and cylindrical form (e.g. *Hydra, Adamsia* etc.), whereas, the latter is 'umbrella-shaped' and free-swimming form (e.g. *Aurelia* - commonly called jelly fish). Those cnidarians which exist in both forms exhibit alternation of generations called **metagenesis**, i.e., polypoid forms produce medusae asexually and medusae form the polypoid forms sexually (e.g. *Obelia*) - Asexual reproduction is by budding and sexual reproduction is by **syngamy**. Development is indirect and includes a free swimming ciliated larva, the **planula**.

Examples: *Physalia, Adamsia, Pennatula, Gorgonia* and *Meandrina*.

Figure 3.4 Cnedoblast

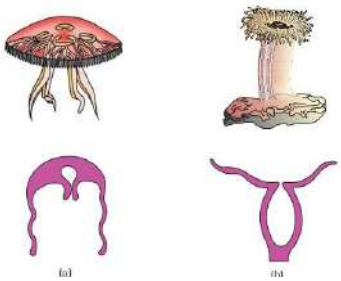


Fig 3.5 (a) Medusa (Auralia) (b) Polyp (Adamsia)

Classification of the phylum Cnidaria (Coelenterata)

Phylum Cnidaria is classified into three classes, namely

1. **Hydrozoa 2. Scyphozo 3. Anthozoa**.

Phylum-Ctenophora

(Close relatives of cnidarians)

Ctenophores, commonly known as '*sea walnuts'* or '*comb jellies'* or '*sea gooseberries'*, are exclusively marine, radially symmetrical, diploblastic organisms with tissue level of organisation. The body bears eight external rows of ciliated comb plates, which help in locomotion, hence the name ctenophora' (Fig. 3.6). Cnidocytes are absent. However, they possess 'glue cells' called **lasso cells** or **colloblasts** which help in food capture. Digestion is both extracellular and intracellular. **Bioluminescence** (the property of emitting light by living organism) is well-marked in the ctenophores. Sexes are not separate

(monoecious). Reproduction takes place only by sexual method. Fertilisation is external. Development is indirect and includes a larval stage called cydippid larva.

Examples: *Pleurobrachia, Hormiphora*.

Figure 3.6 *Pleurobrachia*

Classification of the phylum Ctehophora

1. Phylum Ctenophora is classified into two classes,

1. Tentaculata and 2. Nuda.

Phylum-Platyhelminthes

They have dorso-ventrally flattened body, hence are called flatworms. These are mostly **endoparasites** found in animals, including human beings. Flatworms are the first bilaterally symmetrical, triploblastic and acoelomate animals with **organ-systemlevel** of organisation (Fig. 3.7). Body is not segmented, but some exhibit **pseudometamerism**. They show moderate **cephalization** and **unidirectional movement** (locomotion). Hooks and suckers are present in the parasitic forms. Digestive system, if present, has mouth only; anus is absent. Nervous system is moderately developed with brain (cephalic ganglia) and nerve cords forming 'ladder like' system.

Specialised excretory cells called **flame cells** (protonephridia) help in osmoregulation and excretion. Sexes are not separate (monoecious). Fertilisation is internal and development is indirect with many larval stages (miracidium, sporocyst, redia, cercaria etc.). Poly embryony is common in some (Liver fluke). Some members like *Planaria* possess high degree of **regeneration** capacity.

Examples : *Taenia, Fasciola, Schistosoma, Dugesia*.

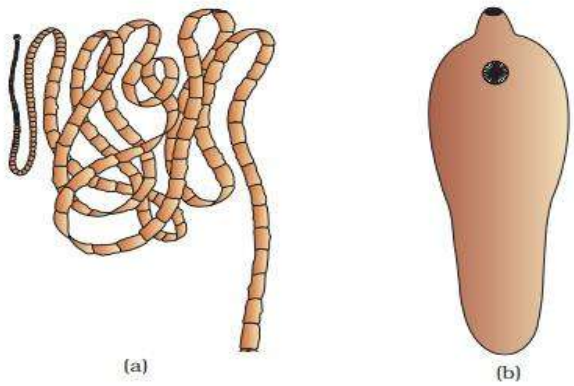


Figure 3.7 (a) *Taenia* (b) *Fasciola*

Classification of the phylum Platyhelminthes

Phylum Platyhelminthes is classified into three classes, namely

1. **Turbellaria 2. Trematoda and 3. Cestoda**.

Phylum-Nematoda

(Aschelminthes)

The body of a nematode is circular in cross-section, hence the name '**roundworms**'. They may be free living or parasitic on plants and animals, aquatic or terrestrial. Round worms have organ-system level of organisation (Figure 3.8). They are bilaterally symmetrical, triploblastic and pseudocoelomate animals. Body is unsegmented and covered by a transparent, tough and protective collagenous cuticle (a unique character). In some, the epidermis is 'syncytial'. Alimentary canal is 'complete' with a mouth, well developed muscular pharynx and anus. Excretory system consists of **renette gland** (excretory gland) and ducts. Nervous system consists of a circum enteric nerve ring with ganglia and nerves. Sense organs like **amphids** and **phasmids** occur. Sexes are separate (dioecious). They exhibit **sexual dimorphism**; often females are longer and larger than males. Males have curved posterior end with a cloacal aperture and one or two copulatory (penial) spicules. Fertilisation is internal, majority are oviparous (e.g. *Ascaris*), a few are ovoviviparous (e.g. *Wuchereria*) and development may be direct (the young ones resemble the adult- called juveniles) or indirect. Growth into adult forms involves typically four moultings in the larva.

Examples: *Ascaris, Wuchereria, Ancylostoma.*

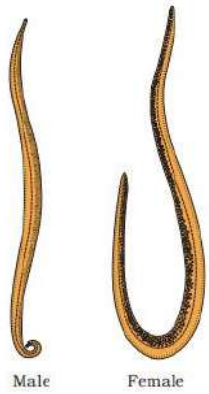


Fig 3.8 *Ascaris*

Classification of the phylum Nematoda

Phylum Nematoda is classified into two classes, namely

1. **Aphasmidia and 2. Phasmidia.**

Phylum-Annelida

`The term annelida (L. annulus: little ring and Gr. edios: form) was coined by **Lamarck**. They may be aquatic (marine and freshwater) or terrestrial; free-living, and sometimes parasitic. They exhibit **organ-system level of body organisation** and **bilateral symmetry**. They are triploblastic, metamerically segmented (metamerism) and coelomate (schizocoelic coelom) animals (Fig.3.9). Their body and the coelom are divided by transverse septa into segments or metameres. They possess longitudinal and circular muscles in the body wall, which help in locomotion. Coelom with coelomic fluid provides a **'hydrostatic skeleton'** giving stiffness to the body parts thus aiding in locomotion. Aquatic annelids such as *Nereis* possess lateral appendages, the **parapodia**, which help in swimming; chitinous setae and suckers also help in locomotion in some. **Cephalization** is more pronounced with distinct head and sense organs. Respiration is by simple diffusion through the body wall and in *Nereis* highly vascularised parapodia help in respiration. A closed circulatory system is present. Respiratory pigments such as haemoglobin, chlorocruorin are found dissolved in the plasma (a feature unique to the invertebrates). Nephridia (metanephridia- nephridia with nephrostomes), which are 'ectodermal' in origin, help in osmoregulation and excretion. Nervous system consists of paired (cerebral and sub-pharyngeal) ganglia connected by lateral nerves around the pharynx forming a nerve ring and to a ganglionated 'double ventral nerve cord' (annelidan type of nervous system). Sense organs like eyes, palps and tentacles occur in some. They may be dioecious (sexes are separate- e.g. *Nereis*) or monoecious (hermaphrodites –e.g. earthworms and leeches). Reproduction is usually sexual. Cleavage is holoblastic (complete) and spiral. Development is direct in the monoecious (bisexual) annelids and indirect in the dioecious (unisexual) annelids. Characteristic larval form, the **trochophore** occurs in the life history.

Examples: *Nereis, Pheretima, Megascolex* and *Hirudinaria.*

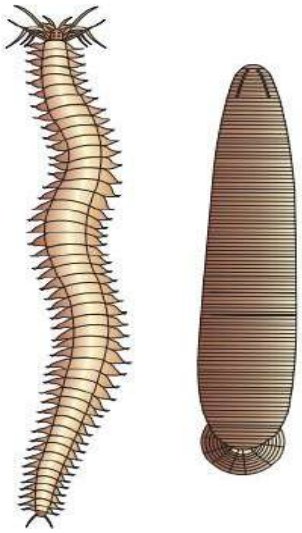


Figure 3.9 (a) *Nereis* (b) *Hirudinaria*

Classification of the phylum Annelida

Phylum Annelida is classified into three classes, namely

1. Polychaeta 2. Oligochaeta 3. Hirudinea

Phylum-Arthropoda

Arthropoda is the largest phylum of the Kingdom: Animalia, and it includes the largest Class called Insecta. Over two- thirds of all named species on earth are arthropods accounting for 80% of the animal species (Figure 10). They are bilaterally symmetrical, triploblastic, metamerically segmented and coelomate (schizocoelomate) animals. The body of arthropods is covered by a chitinous exoskeleton as a protection and to prevent loss of water and it is periodically shed off by a process called **moulting** or **ecdysis** to allow growth of the body. The body is segmented and consists of head, thorax and abdomen. They have jointed appendages (arthros: joint: podium : foot). Muscles are striated and aid in rapid locomotion. (Note: striated muscles appeared for the first time in evolution, in the arthropods). Coelom is reduced to the spaces around excretory and genital organs. Body cavity is a haemocoel; it is not a true coelom but derived from mostly the embryonic blastocoel. Respiratory organs are gills, book gills, book lungs or tracheae. Circulatory system is of open type. Heart is dorsal in position. In some (crustaceans and chelecerates the blood (haemolymph) contains a 'copper' containing respiratory pigment called **haemocyanin**. Nervous system is of annelidan type consisting of a nerve ring (around oesophagus) and a double ventral nerve cord. Sensory organs like antennae, eyes (compound and simple), statocysts (organs of balance/equilibrium) are present. Excretion takes place through **malpighian tubules**, **green glands**, **coxal glands**, etc. They are mostly dioecious (unisexual / gonochoric). Fertilisation is usually internal. They are mostly oviparous. Development may be direct or indirect. Life history includes one to many larval stages followed by metamorphosis.

Examples: *Periplaneta, Palaemon, Cancer, Palamnaeus, Aranea*;

Economically important insects - *Apis, Bombyx, Kerria* (Laccifer); Vectors of common pathogens -*Anopheles, Cufexand Aedes*; Gregarious pest - *Locusta*; Living fossil - *Lirmdus*.

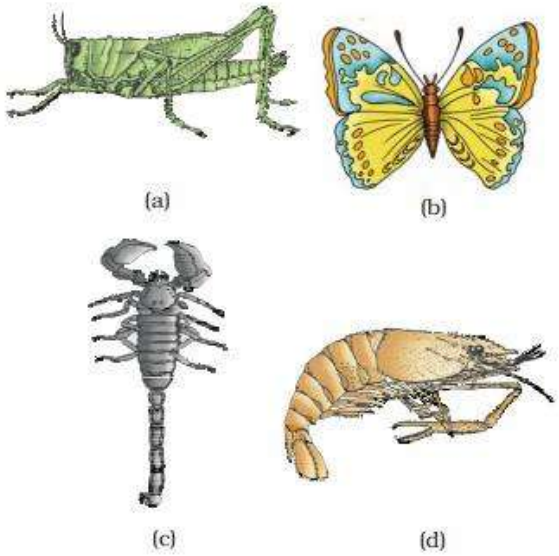


Fig 3.10 (a Locust) (b) Butter fly (c) Scorpion (d) Prawn

Classification of the phylum Arthropoda

Phylum Arthropoda is classified into three sub-phyla,

1. **Trilobita** 2. **Chelicerata** and 3. **Mandibulata.**

Phylum-Mollusca

This is the second largest phylum (Figures 3.11) in the Kingdom Animalia. Molluscs are terrestrial or aquatic (marine or fresh water). They are bilaterally symmetrical (some are asymmetrical, e.g. snail) and coelomate animals. Body is covered by a calcareous shell (mostly external, in some internal or reduced or absent) and is un-segmented with a distinct head, muscular foot and visceral mass / visceral hump. A soft and spongy layer of skin forms the mantle (pallium) over the visceral mass. The space between the visceral mass and the mantle is called the 'mantle cavity' in which feather like gills (ctenidio) are present. They have respiratory and excretory functions. The anterior head region has sensory tentacles. The body cavity is a haemocoel, and the true coelom is confined to the kidneys, gonads and pericardial space. The buccal cavity contains a file-like rasping organ called **radula** for feeding except in the bivalves and tusk shells. Except for cephalopods circulatory system is of open type; blood contains a copper containing respiratory pigment, the **haemocyanin.** Nervous system consists of ganglia, commissures and connectives; sense organs are tentacles, eyes and **osphradium** which helps in testing the purity of water - present in the bivalves and

gastropods. Excretory organs are metanephridia (commonly called kidneys). They are usually dioecous (unisexual / gonochoric) and oviparous with indirect development which includes a characteristic ciliated **Veliger larva** .

Examples: *Pila, Pinctada, Sepia, Loliga, Octopus, Aplysia, Dentalium.*

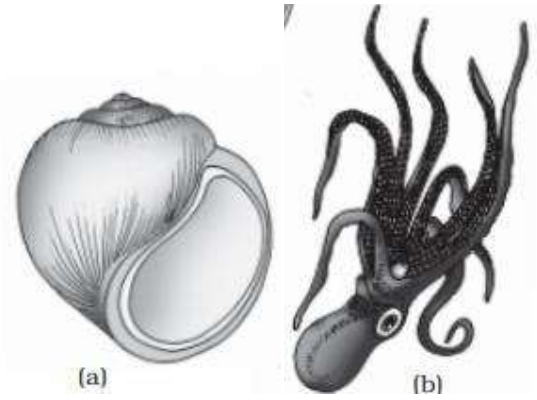


Fig 3.11 (a) *Pila* (b) *Octopus*

Classification of the phylum Mollusca

Phyllum Mollusca is classified into seven classes, namely

1. **Aplacophora** 2. **Ployplacophora** 3. **Monoplacophora** 4. **Gasrtopoda** 5.**Scaphopoda** 6. **Pelecypoda** and 7. **Cephalopoda.**

Phylum-Echinodermata

The echinoderms (Gr. echinos: spiny; dermos : skin) are non-chordate deuterostomes and enterocoelomates. All are marine. The adult echinoderms are radially symmetrical (pentamerous radial symmetry), but the larvae are bilaterally symmetrical. Skin is thick and spiny; echinoderms possess a mesodermal endoskeleton of calcareous **ossicles**, which support the spines, hence the name 'Echinodermata' (spiny bodied animals). In some, the spines are modified into '**pedicellariae**'. The most distinctive feature of echinoderms is the presence of **water vascular system** or **ambulacral system** derived from the coelom which helps in locomotion, capture and transport of food and respiration (Figure 3.12). Water enters the ambulacral system through the madreportie. Circulatory system is of open type, without heart and blood vessels. Respiratory organs are papulae or 'dermal branchiae' (thin outgrowths of the body wall between the spines); cloacal **respiratory trees** (sea cucumbers), etc. Special excretory organs are absent (excretion is by simple diffusion). Nervous system is poorly developed and brain is absent; sense organs are poorly developed. Sexes are separate (dioecious) but do not exhibit sexual dimorphism. Reproduction is sexual. Fertilisation is usually external. Development is indirect with a free-swimming bilaterally symmetrical larva. Power of regeneration is remarkable. Some exhibit **autotomy (**auto: self; tome : cut; self mutilation or self amputation), when captured by a predator and the lost body parts are regenerated. A hypothetical larva, **dipleurula** is considered the ancestor of all echinoderms.

Examples: *Asterios, Echinus, Antedon, Cucumaria* and *Ophiura* .

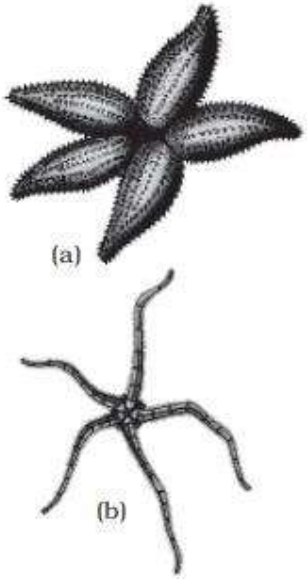


Fig 3.12 (a) *Asterias* (b) *Ophiura*

Classification of the phylum Echinodermata

Phylum Echinodermata is classified into two sub-phyla namely

1.**Pelmatozoa** and 2. **Eleutherozoa**.

Sub-phylum- 1: Pelmatozoa includes single class **Crinoidea**

Sub-phylum 2. Eleutherozoa is classified into four classes 1. **Asteroidea** 2. **Ophiuroidea** 3. **Echinodea** and 4. **Holothuroidea**

3.2 Annelida: Earthworm

Earthworm is a reddish brown terrestrial invertebrate that inhabits the upper layers of the moist soil rich in decaying organic matter. It is nocturnal and during the daytime, it lives in burrows made by boring and swallowing the soil. In gardens, they can be traced by their faecal deposits known as '**worm castings**'. They are considered, the friends of farmers. The common Indian earthworms are ***Pheretima***, and ***Megascolex***. *Drawida grandis* of south India is the longest earthworm in India. *Chaetogaster annandalei* is the smallest earthworm, while *Megascolides australis* is the longest earthworm.(Figure 3.13)

Morphology

Pheretima posthuma has a long cylindrical body which is diviided into 100 to 120segments (metameres). The dorsal surface of the body is marked by a dark mid-dorsal line (representing the dorsal blood vessel) along the longitudinal axis of the body. The ventral surface of the body shows genital apertures (pores). The anterior end bears a lobe which serves as a covering for the mouth, the **prostomium**. The prostomium bears some sense receptors. The first body segment is the **peristomium** which surrounds the mouth. In a mature worm, the segments 14-16 are covered by a prominent dark band of glandular tissue called **clitellum** or **cingulum** (L. clitellum: a pack saddle; cingulum: a belt). The body is

divisible into three prominent regions -the pre-clitellar, clitellar and post-clitellarregions . Four/ pairs of spermathecal apertures are situated on the ventro-lateral sides of the inter-segmental grooves, from 5th to 9th segments (5/6,6/7.7/8 and 8/9). A single female genital pore is present in the mid-ventral line of the 14th segment. A pair of male genital pores is present on the ventro-lateral sides of the18th segment. Numerous minute pores called nephridiopores open on the surface of the body from the 3rd segment to the last. In each body segment, except the first, last (pygidium) and clitellum (in mature worms) there are rows of s-shaped chitinous setae or chaetae embedded in the epidermal pits (setal or setigerous sacs) in the middle of each segment. Setae can be protruded or retracted. They play an important role in locomotion.

Fig 3.13 Earthworm

Anatomy

The body wall of earthworm is covered externally by a thin non-cellular cuticle below which is the epidermis, two muscle layers (outer circular and inner longitudinal) and the innermost coelomic epithelium. The epidermis is made up of a single layer of columnar epithelial cells which contain secretory gland cells. The coelomic epithelium is derived from the mesoderm and consists of the outer parietal (somatic) layer and inner splanchnic (visceral) layer. The space between the body wall and alimentary canal is called **coelom** . It is a schizocoelom and is divided into compartments by septa filled with coelomic fluid. The coelomic fluid provides a 'hydrostatic skeleton for the earthworm during locomotion.

Digestive system

The alimentary canal is a straight tube and runs from the first to the last segment of the body. (Figure 3.14). A terminal mouth opens into the buccal cavity (1-3 segments) which leads into the muscular pharynx (4th segment). A small narrow tube, oesophagus (5-7 segments), continues into a muscular gizzard (8-9 segments). It helps in grinding the soil particles and decaying leaves, etc., (grinding mill). The stomach extends from the segments 9 to 14. The food of earthworm is decaying leaves and other organic matter mixed with the soil. Calciferous glands, present in the stomach, neutralise the humic acid present in the humus of the soil. The intestine starts from the 15th segment and continues till the last segment. A pair of short and conical intestinal caecae project from the intestine in the 26th segment. An internal median fold of the dorsal wall of the intestine called **typhlosole**, helping in increasing the area of absorption, is poorly developed in *Pheretima* (between the 26th and the rectum, which occupies the last 23 to 28 segments). The alimentary canal opens to the

exterior by a small rounded aperture called anus. The ingested soil rich in organic matter passes through the digestive tract where digestive enzymes breakdown complex food into smaller absorbable units. These simpler molecules are absorbed through intestinal membranes and are utilised for various metabolic activities.

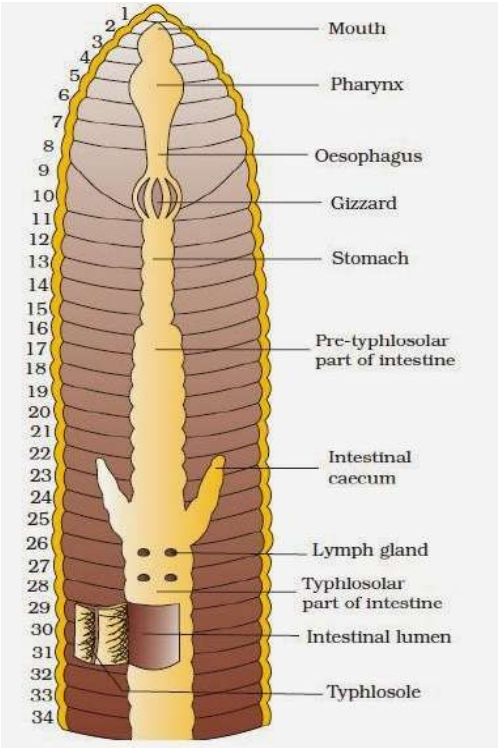


Fig 3.14 Earthworm digestive system

Nervous system

Nervous system consists of a nerve ring around the pharynx (in the 3rd and 4th segments) and a double ventral nerve cord. The cerebral ganglia (brain) along with other nerves in the ring integrate sensory input as well as command muscular responses of the body. Sensory system consists of receptor cells that receive light, touch and chemical stimuli. These sense organs are located mostly in the anterior part of the body.(Figure 3.15)

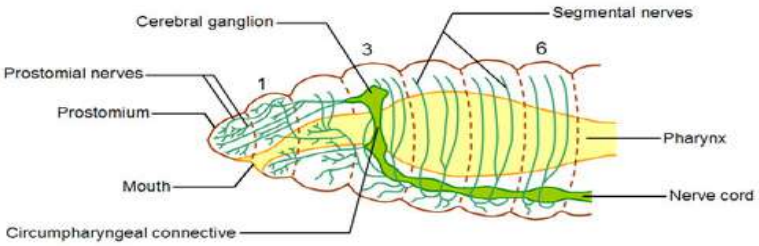


Fig 3.15 Earthworm Nervous system

GLOSSARY

Amphids: Cuticular depressions present on the lips surrounding the mouth in nematodes. They serve as chemoreceptors
Autotomy: The process of voluntary breaking of the injured body part.
Cecaria: A free swimming larva in the life history of liver flukes
Choanocyte:a specialized flagellated cell with a cup shaped collar around the base of flagellum.
Clitellum: It is a belt shaped thickening of the skin, in a specific region of the body usually between 14 to 16 segments in pheritima.
Ctenidia: They are respiratory organs of molluscs.
Flame cells: It is a hollow cell containing a tuft of cilia in the inner space. It is excretory and osmoregulation in function.
Madreporite: It circular porous plate present in the body of most echinoderms. Through its pores sea water enters the water vascular system.
Miracidium: a free swimming larva of liver flukes.
Moulting or **Ecdysis**: The process of casting of the outer body wall.
Muller's larva: The characteristic larva of turbellarians. It bears apical tuft of cilia.
Nepredia: They are highly coiled excretory organs derived from ectoderm.
Osculam: A large opening present at the free end of a sponge body.
Ostia: They are numerous openings present on the body of sponges.
Parapodia: They are hollow biramous appendages of the polychaetes.
Pedecellariae: They are 'forceps like structures' in the body of sea stars and sea urchins.
Phasmids: They are well developed in parasitic nematodes and are glandulo-sensory in function.
Polyembryony: Formation of several young ones from a single zygote.
Polyp: It is a flower shaped or hydra shaped zooid of colonial cnidarians like *Obelia*.
Radula: It is a thin ribbon shaped body lying in buccal cavity of molluscans.
Redia: It is an alongated larva of liver flike produced by sporocyst.
Setae: They are small *f* – shaped chitinous structures present in the pits of body wall of earthworms.
Spongocoel: It is the large central cavity of a sponge body.
Trochophore: It is the characteristic larva of annelids.
Zooid: it is a individual member of a coelenterate colony.

VERY SHORT ANSWER TYPE QUESTIONS

1. What are the functions of canal system of sponges?
2. What is metagenesis? Animals belonging to which phylum exhibit metagenesis?
3. What are the excretory cells of flat worms called? What are the other important functions of these specialized cells?
4. What is botryoidal tissue?
5. What are the respiratory structures of Limulus and Palamnaeus respectively?
6. Which Arthropod, you have studied, is called a living fossil? Name its respiratory organs?
7. What is the function of the radula ? Give the name of group of Molluscs which do not produce radula ?
8. What is Aristotle's lantern? Give one example of an animal possessing it?

SHORT ANSWER QUESTIONS

1. Write a short notes on salient features of the Anthozoans ?
2. Write short notes on salient features exhibited by Polychaetes?
3. What are the chief characters of the Crustacians?
4. What are salient features of the Echinoids?

Unit 4

ANIMAL DIVERSITY – II

SUMMARY

The phylum **Chordata** constitutes about 60,000 known species of highly evolved, heterogeneous group of organisms**.** The evolution of the chordates dates back to more than half a billion years. The development of a flexible rod like **'notochord'** along the dorsal aspect of the embryo and the ***attachment of various muscles to that 'endo-skeletal structure'*** helping side to side 'swinging movements' can be considered a major factor in the evolution of chordates. Chordates are ***'enterocoelous' deuterostomes,*** with their closest invertebrate relatives in the group ***Echinodermata.***

A mid dorsal, ectodermal, hollow, non-ganglionated 'nerve cord' (above the notochord), which differentiates into the **'brain'** and **'spinal *cord'-*** is another contrasting feature, when compared to an invertebrate (non-chordate).The notochord is replaced by a **'vertebral column',** which encloses and protects the nerve cord, in the higher chordates . There are two more distinguishing features-the ***pharyngeal slits*** and muscular **post-anal tail.** The urochordates and the cephalochordates are the ***non-vertebrate chordates.*** The appearance of 'jaws' is perhaps the ***major evolutionary step*** that led to the domination of the 'jawed fishes' during the **Devonian Period.** The amphibians ***invaded land,*** but they remained an *'imperfect group'* as they could not adapt completely to terrestrial life. They have to return to water to lay eggs. The next group to have evolved were the reptiles and they (the giant bodied dinosaurs) dominated the Earth, during the **Mesozoic Era.** They developed a **dry *scaly skin* and *'cleidoic eggs'*** (also called **'amniotic *eggs').*** The reptiles gave rise to two major groups - the **Aves** and the **Mammalia.** Kidneys evolved from the primitive ***'pronephros'* to *'mesonephros'*** and finally the ***'metanephros'***. There was a continuous complexity in the development of the **'brain'.** Fossil records of ***connecting links*** such as the ***'osteolepid fishes', 'labyrinthodont amphibians', 'therapsid reptiles'* and *'theropod dinosaurs'*** are available to ***endorse*** the presumed course of chordate evolution. The origin of **amnion** and other foetal membranes in the reptiles, ***air sacs, feathers*** of *birds,* the **hair, mammary *glands*** and ***chorio-allantoic placenta*** of mammals are the major ***'Bioarchitectural wonders',*** the chordate world witnessed through the course of evolution. The current ERA is definitely the **'Age of the Mammals'.** *Homo sapiens sapiens* the 'modern man' is sitting on the top, 'visualising' the **entire history of evolution** on his **'mind's screen'** There was a tremendous ***'genetic transformation'*** making man **unique.** For example, the gene FOX *P2* is believed to play a key role in **human language expression** (along with some other essential genes) that kept man- **apart *from the other organisims.*** They enabled him develop ***cognitive skills,*** richly deserving his specific epithet **'sapiens'** (meaning **'wise'/'intelligent'**)- a name which was so optimistically given by **Linnaeus.** Well, we had a look into the ***bioarchitecture*** of ***chordate body*** and **who is this *emerging architect?*** Ofcourse **MAN** himself, because he is guiding the process of evolution **- making *himself the*** 'EMERGING BIOARCHTTECT'.

4.1 General characters of Phylum: CHORDATA

Chordates are one of the most familiar groups of animals to mankind. Phylum ***Chordata*** *includes all those animals that possess the notochord (a* primary *endoskeletal element, their* ***chief distinctive*** *character) at some stage in their life time. It is one of the major* animal phyla in terms *of the number of species. Chordates are believed to have descended from* ***echinoderm larvae-like ancestors*** *during the Precambrian period. Chordates include* ***protochor-dates*** *(tunicates. lancelets) and* ***vertebrates*** *(cyclostomes, fishes,* amphibians, reptiles, ares and mammals). Most *of them are aquatic and some are amphibious or terrestrial* animals. Though they *exhibit variation in the size and shape of their bodies, they display similarity in their basic body plan. The first and the second largest of the living animals, namely blue whale* ***(Balaenoptera musculus*** - a marine mammal) and *whale shark* ***(Rhinodon typus)*** *are members of the phylum Chordata.*

The four principal hallmark characters of Chordata

1. Notoohord: It is a flexible rod like structure situated along the mid dorsal line between the gut and the nerve cord. It is the first part of the endoskeleton to appear in the embryo. It is derived from the embryonic **chorda mesoderm.** It is made up of a core of 'Vacuolated cells' surrounded by an inner thick **fibrous** and an outer thin **elastic** connective tissue sheaths. It is persistent throughout their life in the **lancelets** and **cyclostomes.** It is present in the tail of the tadpole larva of an **ascidian** which is lost in its adult stage due to **retrogressive metamorphosis**. It is present in the embryonic stages, but is replaced partly or wholly by the vertebral column in the adults of higher chordates. Remnants of notochord occur as **nuclel pulposi** in the **intervertebral discs** of mammals.(Figure 4.1)

2. Dorsal tubular nerve cord: A single, hollow tubular and fluid filled nerve cord is situated above the notochord and below the dorsal body wall. It is **non-ganglionated,** unlike that of the non-chordates. It is produced in the embryonic stage by the 'sinking in' of the median dorsal strip of **ectoderm** above the **notochord.** In the higher chordates, it gets enlarged to form a distinct **brain** at the anterior end and the rest of it becomes the **spinal cord.**

3. Pharyngeal slits or clefts: Pharyngeal slits are a series of lateral perforations in the wall of the pharynx through which water flows out from the pharyngeal cavity. They are **ecto-endodermal** in origin. They are persistent throughout the life in the protochordates, fishes and some amphibians. The walls of the pharyngeal slits develop vascular lamellae to become 'gills' (branchiae) and are helpful in the exchange of respiratory gases. They are present in the larval stages, but are absent in the adults of many amphibians. Among the amniotes, non-functional pharyngeal pouches appear in the early embryonic life and disappear later. The occurrence of such structures in the early embryos of amniotes provides a clue to their 'aquatic ancestry'.

4. Post - anal tail: Chordates have a tail extending posterior to the anus. It is lost in many species during the late embryonic development. It contains skeletal elements and muscles. However, coelom and visceral organs are absent in it. It provides the propelling force in the locomotion of many aquatic species and acts as a 'balancing organ' in some terrestrial forms such as Kangaroos. Chordates share **deuterostomeate condition, radial** and **indeterminate** cleavage and **enterocoelom** with the echinoderms.

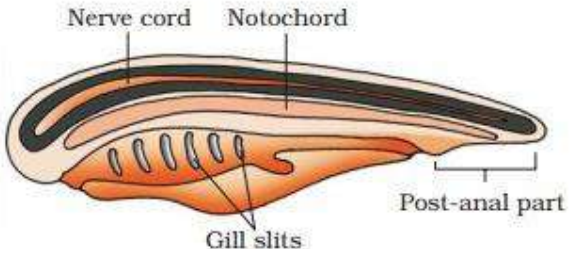


Fig 4.1 Typical chordate

Other chordate Characterts

Bilateral symmetry, triploblastic condition, organ- system level of organisation, metamerism, cephalisation, 'enterocoelic' coelom (except in the higher chordates in which it is secondarily schizocoelic), 'complete' digestive tract, closed circulatory system, ventral 'myogenic' heart (except in the lancelets), phosphocreatine (muscle phosphagen), etc., constitute the other important features of the chordates. Phylum Chordata is divided into three subphyla: **Urochordata or Tunicata, Cephalochordata and Vertebrata.** Urochordata and Cephalochordata are together referred to as **'protochordates'.**

4.1.1 Pisces (L. *piscis*- fish)

Fishes, the *'first jawed vertebrates', are completely aquatic and gill breathing animals. The extinct jawless fishes, the* ***ostracoderms*** *gave rise to the earliest jawed fishes during the* **Silurian** *period.* ***Devonian*** *period is considered the* ***'Golden age of fishes',*** *because they emerged as the predominant group during that time. They constitute the most* ***diverse and largest*** *vertebrate group. They show variation in their body size, shape, and colour. They are one of the economically most important animal groups to mankind.* ***Coelacanths*** *(marine) and* ***Dipnoi*** *(fresh water) are the extant lobe finned fishes.* ***Sharks, rays and ray-finned fishes*** *account for the bulk of living fishes. Osteolepid fishes which are of the same group as Latimeria are believed to be in the line of evolution of the next higher group of vertebrates. The study of fishes is known* ***as Ichthyology.***

General characters

* Fishes are completely aquatic poikilothermic (cold blooded) animals.
* Body of a fish is usually streamlined and differentiated into head, trunk and tail.
* Exoskeleton consists of mesodermal scales or bony plates. A few are scaleless.
* Endoskeleton may be cartilaginous or bony. Skull is monocondylic. Vertebrae are **amphicoelous** (centrum is concave at both anterior and posterior faces).
* Locomotion is assisted by unpaired (median and caudal) fins along with paired (pectoral and pelvic) fins.
* Mouth is **ventral** or terminal. Teeth are usually **acrodont, homodont** and **polyphyodont.**
* Exchange of respiratory gases is performed by the **gills.** Heart is 'two chambered' and is described as **branchial heart'** as it supplies blood only to the gills. The circulation is single circulation as blood reaches the heart only once, in the course of each circulation, making the heart a **'venous heart'** (heart receives only venous/ deoxygenated blood from the body parts).
* Kidneys are **mesonephric.** Fishes are mostly **ammonotelic** and some are **ureotelic** (cartilaginous fishes).
* Cranial nerves are 10 pairs. **Meninx primitiva** is the only 'meninx' enveloping the central nervous system.

* Internal ear consists of three semicircular canals. **Lateral-line sensory system** (to detect movement and vibration in the surrounding water) is well-developed. Eyes are without eyelids and each eye ball is protected by a **nictitating membrane.**
* Sexes are separate. Fertilization is internal or external. Development may be direct or indirect.

Pisces include two extant classes i.e. **Chondrichthyes and Osteichthyes.**

4.1.2 Class - Chondrichthyes

(Gr. ***chondros-*** cartilage; ***ichthys-***fish)

They are marine fishes which possess cartilaginous endoskeleton. Caudal fin is **heterocercal** (asymmetrical both externally and internally). Skin is covered by dermal **placoid** scales also called 'dermal denticles'. Teeth are modified placoid scales which are backwardly directed. Sharks are highly predaceous. Respiratory gaseous exchange is performed by five to seven **lamelliform** gills, without operculum, on each side. Air bladder is absent, and so they have to swim constantly to avoid sinking (bony fishes have 'air bladder' acting as a 'hydrostatic organ' helping the fish float easily at the desired level without much expenditure of energy). Cartilaginous fishes are **ureotelic** and store urea in their blood to maintain osmotic concentration of body fluids (physiological uraemia). In males, pelvic fins bear **claspers** to facilitate internal fertilization. They are mostly **viviparous**.(Figure 4.2).

e.g. *Scoliodon* (dog fish), *Prisris* (saw fish), *Carcharodon* (great white shark), *Dasyatis / Trygon* (sting ray; possesses poison sting), *Torpedo* (electric ray; dorsal muscles are modified into electric organs), *Sphyrna* (hammer - headed shark).

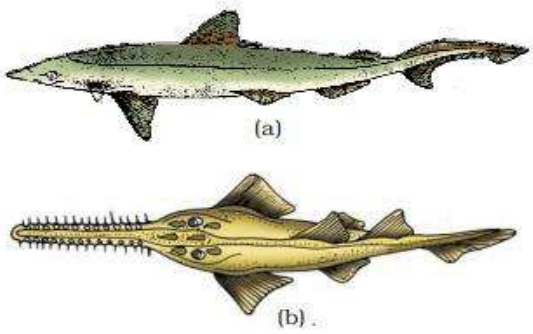


Fig 4.2 (a) *Scoliodon* (b) *Pristis*

4.1.3 Class - Osteichthyes (Gr. *osteon-* bone; *ichthys- fish)*

They are bony fishes which live in all kinds of aquatic habitats. Caudal fin is **homocercal** (symmetrical externally and asymmetrical internally) in **teleost fishes** and **diphycercal** (symmetrical both externally and internally) in lung fishes and *Latimeria.* Exoskeleton is in the form **of cosmoid, ganoid, cycloid or ctenoid scales.** Mouth is usually **terminal.** Respiratory gaseous exchange is performed by four **filamentous gills** covered by an **operculum.** on each side. An air bladder is present with or without connection to the gut. It is either helpful in gas exchange (lung fishes) or in maintaining buoyancy (hydrostatic function) in most of the 'ray-finned' fishes. They are mostly **ammonotelic.** Sexes are separate. Fertilization is generally external. Most forms are **oviparous.** (Figure 4.3)

Examples : *Exocoetus* (flying fish), *Hippocampus* (sea horse; male has a brood pouch), *Catla* (katla), *Labeo* (Rohu). *Glorias* (magur). *Bettasplendens* (Siamese fighting fish), *Pterophyllum* (angel fish). *Echeneis* (suker fish).

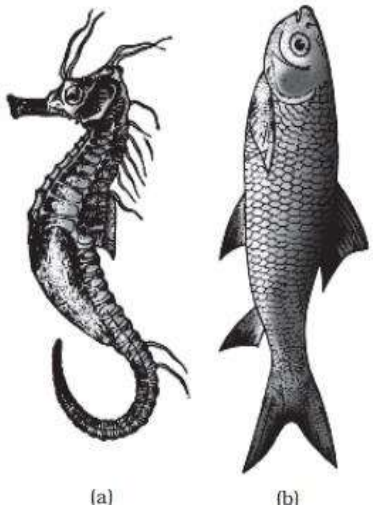


Fig 4.3 (a) *Hippocampus* (b) *Catla*

4.1.4 Class - Amphibia (Gr. amphi-both; bios-life)

Amphibians *are the first vertebrates to come out of water and 'walk' on land. They are the tetrapods which have the ability to live in the aquatic habitat of their ancestors.* the *fishes (osteolepids) and in the terrestrial habiiai that they* first invaded. They flourished *during the* ***carboniferous period.*** *They could not become completely terrestrial* animals as they are *still tied to* ***aquatic habitat for reproduction and development*** *(because the eggs of amphibians dry out quickly if laid on land and they do not have a 'shell'* to suit the hard *surface on land). The living* amphibians are ***anurans*** or ***salientians*** *(frogs and toads),* ***urodeles/caudates*** *(salamanders* and newts) and apodans (caecilians / blind worms). The *study of amphibians is known as* ***batrachology.***

General characters

* They are the **first tetrapods** and lead a **dual mode of life**. i.e. on land and in freshwater.
* Body is divided into distinct **'head'** arm '**trunk**'- Tail may or may not be present.
* Skin is **soft, scale-less** (except the members of Apoda), **moist** and **glandular.**
* The body bears two pairs of **equal** or **unequal pentadactyle** limbs (caeciiians are limbless)
* Skull is **dicondylic** as in mammals. Vertebrae are mostly **precoclous** (centrum is concave at its anterior face only) in the anurans. **amphicoelous** in the caecilians and usually **opisthocoelous** (centrum is concave at its posterior face) in the urodeles. **Sternum** appeared for the first time in the amphibians.
* Mouth is large; teeth are **acrodont. homodont** and **polyphyodont.**
* Respiratory gaseous exchange is mostly **cutaneous, pulmonary** and **bucco-pharyngeal** respirations also occur. Branchial respiration is performed by larvae and some adult urodeles.
* Heart Is three-chambered with **sinus venosus** and **conus arteriosus.** Three pairs of aortic arches and well-developed portal systems are present; erythrocytes are nucleate.
* Kidneys are **mesonephric; ureotelic.**
* Meninges are the inner **piamater** and outer **duramater:** cranial nerves are 10 pairs.

* Middle ear consists of a single ear ossicle, the **columella auris** which is the modified **'hyomandibula'** of the fishes. **Tympanum, lacrimal** and **harderian** glands appeared for the first time in the amphibians.
* Sexes are separate and fertilization is mostly external. Development is mostl; indirect. **e.g.** *Bufo* (toad), *Rana* (frog), *Hyla* (tree frog). *Salamandra* (salamander), *Ichthyophi* (limbless amphibian), *Rhacophorus* (flying frog). (Figure 4.4)

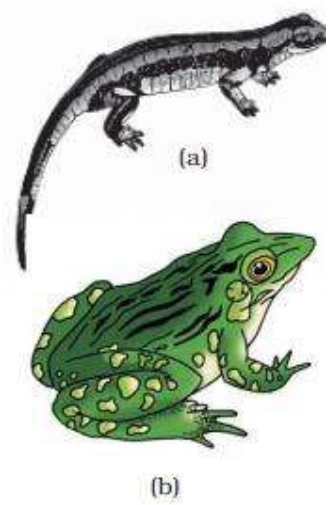


Fig 4.4 (a) Salamandra (b) Rana

4.1.5 Reptilia (L. *reptilis* - creeping)

Reptiles are ectothermic (organisms that regulate their body temperature largely by exchanging heat with their surroundings; cold-blooded) amniotes. The extinct ***labyrinthodont*** *amphibians gave rise to reptiles during the carboniferous period. They emerged as the dominant vertebrate group during the* ***Mesozoic era*** *(Golden age of reptiles). Most reptiles lay water tight* ***'cleidoic'*** *eggs (covered by porous calcareous shell - to allow the passage of air to provide oxygen) on land with extra embryonic membranes namely* ***amnion, allantois, chorion*** *and* ***yolk sac,*** *which make the egg an independent 'life support system'. Thus, the* ***'amniotic egg'*** *helped the reptiles to abandon ties with their ancestral aquatic habitat. In addition to cleidoic eggs, the evolution of 'dry scaly skin' to prevent water loss, two pairs of pentadactyl limbs with clawed digits for moving on land, pulmonary breathing and internal fertilization are the key adaptations that led to the success of reptiles. The class reptilia includes the extinct* ***dinosaurs*** *(terrible lizards) and the extant* ***chelonians, crocodilians, snakes, lizards*** and ***Sphenodon.*** *The study of poikilothermic tetrapods is called* ***herpetology.***

General Characters

* They are the first true terrestrial, usually creeping or burrowing, amniotic tetrapods.
* Body is divided into **head, neck, trunk and tail.**
* Skin is rough and dry. The exoskeleton occurs in the form of horny epidermal **scales, shields, and claws** (which appeared for the first time in reptiles).
* Dentition is **acrodont, homodont and polyphyodont** (thecodont in crocodiles as seen in the mammals). Chelonians are 'edentate'.
* Skull is **monocondylic** and many have **temporal fossae**. Each half of the lower jaw is formed by **six bones.** Vertebrae are mostly **procoelous.** The first two cervical vertebrae

are specialized into **atlas** and **axis** to facilitate independent movement of the head from the rest of the body; sacral vertebrae are **two** in number.

* The exchange of respiratory gases takes place only through lungs. They use **ribs and intercostal muscles** in ventilation (this feature developed in the reptiles for the first time in the vertebrate evolution). In turtles, gaseous exchange takes place through the **vascular cloacal wall**.
* Heart is incompletely four-chambered, except in the crocodiles, in which the heart is four-chambered. **Sinus venosus** is present but **conus arteriosus** is absent. The three aortic arches arise directly from the ventricle. Erythrocytes are nucleate.
* Kidneys are **metanephric. Mesonephric duct** (Wolffian duct) of the embryo functions as 'vas deferens' in the males. They are **'uricotelic'** (uricotelism is an adaptation to conserve water).
* Cranial nerves are 12 pairs, except in the snakes (10 pairs)
* **Tympanic membrane** is found at the inner border of the external auditory meatus. Middle ear has a single ear ossicle called **columella auris.** **Jacobson's organs**, the specialized olfactory structures, are highly developed in **lizards and snakes.**
* Males usually possess a muscular copulatory organ, except in the rhynchocephalians. Lizards and snakes have a pair of **hemipenes** (penis is formed by the apposition of the two hemipenes).
* Cloaca is three-chambered as seen in birds. They are the anterior **coprodaeum.** middle **urodaeum** and posterior **proctodaeum.**
* Fertilization is internal; mostly oviparous (some snakes are viviparous). Eggs are **megalecithal and cleidoic.** Cleavage is **meroblastic and discoidal.** During development, extra embryonic membranes are formed as in the other group of sauropsids and mammals. (Figure 4.5)

The extant reptiles are grouped into four orders

1. Chelonia : *Chelone* (marine green turtle), *Testado* (terrestrial form), *Trionyx* (fresh water form)
2. Rhynchocephalia : *Sphenodon* (a 'living fossil', endemic to New Zealand)
3. Crocodilia : *Crocodylus palustris* (Indian crocodile or maggur), Alligator (alligator), *Gavialis gangeticus* (Indian gavial or gharial)
4. Squamata :
a) Lizards : *Hemidactylus* (wall lizard), *Chameleon, Draco* (flying lizard)

b) Snakes :

i) Poisonous snakes : Naja naja (cobra), *Ophiophagus hannah* (King cobra), *Bungams* (krait), *Daboia / Vipera russelli* (chain viper)

ii) Non-poisonous snakes : *Ptyas* (rat snake), *Tropidonotus* (grass snake or pond snake)

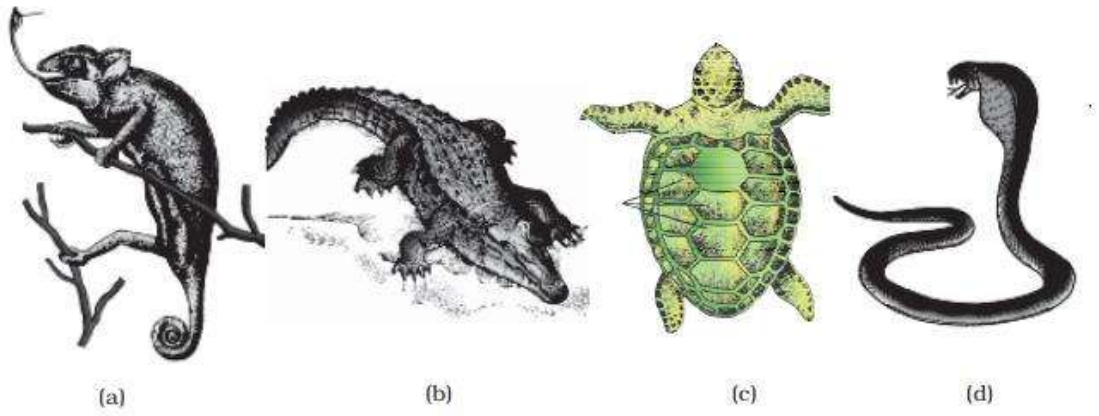


Fig 4.5 (a) *Chameleon* (b) *Crocodilus* (c) *Chelon* (d) *Naja*

4.1.6 Class - Aves (L. avis-bird)

The class Aves includes a few extinct and a large number of extant birds. They are feathered, bipedal endothermic vertebrates. Modem flying birds have undergone modifications in their morphological anatomical and physiological features as adaptations to suit their aerial mode of life. Feathers, wings powerful breast musculature, ***pneumatic bones,*** *endothermy, with high metabolic rate, keen sense of vision, etc., are the major 'flight adaptations' which enabled them to evolve as* ***'the masters of air' (J. Z. Young).***

The presence of typical reptilian characters such as epidermal ***scales on legs, presence of interclavicle, uricotelism, megalecithal eggs, development with the four extra embryonic membranes*** *in modem living birds, convinced* ***T. H. Huxley*** *to describe them as* ***"Glorified reptiles****'. The demands of flight paved the way for the evolution of a similar general body form in many flying birds.* ***Theropods*** *of the* ***Jurassic Period*** *gave rise to birds which got modernised in the* ***Cretaceous Period.*** *The study of birds is* ***known as ornithology.*** ***Dr. Salim Ali*** *is a world famous* ***Indian ornithologist*** ('Bird man of India').

General Characters

* Body is streamlined and is distinguished into **head, neck, trunk** and **rudimentary tail.**
* The fore limbs are modified into 'wings' and hind limbs are adapted for walking, running, swimming, perching (sitting on a branch) etc.
* Skin is dry and devoid of glands, except the oil or **preen gland** or **uropygial gland** at the base of the tail.
* Exoskeleton consists of epidermal feathers (a unique feature), scales on legs, claws on toes and horny covering on the beak **(rhamphotheca).**
* Endoskeleton is fully ossified. Long bones are hollow with air cavities (pneumatic). Skull is **monocondylic.** Vertebrae are heterocoelous. The last thoracic, lumbar, sacral and anterior few caudal vertebrae are fused to form a **synsacrum.** It is fused with pelvic girdle to provide support to hind limbs. A few posterior most caudal vertebrae are fused to form the **pygostyle** that provides support to the tail **feathers.** Sternum has a **keel/carina** for the attachment of flight muscles (except in the ratite birds). Both the clavicles are fused with the interclavicle to form a 'V - shaped bone, called **furcula** or'

wish bone' or' **Merry thought bone'**. Ribs are **double headed** as in the crocodiles and therian mammals.

* All modern flying birds are provided with powerful **breast muscles** (flight muscles), chiefly the **pectoralis major and pectoralis minor.**
* **Teeth are absent** in the extant birds. Oesophagus is often dilated into a crop for the storage of food. Stomach is usually divided into glandular **proventriculus** and muscular **gizzard** (grinding mill). Cloaca is **three chambered** as in reptiles.
* Respiratory system consists of compact, spongy, undistensible lungs 'without alveoli'. The lungs are associated with **air sacs.** Air sacs facilitate 'continuous oxygenation' of blood and 'pneumaticity' of bones (a unique feature). Voice box is **syrinx** that lies at the junction of the trachea and bronchi.
* Heart is four chambered. **Sinus venosus** and **conus arteriosus** are absent as in mammals. Only **right systemic arch** is present. **Renal portal system** is reduced. Erythrocytes are nucleate as in reptiles.
* Kidneys are **metanephric and three-lobed.** Urinary bladder is absent[7] except in ostrich. Birds are **uricoteiic** like the reptiles.
* Brain is large. Olfactory lobes are reduced. Cranial nerves are 12 pairs.
* Eyes possess **sclerotic plates.** A comb shaped vascular 'pecten' projects from the retina into the **vitreous humour** (except in kiwi). Middle ear has a single ear ossicle, the **columella auris.** Olfactory sense is usually poor, except in kiwi.
* Sexes are separate. Testes are paired, but the ovary and oviduct of the right side are almost completely atrophied in a **mature female.** Copulatory organ is absent in males except in **ratites, ducks, geese, etc.**

All birds are oviparous, Eggs are megalecithal and cleidoic. Fertilization is internal. Cleavage is Meroblastic and discoidal as in reptiles. Hatchlings are 'altricial' in the flying birds and 'precocial' in the flightless birds. (Figure 4.6)

e.g. *Corvus* (crow), *Columba* (pigeon), *Psittacula* (parrot), *Pavo* (peafowl; National bird of india), *Aptenodytes* (penguin), *Neophron* (vulture). *Coracias benghalensis* (blue jay; State bird of A.P.), *Struthio* (Ostrich)

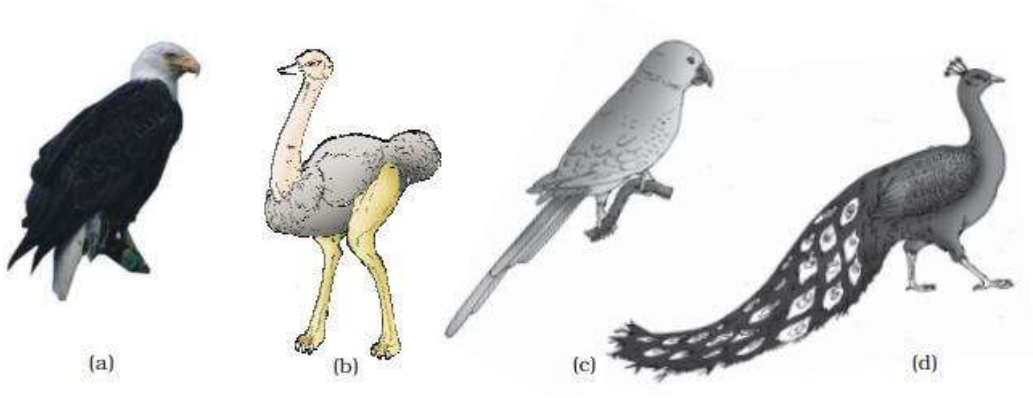


Fig 4.6 (a) *Neophron* (b) *Struthio* (c) *Psittacula* (d) *Pavo*

4.1.7 Class - Mammalia (L. mamma-breast)

Class mammalia consists of extinct and extant animals including humans. They are hairy, homeothermic amniotes. They nourish their young with milk secreted by specialised mammary glands from which the word 'mammalia: was coined. They show lot of variations in size and shape. The smallest of all the mammals is the recently discovered ***ketti's hognosed bat I 'Bumblebee bat'*** *in Thailand (weight- 2gms) and the biggest is* ***Balaenoptera musculus*** *(blue whale) weighing more than 130 tons. Extinct 'mammal like'* ***therapsid reptiles*** *gave rise to the early mammals in the* ***Triassic period. Coenozoic era*** *is referred to as* ***'the age of mammals'*** *as they became the predominant tetrapod group during this era. Mammals fall under three categories namely* ***monotremes*** *(egg laying mammals),* ***marsupials*** *(pouched mammals) and* ***eutherians*** *(true placentals). Intelligence and 'parental care' have reached their climax in mammals. The study of mammals is known as* ***mammalogy.***

General characters

* The body is divided into head, neck, trunk and tail.
* Body is covered by hair, which is one of the unique characters of mammals. Hair is reduced in **whales, armadillos** etc. Hair is present at least in some stage of development in all mammals.
* Skin is glandular and consists of **sweat glands** (sudoriferous), **scent glands** and **sebaceous** glands. **Mammary glands** are modified sweat glands.
* Skull is **diconidylic.** Each half of the lower jaw consists of a 'single' bone, the **dentary**. Most mammals have **seven cervical vertebrae,** six in *Choloepus* (two-toed sloth) and *Trichechus* (manatee) and nine in *Bradypus* (three-toed sloth). Sacral vertebrae are **two** to **five.** Vertebrae are of the **amphiplatyan** type (centrum is flat at both faces). Ribs are double-headed.
* Buccal cavity is separated from the upper nasal cavity by a secondary palate. Teeth are **thecodont, heterodont** and **diphyodont.** Four pairs of salivary glands are present in association with the buccal cavity (3 pairs in man).
* Respiratory gaseous exchange occurs through lungs. Glottis is guarded by **epiglottis. Larynx** is the sound-producing organ.
* Heart is four-chambered. Oxygenated and de-oxygenated types of blood are completely separated. Only the left systemic arch is present. **Renal portal system** is absent. Mature RBC is circular, biconcave and **enucleate.**
* Mammals have a relatively large brain when compared to that of other animals in relation to body size. The four optic lobes constitute **corpora quadrigemina.** The two halves of cerebrum are connected by **corpus callosum.** The CNS is enveloped by three meninges. The middle menix called **arachnoid membrane.** is present in mammals only. Cranial nerves are twelve pairs.
* Eyes have movable eye lids with 'eye lashes'. External ear has a large fleshy and cartilaginous flap called **pinna.** Middle ear possesses three ear ossicles. They **are malleus, incus** and **stapes. Cochlea** of the internal ear is **spirally coiled** and bears the **'organ of Corti** which is the receptor of sound.
* Functional kidneys are bean shaped and **metanephric.** Nephron has **loop of Henle** which helps in the formation of concentrated urine. Mammals are'ureotelic'.
* Sexes are separate. Sexual dimorphism is generally well-marked. Testes are usually found in scrotal sacs outside the abdomen. Intra-abdominal testes are found in the

monotrernes, cetaceans (whales and dolphins), **sea cows, elephants,** etc. Males have copulatory organ called penis.

* Fertilization is internal. Mammals, except the monotremates, are viviparous. Development is intra-uterine. Developing embryo is attached to the uterine wall of the mother by a **placenta,** for nutrition and respiration (absent in the monotremes). (Figure 4.7)

Examples

Ornithorhynchus (duckbilled platypus), *Macropus* (Kangaroo), *Pteropus* (flying fox), *Camelus* (camel). *Macaca* (monkey), *Rattus* (rat). *Canis* (dog), *Felis* (cat), *Elephos* (elephant), *Equus* (horse), *Delphinus* (common dolphin), *Bclaenoptera* (blue whale), *Panthera tigris* (tiger: National Animal of India). *Panthera leo* (lion), *Antelope* (state animal of A.P)

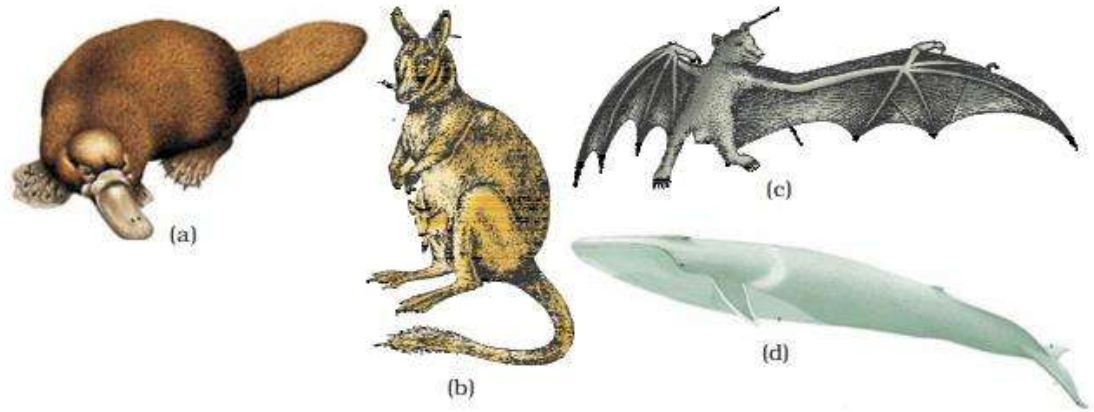


Fig 4.7 (a) *Ornithorhynchus* (b) *Macropus* (c) *Pteropus* (d) *Bclaenoptera*

4.2 *Rana tigrina*

Class : Amphibia
Order : Anura/ Salientia
Family : Ranidae

The body of frog is somewhat spindle shaped and slightly flattened dorsoventrally. Skin of frog is **thin, scaleless** and **moist.** It is attached loosely to the underlying muscles at certain points only. The skin on the dorsal surface is generally olive-green with irregular dark spots. On the ventral surface, the skin is uniformly pale yellow. Frog never drinks water but absorbs it through the skin.

Body Divisions

The body of a frog is divisible into **head and trunk.** The neck and tail are absent. Above the snout, a pair of external nostrils is present. The eyes are bulged and covered by a nictitating membrane that protects them while in water. Behind each eye, a membranous tympanum (ear drum) receives sound waves. The forelimbs and the hind limbs help in swimming, walking, leaping and burrowing. The hind limbs bear five digits each. They are larger and more muscular than the forelimbs, which bear four digits. Feet have webbed digits and the web helps in swimming.

Frog exhibits sexual dimorphism. Male frog can be distinguished by the presence of sound amplifying **vocal sacs** and also a **copulatory pad** on the first digit of each forelimb (copulatory pads are absent in female frogs).

Coelom and Viscera

The body cavity/coelom of frog accommodates different internal organs **or viscera.** which are covered by visceral peritoneum.

Blood Vascular System

The blood vascular system consists of the heart, blood vessels and blood. The heart is a muscular organ situated in the upper part of the body cavity. It has two separate atria and a single undivided ventricle. It is covered by a double layered membrane called **pericardium**. A triangular chamber called **sinus venosus** joins the right atrium on the dorsal side. It receives blood through three **vena cavae** (caval veins). The ventricle opens into the **conus arteriosus** on the ventral side. The conusarteriosus bifurcates into two branches and each of it divides into three aortic arches namely **carotid, systemic and pulmocutaneous.** Blood from the heart is distributed to all parts of the body by the branches of aortic arches. Three major veins collect blood from the different parts of the body and carry it to the sinus venosus.

Portal Systems: Special venous connections between the intestine and liver as well as lower parts of the body and kidneys are present in frog. These are called hepatic and renal portal veins, respectively.

Blood: Blood is composed of plasma and cells. The blood cells are **erythrocytes, leucocytes** and **thrombocytes.** RBCs are nucleate. WBCs are nucleated amoeboid cells which help in defence. Thrombocytes help in **haemostasis** (stopping of bleeding).

Lymphatic system: In addition to the blood vascular system, frog has lymphatic system. The lymphatic system consists **of lymph, lymph channels and lymph nodes.** The lymph is different from blood. It lacks RBC's and contains a few proteins. (Figure 4.8)

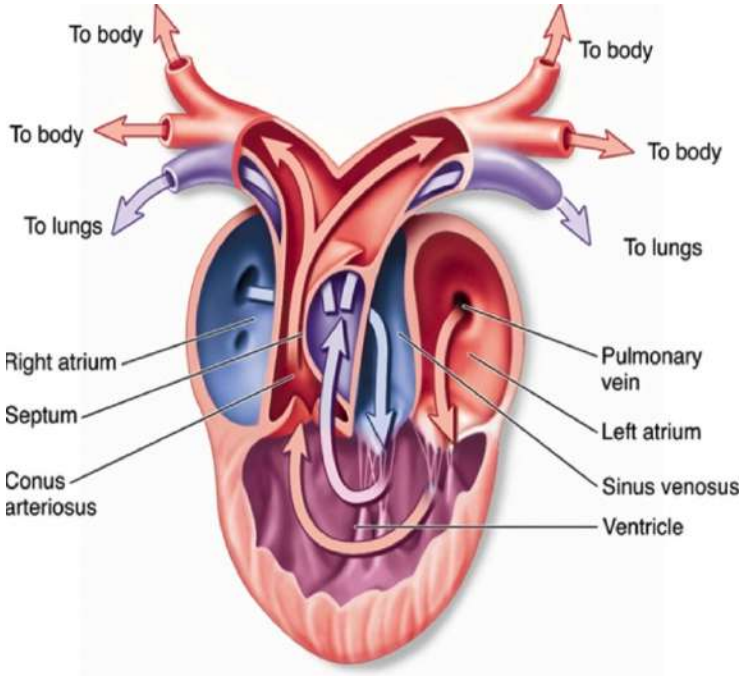


Fig 4.8 Structure of Frog heart

Reproductive System

The male reproductive system consists of a pair of yellowish and ovoid testes, which are attached to the kidneys and dorsal body wall by a double fold of peritoneum called **mesorchium.** Each testis is composed of innumerable **seminiferous tubules** which are connected to form 10 to 12 narrow tubules, the **vasa efferentia.** They enter the kidneys and open into the **Bidder's canal** which is connected to the ureter through transverse canals of the kidney. The urino-genital ducts of both the sides open into the cloaca.

The female reproductive system consists of a pair of ovaries, oviducts and cloaca. The ovaries are attached to the kidneys and dorsal body wall by a double fold of peritoneum called **mesovarium.** The ovaries have no functional connection with the kidneys. The oviducts are two long, white and convoluted tubes. Their anterior ends form funnel-like openings called Ostia. The posterior ends of oviducts enlarge into **ovisacs** before they open into the cloaca separately. (Figure 4.9)

During **amplexus,** the mass of eggs and the mass of sperms released by the female and the male are called **spawn and milt** respectively. Fertilization is external and takes place in water. Development involves an aquatic gill breathing, herbivorous larval stage called **tadpole,** which metamorphoses into an air breathing, carnivorous adult frog. Tadpole of frog resembles *a* fish pertaining to taking in water and respiring through gills·

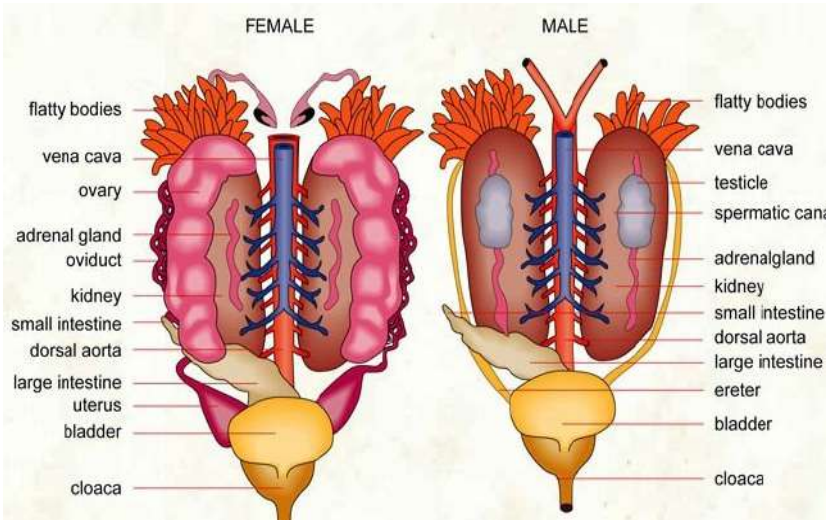


Fig 4.9 Frog: Female and male reproductive system

GLOSSARY
CHORDATA
Atrium: One of the chambers of the heart.
Creatine phosphate: A high energy phosphate compound , found in the muscles of vertebrates and some invertebrates, used to regenerate ATP.
Endostyle: A longitudinal cilated groove present on the ventral wall of the pharynx of tunicates.
Filter feeding: The feeding process by which particulate food is filtered by ciliary action from the water from which it is suspened .
Mesonephros: The functional kidney of adult fishes, amphibians and embryos of ' amniotes'.
Pelagic animals: Animals living on the open oceans or seas.

Portal system: A system of larger veins beginning and ending in a plexus of capillaries e.g. hepatic and renal portal system of vertebrates.
Retrogressive metamorphosis: Metamorphosis of a larva with advanced characters into a degenerate adult.
Solenocyte: It is a tubular terminal flame cell like structure of protonephridium.

PISCES

Acrodont: Having teeth attached to the edge of the jawbone without sockets.
Claspers:they formed from the posterior portion of pelvic fins in male cartilaginous fish. They serve as intromittent organs used to channel semen into the female cloaca during mating.
Coelocanth: An ancient , extant bony fish which was thought extinct until 1938.
Ctenoid scales: A fish scale having marginal projections that resemble the teeth of comb, found in many teleost fishes.
Cycloid scale: A fish scale which is thin and shows concentric lines of growth, found in lung fishes and some teleost fishes.
Dipnoi: They are agroup of fish commonly known as 'lung fish', their lungs being modified bladders.
Ganoid scales: Thick, bony scale of some primitive bony fishes.
Ostracoderms: Extinct Palaeozoic fishlike jawless vertebrates, characterised by armoured body.
Placoid scales: The type of scales found in cartilaginous fishes, with a basal plate of dentine embedded in the skin.
Polyphyodont: A type of dentition in which the teeth are naturally shed many times and replaced during the lifetime of vertibrates.

AMPHIBIA

Alveolus: A small cavity or pit, such as microscopic air sac of the lungs.
Amplexus: The copulatory embrace of frogs or toads during which the male and female shed their gametes.
Chyme: Semifluid mass of partially digested food formed in the stomach.
Columella auris: A small rod like bone in the middle ear of frogs, reptiles and birds that transmit sound to inner ear.
Conus artiriosus: It is a single wide arterial vessel leaving the ventricle and passing ventrally over the right atrium.
Dura mater: It is a outermost membrane of the brain and spinal cord.
Harderian gland : A gland associated with eye that secrets fluids.
Labyrinthodontia: A group of extinct amphibians typically resemblesheavy bodied salamanders and crocodiles.
Lacrimal glands: These are paired glands, one in each eye. They secrete tears.
Piamater: It is the delecate, Inner most and vascularised membrane enveloping the brain and spinal cord.
Sinus venosus: An enlarged region between the vena cavae and the right atrium.

REPTILIA

Allontois: It is one of extra embryonic membrane of the amniotes.It poarticipates in respiration and excretion in sauropsids and also in the formation of placenta in most of the

therians.
Amnion: It is the inner most of the extra embryonic membranes. It is afluid filled sac enclosing the embryo in the amniotes.it is protective in function.
Chorion: It is outer most extra embryonic membrane that surrounds the embryos of amniotes. It participates in the formation of placenta.
Hemipenis: It is one of the pairs of intromittent organs of male squamates.
Meroblastic cleavage: It is the partial cleavage which occurs in the megalecithal eggs.
Metanephros: It is the functional kidney of adult amniotes.
Temporal fossae: These are shallow deprssions in the temporal regions of the scull of many reptiles:

AVES

Altricial hatchlings: It is the hatchlings of carinate bird which is incapable of moving around on its own soon after hatching.
Heterocoelous vertebra: It is the type vertibra in which the articulating surfaces of teh vertebral centrum are 'saddle-shaped'.
Pectin: It is a comb like process that projects from retena of birds and some reptiles.
Precocial young: It is a hatchling of ratite bird, which is capable of moving around on its own soon after hatching.

MAMMALIA

Cochlea: A tubular cavity of the inner ear containing the essential organs of hearing occurring in crocodiles, birds and mammals.
Diphyodont dentition: It is the type of dentition in which two sets of teeth are formed. They are deciduous and permanent sets of teeth replace the milk teeth.
Heterodont dentition: it is the type of dentition in which teeth are differentiated into cutting, tearing, and grinding teeth.
Placenta: The vascular structure, formed from embryonic and maternal tissue, through which the embryo and foetus are nourished.
Sebaceous glands: These are a type of mammalian epidermal glands associated with hair follicles. They secrete sebum which keeps the skin and hair smooth and lustrous.

VERY SHORT ANSWER QUESTIONS

1. What is the importance of air bladder in fishes?
2. How does the heart of an Amphibian differ from that of a reptile?
3. How do you distinguish a male frog female frog?
4. Name one poisonous and one non poisonous snake found in South India?
5. What is Jacobson's organ? What is their function?
6. What is a pneumatic bone? How do they help birds?
7. Distinguish between Altricial and Precocial hatchlings ?

SHORT ANSWER QUESTIONS

1. Compare and contrast cartilaginous and bony fishes?
2. Write eight salient features of the class Amphibia ?
3. List out the extant orders of class reptilia? Give one example for each order?
4. What are modifications that are observed in birds that help them in flight?
5. What are the features peculiar to raite birds? Give two examples?
6. Write the generic names of the following?
   a) An oviparous mammal
   b) Flying fox
   c) Blue whale
   d) Kangaroo.
7. Describe the structure of the heart of the frog with neatly labeled diagram?

Unit 5

BIOLOGY IN HUMAN WELFARE

SUMMARY

At least one-third of all animal species are estimated to be parasites according to one estimation. In ancient Greece, a person, who flattered and amused the host in return for free meals (a ***professional dinner guest),*** was used to be called a parasite.

It is stated that the single most ***'undiagnosed* health *challenge'*** in the **history** ***of the human race*** is ***'parasites'.*** More than 130 parasites are known to invade humans as hosts. As many people are not aware of the presence of certain parasites until it is too late to be helped, parasitism is described as a **'Silent *Epidemic'*. Most parasites tend to disturb the immunological system.**

Diseases such as **malaria,** ***polio, plague, amoebiasis, dengue, filariasis, taeniasis,*** are more common in the ***tropical countries.*** Due to the efforts of WHO, Small Pox was wiped out decades ago. Plague, which killed millions in the past, is almost a ***part of history now***. However malaria is still evading control. Education on personal hygiene, providing proper sanitation facilities by the local administrations, will go a long way in preventing many tropical diseases.

Did the parasite come first or the host? It is believed that certain organisms enter the body of another organism accidentally and settle in it, slowly turning into a parasite. Have you ever heard that in the course of evolution, certain ***prokaryotic organisms*** entered the bodies of ***eukaryotes*** and remained in them forever acting as integral parts of the eukaryote's cells, and even playing a vital role in the life of the eukaryote? **Can *you guess one such prokaryote?*** Did it ever occur to you that **mitochondria** could be one such type of prokaryotes?

On the other hand, the youth are getting addicted to ***drugs*** **and alcohol - an** influence of the western culture, spread by the television and movies. The harmful effects of ***tobacco*** are well publicised nowadays and the youth are sufficiently educated on that.

5.1 Parasitism

An intimate association between two organisms of different species in which, 'one is benefited and the other one is often adversely affected' is called ***parasitism.*** The word parasitism comes from a Greek word *'parasitos'* (para - at the side of; sitos -food or grain) which means *'one eating at another one's* table' The organism that obtains nourishment is called the ***'parasite'*** (the gainer) and the organism from which the nourishmer. is obtained is called the **'host'** (the loser).

5.1.1 Types of parasites

Based on the interaction between the host and the parasite, various types of parasites are recognised. Some of them are listed below.

i) Ectoparasite: A parasite that lives on the surface of the host's body is called ectoparasite.

e.g. head lice and itch mites on humans, ticks on dogs, copepods on marine fishes, etc.

ii) **Endoparasite:** A parasite that lives inside the body of the host is called endoparasite. Based on the place where they live, they are again classified into three types, namely:

a) **Cytozoic (intracellular) parasites:** They live within the host's cells.
e.g. *Plasmodium vivax* in man, Nosema *notabilis* in *Sphaerospora polymorpha,* etc.

b) **Histozoic (intercellular) parasites:** They live in between the cells of the tissues and organs of the host.
e.g. *Wuchereria bancrofti, Entamoeba histolytica,* etc.

c) **Coelozoic parasites:** They live within the cavities of the host's body. They are called enterozoic if they live in the alimentary canal,
e.g. *Ascaris liunljcoides*

iii) **Hyperparasite (Parasite In/on a parasite):** It is a parasite which lives in/on the body of another parasite,
e.g. Nosema *notabilis* (a cnidosporan parasite) lives in *Sphaerospora polymorpha* (also a cnidosporan parasite) which lives in the urinary bladder of toad fish.

iv) **Monogenetic parasite:** It is a parasite which completes its life cycle in only one host.
e.g. *Entamoeba histolytica, Ascaris lumbricoides.* etc.

v) **Digenetic parasite:** It is a parasite which requires at least two hosts to complete its life cycle.
e.g. *Plasmodium vivax, Wuchereria bancrofti,* etc.

5.1.2 Parasitic adaptations

Parasites have evolved special adaptations to meet the requirements and lead successful life in the hosts.

* In order to live in the host, some parasites have developed structures like hooks, Suckers, rostellum, etc., for **'anchoring', e.g.** *Taenia solium*
* Some intestinal parasites have developed **protective cuticle** to withstand the action of the digestive enzymes of the host. **e.g.** *Ascaris lumbricoides*
* Some intestinal parasites produce **'anti enzymes'** to neutralize the effect of host's digestive enzymes,
e.g. *Taenia solium*
* Some parasites live as **'obligatory anaerobes'** as the availability of oxygen is very rare for them.
e.g. *Entamoeba histolytica, Taenia solium,* etc.
* Some intestinal parasites live as **'facultative anaerobes'** i.e., if oxygen is not available, they live anaerobically and if oxygen is available, they respire aerobically. **e.g.** *Ascaris lumbricoides*
* The morphological and anatomical features are greatly simplified while emphasizing their **reproductive potential** For example; an Ascaris lays nearly two lakh eggs per day. *In Taenia solium* the body is divided into 700 to 900 proglottids of which each proglottid acts as a unit of reproductive system and releases approximately 35,000 eggs.
* Th Life cycles of endoparasites are more complex because of their extreme specializaiion. For example, life cycle of certain parasites like *Fasciola* hepatica (sheep liver fluke) is very complex involving many developmental stages *and* two intermediate hosts, to increase the chances of reaching a new definitive host.
* Certain parasites like *Entamoeba* develop cysts to tide over the unfavourable conditions like desiccation while reaching the new host.
* Some parasites elude production of vaccines against them (smart parasites!) as they keep changing their surface antigens form time to time.
e.g. *Plasmodium,* HIV, etc.

5.1.3 Effects of parasites on hosts

In general, the parasites cause weakening of the body of their hosts by causing the deprivation of nutrients, fluids and metabolites as they compete with their hosts for the same. They may also cause pathological effects in their hosts such as

* **Parasitic** castration: Some Prarasites cause the degeneration of gonads of the host, making it sterile. Thus effect is called parasitic **castration,**
  e.g. Socculina (root headed barnacle, a crustacean) causes the degeneration of ovaries in the crab *Carcinus maenas.*
* **Neopiasia :** Some cause an abnormal growth of the host cells in a tissue to form new structures. This effect is called **neoplasia** which leads to cancers,
  e.g. Some viruses
* **Gigantisn:** Some parasites cause ar. abnormal increase in the size of the host. This effect is called **gigantism**
  e.g. The larval stages of Fasciola hepatica cause gigantism in snail (an intermediate host)
* **Hyperplasia:** Some parasites cause ar. increase in the **number of cells.** This effect is called **hyperplasia.**
  e.g. *Fasciola hepatica* in the bile ducts of sheep
* **Hypertrophy:** Some parasites cause an abnormal increase in the **volume/size** of the infected host cells. This effect is called **hypertrophy.**
  e.g. RBC of man infected by *Plasmodium*
* Most of the parasites cause various types of diseases like
  i) African sleeping sickness by *Trypanosoma gambiense*
  ii) Delhi boils/Tashkent ulcers/Oriental sores by *Leishmania tropica*
  iii) Kala azar/Dum dum fever/Visceral leishmaniasis by *Leishmania donovani*
  iv) Malaria by Plasmodium *sps*
  v) Elephantiasis by *Wuchereria bancrqfti.*

5.2.1 *Entamoeba histolytica*

Systematic position

Phylum : Protozoa

Subphylum : Sarcomastigophora

Class : Rhizopodea.

Entamoeba histolytica (Gr: *entos* - within; *amoibe* - change; *histos* - tissues; lysis - dissolve) is a microscopic and monogenetic parasite that inhabits the large intestine and causes ***amoebic dysentery*** or ***amoebiasis*** in man. The mode of infection is through contaminated food and drinking water. House flies, cockroaches, etc., act as 'mechanical vectors'.

It is cosmopolitan in distribution but more common in the tropical and subtropical regions of the world. It is common in the people of rural and densely populated urban areas wherever the hygienic conditions are poor.

Structure

Entamoeba histolytica passes through three distinct stages in its life cycle, namely:

i) Trophozoite stage
ii) Precystic stage and
iii) Cystic stage

Trophozoite stage: - It is the most active, motile, feeding and **Pathogenic stage** that lives in the mucosa and sub-mucosa membranes of the large intestine. It moves with the help of a single blunt finger like pseudopodium called lobopodium which is produced anteriorly. The body of the trophozoite is surrounded by plasmalemma. Its cytoplasm is differentiated into an outer clear, viscous, non-granular ectoplasm and the inner fluid like granular endoplasm. Ribosomes, food vacuoles and a vesicular, **cartwheel shaped nucleus** are present in the endoplasm. However contractile vacuoles, endoplasmic reticulum, Golgi apparatus and mitochondria are absent. The absence of mitochondria indicates the ***'obligate anaerobic nature'*** of *Entamoeba* histolytica. It produces the proteolytic enzyme called histolysin due to which the species name **'histolytica'** was assigned to it. Due to the effect of this enzyme, the mucosa and sub-mucosa of the gut wall are dissolved releasing some amount of blood, tissue debris which are ingested by the trophozoites. Hence, the food vacuoles are with erythrocytes, fragments of epithelial cells and bacteria. The mode of nutrition is **holozic**. Presence of **'RBC in food vacuoles'** and cartwheel shaped nucleus are the characteristic features of the trophozoites of *Entamoeba histolytica.*(Figure 5.1)

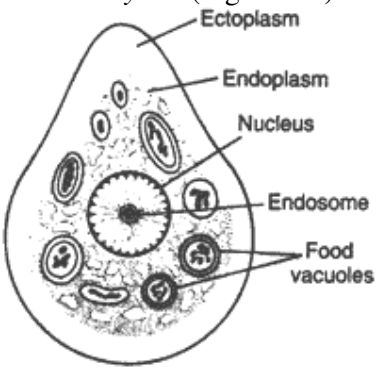


Fig 5.1 *E.histolitica* Trophozite

Precystic stage: It is the non-feeding and non-pathogenic stage of *Entamoeba histolytica* that is found in the lumen of the large intestine. It is a small, spherical or oval, non-motile form. The cytoplasm of the precystic stage stores ***glycogen granules*** and **chromatoid bars** (made of ribonucleo protein) which act as reserve food.

Cystic stage: It is round in shape and is surround by a thin, delicate and highly resistant cyst wall. It is found in the lumen of the large intestine. The process of development of cyst wall is called ***encystation*** which is a means to tide over the unfavourable conditions that the parasite is going to encounter while passing to a new host. Soon after the encystation, the nucleus undergoes two successive mitotic divisions to form four **daughter nuclei.** This type of cystic stage is called **tetra nucleate cyst** or **mature cyst** which is **'the stage infective to man'.**

Life cycle: The trophozoites undergo binary fissions in the wall of the large intestine and produce a number of daughter entamoebae. They feed upon the bacteria and the host's tissue elements, grow in size and again multiply. After repeated binary fissions, when the trophozoites increase in number, some of the young ones enter the lumen of the large intestine and transform into ***precystic stages.*** Here, the precystic stages transform into ***cystic stages*** which in turn develop into **quadrinucleate cysts/** ***tetranucleate cysts.*** The entire process is completed only in a few hours. These **quadrinucleate cysts/** tetranucleate cysts

come out along with the faecal matter and can remain alive for about 10 days. These cysts reach new host through contaminated food and water. They pass into the small intestine of a new human host where the cyst wall gets ruptured by the action of the enzyme trypsin, releasing the ***tetranucleate amoebae.*** Such tetranucleate excystic amoebae are called **metacysts,**

The four nuclei of the metacyst undergo mitotic divisions and produce eight nuclei. Each nucleus gets a bit of the cytoplasm and thus eight daughter entamoebae or **'metacystic trophozoites'** are produced. These young ones develop into feeding stages called trophozoites. They invade the mucous membrane of the large intestine and grow into ***mature trophozoites***.(Figure 5.2)

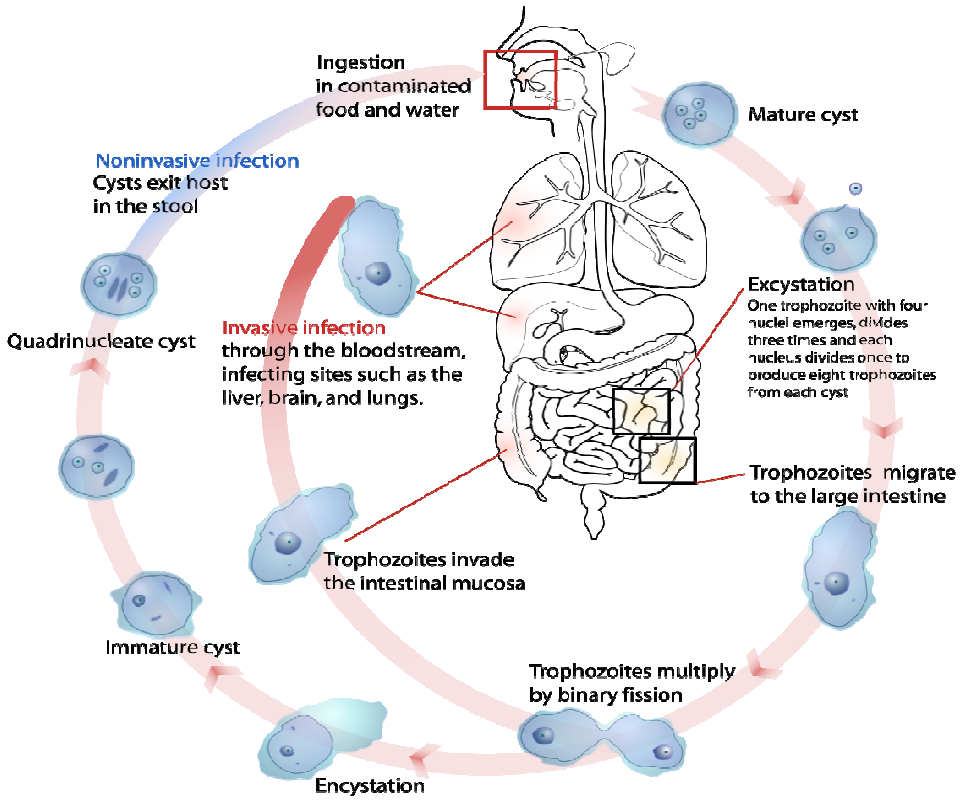


Fig 5.2 *E.histolitica* life cycle

Pathogenicity

The trophozoites 'dissolve' the mucosal lining by **histolysin,** go deep into sub mucosa and cause ulcers. These ulcers contain cellular debris, lymphocytes, blood corpuscles and bacteria. It leads to the formation of abscesses in the wall of large intestine. Ultimately it results in stool with blood and mucous. This condition is called **amoebic dysentery** or **intestinal amoebiasis** or tropical amoebiasis. Some people do not exhibit any symptoms. Such people are called ***'carriers asymptomatic cyst passers'*** as their stool contains the tetranucleate cysts. They help in spreading the parasites to other persons.

Extra-intestinal amoebiasis

Some times, the trophozoites may rupture the wall of capillaries, enter the blood stream and primarily reach the liver where they may cause 'abscesses' (some call it 'secondary amoebiasis'). From there, they may go to lungs, heart, brain, kidneys, gonads, etc., and cause abscesses in those parts leading to ***severe pathological conditions.***

Prophylaxis

The following hygienic habits help prevent spread of this disease:

i) Using boiled and filtered water
ii) Washing hands, fruits and vegetables properly
ii) Using septic tank toilets

5.2.2 Plasmodium vivax

Systematic position

Phylum : Protozoa
Subphylum :Apicomplexa (Sporozoa)
Class : Telosporea

Among the protozoans, *Plasmodium* is one of the most harmful parasites of man. It is a ***digenetic,*** **intracellular parasite** that lives in the ***liver cells*** and ***RBC*** of man. (It is **extracellular** in mosquito). Its **primary host** is the female ***Anopheles*** mosquito and the **secondary host** is man. Reservoir host is monkey. The infective stage is **sickle shaped sporozoite** and the mode of infection is **inoculation.**

Four species of *Plasmodium* cause four types of malaria in man. They are

i) *Plasmodium vivax* - benign tertian malaria
ii) *Plasmodium falciparwn* - malignant tertian malaria or cerebral malaria
iii) Plasmodium *ovale* - mild tertian malaria
iv) *Plasmodium malariae* - quartan malaria

Of all these four species, *Plasmodium vivax* is the most common and most widely distributed malaria parasite. Hence its life cycle along with pathogenicity, treatment and preventive measures are briefly described here.

History of Malaria

The term **'Malaria'** is taken from Italian language which means 'bad air' (Mala - bad; *aria* - air) as it was thought that malaria was due to foul air. ***Charles Laveran,*** a French military doctor discovered *Plasmodiwn* in the blood of a malaria patient **Sir *Patrick Manson,*** a Scottish doctor while working on elephantiasis, suggested that malaria might be spread by mosquitoes. **Sir Ronald Ross,** a British army doctor, while working in Secunderabad, Telangana State, India, identified the oocysts of *Plasmodium in* the stomach wall of female *Anopheles* mosquito on the 20th of August. In recognition of this work, Ross was awarded the ***Nobel Prize*** in 1902 and 20th August of every year is celebrated as **World *Malaria Day* or World Mosquito *Day* - *G.B. Grassi*** and others have described the life cycle of *Plasmodium vivax* in the female *Anopheles* mosquito.

Structure of sporozoite

The ultra-structure of the sporozoite of *Plasmodium vivax* was studied by **Garnham.** It is sickle shaped with a swollen middle part and pointed at both ends of its body. It measures about 15 microns in length and one micron in width. The body is covered by an elastic pellicle with **'microtubules'** which help in the wriggling movements of the sporozoite. The cytoplasm contains cell organelles such as Golgi complex, endoplasmic reticulum, mitochondria and a nucleus. Cytoplasm also shows many convoluted tubules of unknown function throughout the length of the body. It contains a cup like depression called ***apical cup*** at the anterior end into which a pair of ***secretory organelles*** opens. They secrete a cytolytic enzyme, which helps in the penetration of sporozoite into the liver cells. (Figure 5.3)

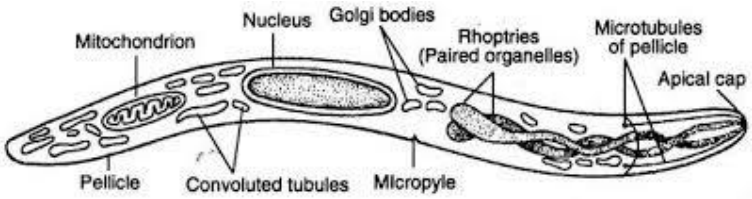


Fig 5.3 *P.vivax* sporozoite

The life cycle of *Plasmodium* is completed in two hosts as mentioned earlier.

Life cycle of Plasmodium in man (The human phase)

In man, the *Plasmodium* reproduces by asexual reproduction called **schizogony.** It occurs in liver cells (hepatocytes) as well as in RBC. In liver cells, it is called **hepatic schizogony** and in RBC it is called **erythrocytic schizogony.**

Hepatic schizogony

This was discovered **by Shortt** and **Garnham.** Whenever, a mosquito infected by *Plasmodium* bites a man, nearly 2000 sporozoites are released into the blood of man through its saliva. Within half an hour, they reach the hepatocytes where they undergo **pre-erythrocytic** and **exo-erythrocytic cycles.**

Pre-erythrocytic cycle

Whenever the sporozoites reach the liver cells, they transform into **trophozoites.** They feed on the contents of the hepatic cells, assume spherical shape and attain the maximum size. This stage is called **schizont** stage. Its nucleus divides several times mitotically, followed by the cytoplasmic divisions resulting in approximately 12000 daughter individuals called **cryptozoites** or the **1st generation merozoites.** They enter the sinusoids of the liver by rupturing the cell membrane of the schizont and the liver cells. This entire process is completed approximately in 8 days. Now these first generation merozoites have two options i.e. they can enter either fresh liver cells and continue exo-erythrocytic cycle or they can enter RBC and continue erythrocytic cycle

Exo-erythrocytlc cycle

If the cryptozoites enter the fresh liver cells, they undergo the changes similar to that of the pre-erythrocytic cycle and produce the second generation merozoites called **metacryptozoites.** These are of two types- the smaller **micro-metacryptozoites** and larger **macro-metacryptozoites.** This entire process is completed approximately in two days. The macro-metacryptozoites attack fresh liver cells and continue another exo-erythrocytic cycle, whereas the micro-metacryptozoites always enter blood stream and attack fresh RBC to continue erythrocytic cycle.

Prepatent period

The interval between 'the first entry of *Plosmodium* into the blood in the form of sporozoites and the second entry of Plosmodium into the blood in the form of cryptozoites is called **prepatent period.** It lasts approximately 8 days. During this period, the host does not show any clinical symptoms of the disease. It is only a means of multiplication.

Erythrocytic Cycle

It was first described by **Camillo Golgi.** Hence it is also called **'Golgi cycle'.** This cycle is initiated either by the cryptozoites of pre-erythrocytic cycle or the micro-metacryptozoites of exo-erythrocytic cycle. In the fresh RBC, these stages assume spherical shape and transform into ***trophozoites.*** It develops a small vacuole which gradually enlarges in size, pushing the cytoplasm and nucleus to the periphery. Now the *Plosmodium* looks like a **finger ring.** Hence this stage is called **signet ring stage.** Soon it loses the vacuole, develops pseudopodia and becomes **amoeboid stage.** With the help of pseudopodia, it actively feeds on the contents of the RBC and increases in size. As a result, the RBC grows almost double

the size. This process is called **hypertrophy.** The malaria parasite digests the globin part of the ingested haemoglobin and converts the soluble haem into an insoluble crystalline **haemozoin.** It is called the **'malaria pigment'** which is a disposable product. During this stage, small red coloured dots appear in the cytoplasm of the RBC known as **Schuffner's dots.** These are believed to be the antigens released by the parasite. Now the *Plosmodium* loses the pseudopodia, further increases in size, occupies the entire RBC and becomes a schizont. It undergoes schizogony similar to that of the pre-erythrocytic cycle and produces 12 to 24 erythrocytic merozoites. They are arranged in the form of the petals of a rose in the RBC. Hence, this stage is called the **rosette stage.** Finally the erythrocyte bursts and releases the merozoites along with haemozoin into the blood. This cycle is completed approximately in 48 hours.

Incubation Period

The period between 'the entry of *Plasmodium* into the blood in the form of sporozoite and the first appearance of symptoms of malaria in man' is called **incubation period.** It is approximately 10 to 14 days.

Formation of gametocytes

After repeated cycles of erythrocytic schizogony, when the number of fresh RBC decreases, some merozoites enter the RBC and transform into gametocytes instead of continuing the erythrocytic cycle. This process generally takes place when the RBCs are present in ***spleen*** and ***bone marrow.***

The gametocytes are of two types namely, smaller **microgametocytes** or **male gametocytes** and larger **macrogametoeytes** or **female gametocytes.** The gametocytes cannot undergo further development in man as the temperature and pH of the blood of man are not suitable for further development. These gametocytes reach the blood circulation and wait to reach the next host. They degenerate and die if they are not transferred to mosquito within a week.

Life cycle of Plasmodium in mosquito (The mosquito phase) - Ross cycle

When a female *Anopheles* mosquito bites and sucks the blood of a malaria patient, the gametocytes along with the other stages of the erythrocytic cycle reach the crop of mosquito. Here all the stages are digested except the gametocytes. Further part of the life cycle consists of:

i) Gametogony
ii) Fertilization
iii) Formation of Ookinete & Oocysts
iv) Sporogony

i)Gametogony: The formation of male and female gametes from the gametocytes is called **gametogony.** It occurs in the lumen of the crop of mosquito.

Formation of male gametes: During this process, the nucleus of microgametocyte divides into eight daughter nuclei called ***pronuclei*** which reach the periphery. The cytoplasm is pushed out in the form of eight flagella like processes. Into each flagellum like process, one pronucleus enters and forms a **micro gamete** or **male gamete**. These male gametes show lashing movements like flagella and get separated from the cytoplasm of microgametocyte. This process is called **exflagellation.**

Formation of female gamete. The female gametocyte undergoes a few changes and transforms into a female gamete. This process is called **maturation.** The nucleus of the female gamete moves towards the periphery and the cytoplasm at that point forms a projection, This projected region is called the ***fertilization cone.***

ii)Fertilization: The fusion of male and female gametes is called fertilization. It also occurs in the lumen of the crop of the mosquito. When an actively moving male gamete comes into

contact with the fertilization cone of the female gamete, it enters it. The pronuclei and cytoplasm of these two gametes fuse with each other, resulting in the formation of a synkaryon. Since the two gametes are dissimilar in size, this process is known as anisogamy. The female gamete that bears the synkaryon is called the zygote which is round and non-motile. iii) Formation of ookinete and oocysts.

iii) Formation of ookinete and oocysts : The zygote remains inactive for some time and then transforms into a long, slender, motile, vermiform ookinete or vermicule within 18 to 24 hours. It pierces the wall of the crop and settles beneath the *basement membrane.* It becomes round and secretes a cyst around its body. This encysted ookinete is now called **oocyst.** About 50 to 500 oocysts are formed on the wall of the crop and appear in the form of small nodules. (Sir Ronald Ross identified these oocysts for the first time).

iv) Sporogony : The formation of sporozoites in the oocysts is called ***sporogony***. According to Bano, the nucleus of the oocyst first undergoes reduction division followed by repeated mitotic divisions resulting in the formation of about 1,000 daughter nuclei. Each bit of nucleus is surrounded by a little bit of the cytoplasm and transforms into a sickle shaped sporozoite. Oocyst with such sporozoites is called ***sporocyst***. When this sporocyst ruptures, the sporozoites are liberated into the haemocoel of the mosquito. From there, they travel into the salivary glands and are ready for infection. The life cycle of *Plasmodium* in mosquito is completed in about 10 to 24 days. (Figure 5.4)

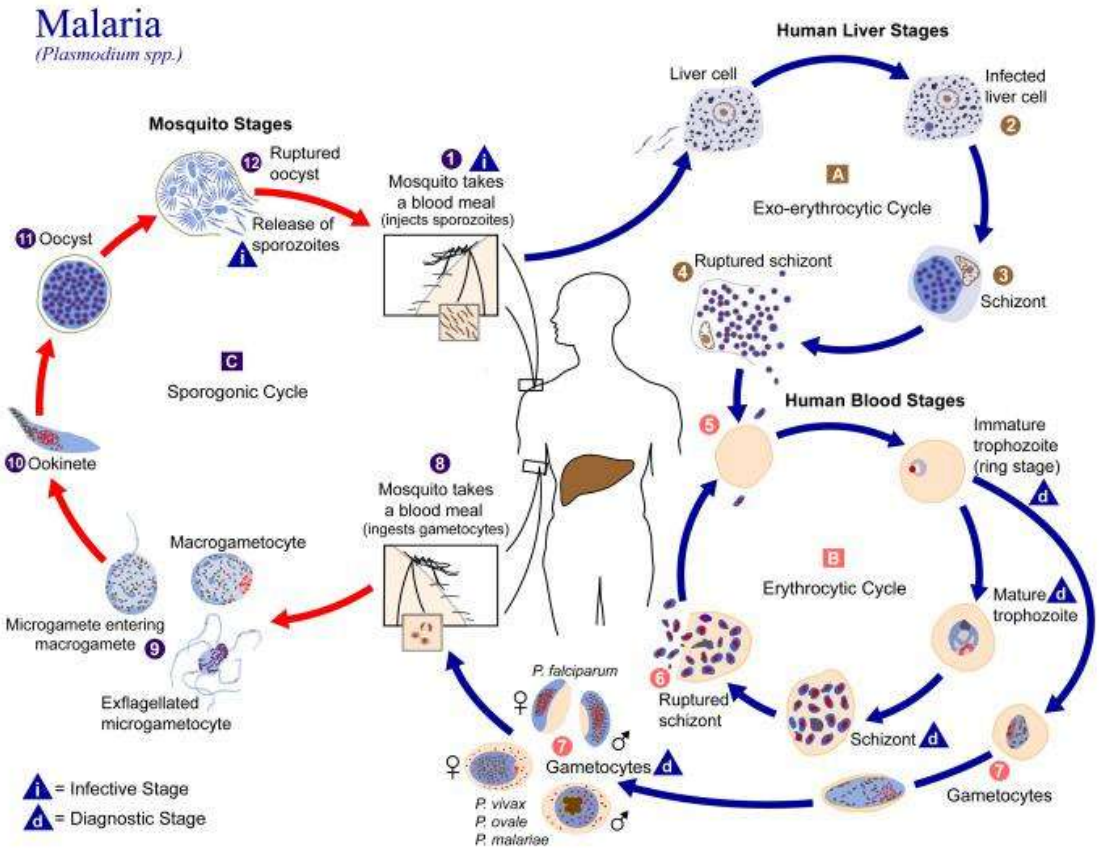


Fig 5.4 *Plasmodium spp.* life cycle

Pathogenicity

Plasmodium vivax causes benign tertian malaria. The clinical symptoms of this disease include bouts of fever which can be expressed in three stages namely cold stage, hot stage and sweating stage.

Cold Stage: Chills, shivering, headache and giddiness.

Hot Stage: High temperature of the body, rapid breathing and an increase in the pulse rate.

Sweating stage: Profuse sweating followed by lowering of the body temperature to the normal level.

Anaemia and **splenomegaly** are noticed in a chronic malaria patient. Relapse of malaria may also be noticed some times.

Relapse of malaria: Some of the stages of macro-metacryptozoites may survive for a long period in liver as dormant stages called **hypnozoites.** Reactivation of these hypnozoites leads to the initiation of fresh erythrocytic cycles resulting in the new attacks of malaria. This is referred to as **relapse of malaria.**

Treatment

Malaria can be cured by **quinine** which is an alkaloid extracted from the bark of Cinchona officinalis.

Prophylaxis

* Spraying of DDT, BHC, etc., insecticides at intervals in mosquito breeding places like pools, ponds, ditches and stagnant water.
* Introduction of larvivorous fishes like Gambusia. insectivorous plants like *Utricularia* into the places where mosquitoes breed.
* Avoiding mosquito bite by using mosquito nets, mosquito repellents, etc.
* Spraying of kerosene, pyrethrum oil etc. on stagnant water.

5.2.3 Wuchereria bancrofti

Phylum : Nematoda
Class : Phasmidia

Wuchereria bancrofti is commonly called the filarial worm as it causes fllariasis in human beings. It is a digenetic, dimorphic, pseudocoelomate and histozoic parasite that lives in the lymph vessels of man. **Sir *Patrick Manson*** identified **female *Culex*** mosquito as its secondary host.

Structure

Sexes are separate and the sexual dimorphism is distinct. The body is long, narrow, filiform and creamy-white in colour. The anterior end is blunt and the posterior end is pointed. Mouth is present at the anterior end and is without any lips.

Male worm: Its posterior end is curved with a cloacal aperture. A pair of unequal, chitinous **'pineal spicules'** or **copulatory spicules'** is present in the cloacal region.

Female worm: Its posterior end is straight. Anus is present near the posterior end. The female genital pore or vulva is present mid ventrally at about one third the length from the mouth. It is **ovoviviparous.**

Life cycle

As we already discussed, it completes its life cycle in two hosts namely man and female *Culex mosquito*.

In man

Both male and female worms are found coiled together in the lymphatic vessels of man. After copulation the female releases the sheathed microfilaria larvae into the lymph of

man. Each sheathed microfilaria larva measures 0.2 to 0.3 mm in length. It is surrounded by a loose cuticular sheath which is supposed to be the modified shell. They migrate to the blood circulation and reside in the deeper blood vessels during the day time. They move to the peripheral blood circulation during the night, : time between 10.00 pm and 4.00 am. This tendency is referred to as **'nocturnal periodicity'.** When a female *Culex* mosquito sucks the blood of an infected person, they enter the gut of mosquito. They die if they are not transferred to mosquito **within 70 days.**

In mosquito

In the mid gut of mosquito, the sheath of the larva is dissolved within 2 to 6 hours of the infection, The ex-sheathed microfilaria larva penetrates the gut wall and reaches the haemocoel of mosquito. From there, it reaches the **'thoracic muscles'** and transforms into a **'sausage shaped larva'** within two days. It is called the **first stage larva or first stage microfilaria.** This undergoes two moultings within 10 to 20 days and transforms into a long, infective **'3rd stage microfilaria'.** It reaches the labium of the mosquito. (Figure 5.5)

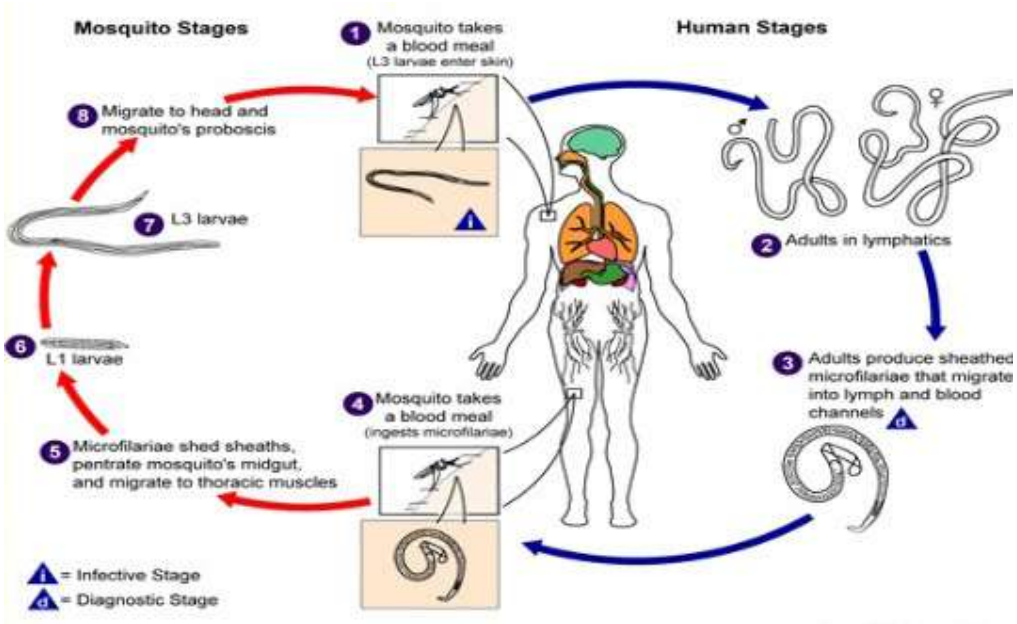


Fig 5.5 *Wuchereria bancrofti* life cycle

In man after the infection

When an infected mosquito bites a man, the 3rd stage microfilaria larvae enter the blood circulation of man and finally reach the lymphatic vessels. Here they undergo the 3rd and the 4th moultings to produce young filarial worms. They attain sexual maturity within 5 to 18 months.

Pathogenicity :

Light infection causes filarial fever which is characterised by headache, mental depression and increase in the body temperature. In general, the infection of filarial worm causes inflammatory effect in lymph vessels and lymph glands. Inflammation in the lymph vessels is called **lymphangitis** *(Gr., angeos - vessels,* itis - inflammation) and that of lymph glands is called **lymphadenitis** (Gr., *adenos - gland, itis* -inflammation). In the case of heavy infection, the accumulation of dead worms blocks the lymph vessels and lymph glands resulting in immense swelling. This condition is called **lymphoedema** (Gr., *oiedema - a swelling)* which is noticed in the extremities of limbs, scrotum of males and mammary glands

in females. Fibroblasts accumulate in these tissues and form the fibrous tissue. In severe cases, the sweat glands of the skin in the affected regions disintegrate and the skin becomes rough. This terminal condition is referred to as ***'elephantiasis'***. (Figure 5.6).

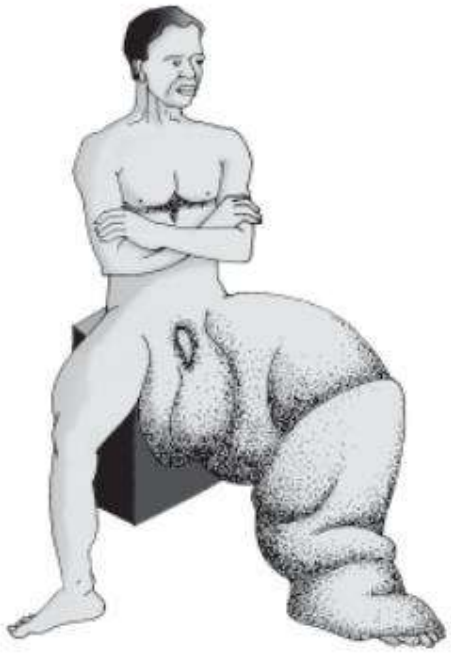


Fig 5.6 Picture showing the man suffering from ***elephantiasis***

5.3.1 Bacterial diseases

i) Typhoid fever: It is caused by *Salmonella typhi* which is a Gram negative bacterium. It mainly lives in the small intestine of man and then migrates to other organs through blood. It can be confirmed by **Widal test**

Mode of infection: Contamination through food and water.

Symptoms: Sustained fever with high temperature upto 104°F, weakness, stomach pain, constipation, headache and loss of appetite. Intestinal perforation and death may also occur in severe cases.

ii) Pneumonia: It is caused by Gram positive bacteria such as ***Streptococcus pneumonias*** and ***Haemophilus irtfluenzae.*** They infect the alveoli of lungs in human beings.

Mode of infection: Contamination by inhaling the droplets/aerosols released by an infected person or even by sharing the utensils with an infected person.

Symptoms: The alveoli get filled with fluid leading to severe problems in respiration. In severe cases, the lips and finger nails may turn gray to bluish in colour.

5.3.2 Viral Diseases

Common cold- It is caused by **Rhino virus** group of viruses. They infect nose and respiratory passage but not lungs.

Mode of infection: Contamination by direct inhalation of the droplets resulting from cough or sneezes of an infected person or indirectly through contaminated objects such as pens, books, cups, door-knobs, computer keyboard or mouse etc.

Symptoms: Nasal congestion, discharge from nose, sore throat, hoarseness, cough, headache, tiredness, etc., which usually last for 3-7 days.

Ringworm : It is one of the most common infectious diseases in man. It is caused by many fungi belonging to the genera ***Microsporum, Trichophyton*** and ***Epidermophyton.*** Heat and

moisture help these fungi grow in the skin folds such as those in the groin or between the toes.

Mode of infection: Contamination by using towels, clothes or combs of the infected persons or even from soil.

Symptoms: Appearance of dry, scaly, usually round lesions accompanied by intense itching on various parts of the body such as skin, nails and scalp.

5.3.4 Prophylaxis

i) In the case of bacterial & viral diseases: The advancements made in biological science have armed us to deal with many infectious diseases effectively. The immunization programmes by the use of vaccines have enabled us to completely eradicate a deadly disease like smallpox. A large number of other infectious diseases like polio, diphtheria, pneumonia and tetanus have been controlled to a large extent by the use of vaccines. :

ii) In general: Biotechnology is at the verge of making available newer and safer vaccines. Discovery of antibiotics and various other drugs has also enabled us to treat infectious diseases effectively.

5.4 tobacco, drugs and alcohol abuse (TDA abuse)

Recent surveys and statistics show that the use of tobacco, drugs and alcohol has been on the rise especially among the youth. This is really a cause of concern as it could result in many harmful effects. Proper education and guidance would enable the youth to safeguard themselves against these dangerous habits and follow healthy lifestyles. Any addict requires counselling and medical help to get rid of the habit.

5.4.1 Tobacco .

Tobacco has been used by human beings for more than 400 years. It contains a large number of chemical substances including **nicotine,** an alkaloid. While buying cigarettes one cannot miss the statutory warning present on the packet **'Smoking is injurious to health'.**

Mode of abuse: It is smoked or chewed as gutkha or used in the form of snuff.

Effect : Smoking increases the carbon monoxide (CO) level and reduces the oxygen level in the blood. Nicotine stimulates the adrenal gland to release adrenaline and nor-adrenaline into blood. These hormones raise the blood pressure and increase the heart rate. Smoking is associated with bronchitis, emphysema, coronary heart *disease,* gastric ulcer and increases the incidence of cancers of throat, lungs, urinary bladder etc. Smoking also paves the way to hard drugs{1} . Yet, smoking is very prevalent in society, both among young and old. Tobacco chewing is associated with increased risk of cancer of the oral cavity.

5.4.2 Drugs

Drugs are the chemical substances used in the treatment, cure and prevention of diseases so as to enhance one's physical or mental well being. For hundreds of years, several plants, fruits and seeds with hallucinogenic properties have been used in folk-medicine, religious ceremonies (such as **'bhang' on the 'Holi festival'** day) and rituals all over the globe. ***When these are taken for a purpose other than the medicinal use or in excess amounts that impair one's physical or psychological functions, it constitutes 'drug abuse'.***

The drugs commonly abused are **opioids. cannabinoids** and **coca alkaloids** . Majority of them are obtained from flowering Plants but some are obtained from certain fungi.

5.4.3 Adolescence and TDA abuse

Adolescence: It is the time period between the beginning of puberty and the beginning of adulthood. In other words, it is the bridge linking childhood and adulthood. The age between 12-18 years is considered **'adolescence period'**. It is both 'a period and a process' during which a child becomes mature. It is accompanied by several biological and

behavioural changes. Thus, adolescence is *a* very **'vulnerable phase'** of mental and psychological development of an individual.

TDA abuse: Curiosity, desire for adventure and excitement, experimentation, are the common causes for the motivation of youngsters towards the use of tobacco, drugs and alcohol. The first use of drugs or alcohol may be out of curiosity or experimentation, but later the person starts using them to escape facing problems. Recently 'stress from the pressure to excel in academics or examinations' has played a significant role in alluring the youngsters to try certain drugs. Television, movies, newspapers and internet also help promoting this wrong perception. Other factors that are associated with tobacco, drug and alcohol abuse among adolescents are unstable or unsupportive family structures and peer pressure.

Addiction and Dependence

The TDA abuse leads to addiction and dependence.

Addiction: It is a psychological attachment to certain effects such as euphoria. The most important thing one fails to realise is, the inherent **'addictive nature'** of tobacco, drugs and alcohol. With the repeated use of TDA, the tolerance level of the receptors present in our body increases. Consequently the receptors respond only to higher doses leading to greater intake and addiction. However it should be clearly borne in mind that **use of TDA even once, can be a fore-runner to addiction.** Thus, the addictive potential of tobacco, drugs and alcohol pull the users into a vicious circle leading to their regular use (abuse) from which they may not be able to get out. In the absence of any guidance or counseling, people get addicted and become dependent on them.

Dependence: It is the tendency of the body to manifest a characteristic and unpleasant condition (withdrawal syndrome) if the regular dose of drugs or alcohol is abruptly discontinued. The withdrawal syndrome is characterised by anxiety, shakiness (tremors), nausea and sweating which may be relieved when the regular use is resumed again. Dependence leads the patients to ignore all social norms.

Prevention and Control

The age-old adage of **'Prevention is better than cure'** holds true here also. Some of the measures useful for prevention and control of TDA abuse among the adolescents are:

i) Avoid undue parental pressure: Every child has his/her own choice, capacity and personality. The parents should not force their children to perform beyond their capacity by comparing them with others in studies, games, etc.

ii) Responsibility of parents and teachers: They should look for the danger signs and counsel such students who are likely to get into the 'trap'.

iii) Seeking help from peers: If peers find someone abusing drugs or alcohol, immediately it should be brought to the notice of their parents or teachers so that they can guide them appropriately.

iv) Education and counselling: Educating and counselling the children to face problems, stress and failures as a part of life.

v) Seeking professional and medical help: A lot of help is available in the form of highly qualified psychologists, psychiatrists and de-addiction and rehabilitation programmers.

GLOSSARY

Abscess: A localized collection of pus at wound.
Abuse: Improper or excessive use.
Anabolic steroids: Technically known as anabolic-androgen steroids (AAS) or steroids are the drugs that mimic the effects of 'testosterone and dihydroteststerone in the body'. They increase the protein synthesis within cells, which results in the build up of cellular tissue (anabolism), especially in muscles.

Appetite: A feeling of hunger.
Bout: an instance of something lasting for a short period as in bout of fever.
Clinical symptoms: Noticeable symptoms of disease.
Cloaca: The cavity at the end of digestive tract into which the intestinal, genital and urinary tract open in the case of vertebrates.
Constipation: Irregular and infrequent or difficult egestion.
Coprophagous: Feeding on faecal matter.
Cosmopolitan: occurring in many parts of the world.
Epidemic: Spreading of infectious disease, affecting many people over a wide area.
Epidemiology: The branch of medical science dealing with transmission and control of disease.
Euphoria: A temporary feeling of an exaggerated joy, well being pride and optimism associated with drugs and alcohol.
Faeces: Solid indigested product discharged through anus.
Filiform: Resembling a thread.
Giddiness: A feeling that you are about to fall: a reeling sensation.
Hallucinations: Illusionary perception.
Inflammation: A response of body tissues to injury or irritation, characterized by pain, swelling, redness and burning sensation.
Instinct: Inborn pattern of behaviour.
Intravenous: Direct injection into the vein using a syringe.
Lesion: An injury to living tissue.
Liver sinusoids: Tiny blood filled spaces in the liver.
Masculinisation: Development of features like those of men.
Moultings: Periodic shedding of the cuticle or the outer skin in some animals or larval stage.
Nasal congestion: Blockage of nose.
Neuro-transmitter: A neuro chemical that transmits nerve impulses across a synapse.
Ovoviviparous: Producing the eggs that hatch within the body bt the juveniles do not draw any nourishment from the mother.
Pathogen: Any disease producing agent.
Peer: A person who is equal standing with another in a group: a frien or classmate.
Phasmids: Caudal sensory organs present in nematodes.
Quagmire: A soft wet area of low-lying land that sinks under foot.
Sausage shaped: more or less a long brinjal shaped.
Schizogony: A type of multiple fission that occur in many epicomplexan protozoans during asexual life cycle.
Snorting: An act of forcible inhalation of drugs.
Stool: Faecal matter.
Tranquilizers: A drug used to reduce stress or tension without reducing mental activity.
Ulcer: A circumscribed inflammatory lesion on the skin or an internal mucus membrane resulting in the necrosis of the skin.
Vaccine: Immunogen consisting of a suspension of weakened or dead pathogenic cells injected in order to stimulate the production of antibodies in the host body.
Vandalism: Deliberate destruction, defacement or damage of public property.
Vermiform: Resembling a worm.
Vicious circle: One trouble leads to another that aggravates the first.
Vulnerable: Susceptible to attack or temptation.
Welfare: Something that aids or promotes.

VERY SHORT ANSWER TYPE QUESTIONS

1. Define parasitism and justify this term?
2. What is a hyperparasite? Mention the name of one hyperparasite?
3. What do mean by parasitic castration? Give one example?
4. Define neoplasia? Give one example?
5. What do mean by parasitic castration?
6. Write any two diagnostic features of tropozoite of *Entamoeba histolytica?*
7. Distinguish between precystic stage and cystic stage of *E. histolytica*?
8. Define asymptomatic cyst passers with reference to *E.histolytica*?
9. What are heamozoin granules? What is their significance?
10. Define prepatent period? What is its duration in life cycle of *Plasmodium vivax* ?
11. Define incubatin period? What is its duration in life cycle of *Plasmodium vivax* ?
12. What are the Schuffner's dots?
13. What are heamozoin granules? What is ttheir significance?
14. What is exflagellation?
15. What is ookinete? Based on the sets of chromosomes how do you distinguish it?
16. Describe the methods of biological control of mosquitoes?
17. Distinguish between Lymphadenities and Lymphangitis?
18. Define drug abuse?
19. In which way tobacco affect the respiration? Name the alkaloid found in tobacco?

SHORT ANSWER TYPE QUESTIONS

1. Describe the effects of parasites on the host?
2. Describe the structure of a tropozoite of *Entamoeba histolytica?*
3. Describe the life cycle of *E.histolytica*?
4. Describe the structure of tropozoit of *Plasmodium vivax*?
5. What do you know about the exo-erythrocytic life cycle of *Plasmodiumvivax*?
6. Describe the cycle of Golgi in the life history of *Plasmodium vivax*?
7. Explain the pathogenisity of *Wuchereria bancrofti* in man?
8. Write a short notes on typhoid fever and its prophylaxis?
9. What are the adverse effects of tobacco?
10. Write a short notes on Opioids ?
11. "Prevention is better than cure". Justify with regard to TDA abuse?

Unit 6

Periplaneta americana (Cockroach)

SUMMARY

Cockroach belongs to the phylum Arthropoda and the class Insecta. Insecta is the largest class of animals in the Kingdom -Animalia. These are terrestrial animals but adapted to live in all habitats, except in deep waters of the seas. Insects are distinguished from other arthropods in possessing three **tagmata** in the body and three pairs of legs. The study of insects is called **Enmotology.**

Cockroach is an abundantly and easily available insect. It also exhibits all the characteristic features of the class **Insecta**. Besides this, its large size of the body makes it a convenient specimen, for dissection and demonstration. Therefore it is an excellent example for the study of insects.

Cockroach is a common household pest that contaminates our food with its excreta. It can transmit a number of bacterial diseases by contaminating food materials. These are mostly the inhabitants of the tropical countries. However some species are found in the temperate regions. The two common species of cockroaches found in India are: *Blatta orientcdis* and ***Periplaneta americana*.**

Periplaneta Americana – type study

Classification

Phylum : Arthropoda

Class : Insecta

Order : Arthroptera

Family : Blattidae

Genus : *Periplanata*

Species : *Americana*

6.1.1 Habitat and habit

Periplaneta americana, was *a* native of the tropical America. Now it has become a *cosmopolitan* insect. The name *Periplaneta americana* was coined by **Burmeister.** It is usually found in kitchens, hotels, bakeries, warehouses, etc., It is a **nocturnal** insect (it comes out of its hiding places to feed at night times). During the day time it remains inactive and takes rest. Its flattened form of the body enables it to enter small crevices in the floor or walls. It is an **omnivorous** insect, eating all types of food. It locates its food by the sense of smell. *Periplaneta* is a **cursorial** (swift runner) animal.

6.1.2 External Features

Cockroach has an elongated narrow, elliptical, dorso-ventrally depressed body. It exhibits bilateral symmetry. The wings extend beyond the tip of the abdomen in the males. The colour is reddish brown with a light yellow area-around the edges of the pronotum. The complete body is externally covered by a ***chitinous cuticle*** which constitutes the ***exoskeleton*** The cuticle is secreted by the underlying cells of the hypodermis· It is coated externally by a thin layer of wax, impermeable to water. The **oenocytes,** are believed to secrete ***wax***. The cuticle protects the body, prevents loss of water, provides rigidity and offers place for the attachment of muscles. It consists of small plates or **sclerites,** which are joined by soft, flexible **arthrodial membranes.**

Body: The body of cockroach is distinctly segmented and consists of three ***tagmata*** (morphologically distinct parts of the body) namely head, thorax and abdomen.

Head: The head of cockroach is small and triangular. It is called **hypognathous** because it lies hanging almost at right angles to the body with the posterior wider part upwards, and the mouthparts directed down-wards.

The head of cockroach is formed by the fusion of six embryonic segments. It is movably attached to the thorax by a short neck or **cervicum.** It is covered by a number of sclerites which fuse to form a capsule. The top of the head between the eyes is called **vertex.** The vertex has two sclerites called **'epicranial *plates'*** connected by an **'epicranial *suture'*.** Below the vertex, the sclerites covering the head in front are - a large **frons,** a narrow rectangular **clypeus** and a movable **labrum**. Covering the sides of the head, below the compound eyes are the 'cheek sclerites' or **'genae**'. At the back of the head capsule there is a large opening called **occipital foramen.** It is bordered by a sclerite called **occiput.** The

occipital foramen forms a passage for the oesophagus, aorta, nerve cord and tracheae. At the base of each **antenna**, a small whitish speck called **fenestra** or 'ocellar spot' or 'simple eye' is present. Appendages are absent in the first and third segments of the head. The second segment bears a pair of long, slender and segmented **antennae**, one on each side of the head. The **antennae** are tactile and olfactory in function. The fourth segment bears a pair of ***mandibles.*** The fifth segment has a pair of ***first maxillae'.*** The sixth segment bears a pair of **'second maxillae',** which fuse to form the **labium** (also called 'lower lip'). (Figure 6.1)

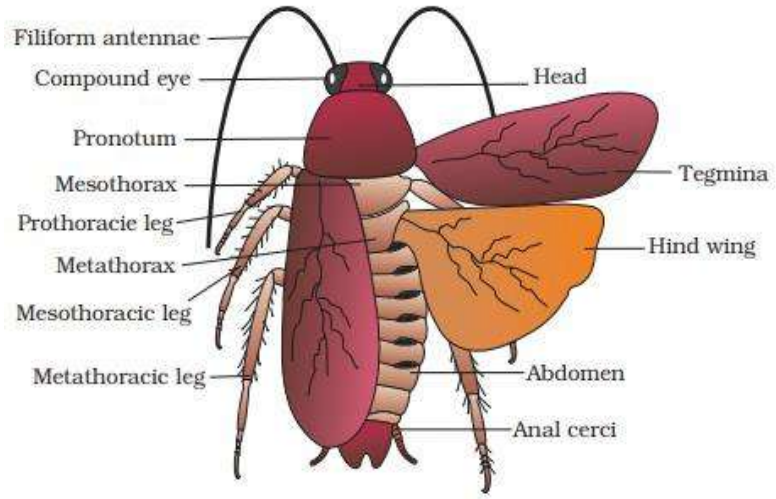


Fig 6.1 *Periplanata*- External features

Mouthparts

The Mouthparts of *Periplaneta are* of **Biting** and **Chewing** type. These are the movably articulated appendages surrounding the mouth. They include a pair of mandibles, a pair of first maxillae, a pair of second maxillae or labium and a tongue or ***hypopharynx.*** They enclose a space called the ***'preoral cavity'.***

Labrum (upper lip)

The labrum is a vertical, rectangular plate, movably connected with the clypeus. It forms the anterior wall of the preoral cavity and is also called the 'upper lip'. It bears **'gustatory sensillae'** on its inner surface. The labrum serves to hold the food and helps in tasting it.

Mandibles

A pair of triangular, hard, unjointed, chitinised mandibles is present on the sides of the mouth, connected with the genae. The inner margins of mandibles have teeth like structures. These teeth help to masticate the food. Two pairs of muscles called **adductor** and **abductor** muscles help in the movement of the mandibles.

First maxillae

A pair of first maxillae is situated on the sides of the mouth immediately behind the mandibles. Each maxilla is 'biramous' and consists of three parts: the protopodite endopodite, and the exopodite. **Cardo and stipes** constitute the protopodite. A five jointed maxillary palp, arising from a sclerite called **palpifer,** on the outer side of the stipes, constitutes the exopodite. The maxillary palps are used for cleaning the antennae and the front pair of legs.

From the distal end of the stipes, internal to the maxillary palp, arises the endopodite. Each endopodite has two parts, an outer broad hood-like **galea** and inner pincer-like (resembling a forceps) **lacinia.** Maxillae serve to hold the food and bring it to the mandibles. The distal end of the prementum bears a pair of ***'paraglossae*** (comparable to **galeae** of the first maxilla), a pair of **'glossae'** (comparable to **laciniae** of the first maxilla). The glossae and paraglossae together constitute the ***ligula.***

Second maxillae (Labium or Lower lip)

The second pair of maxillae lies behind the first pair. Both the second maxillae fuse to form a broad plate like **lobium or *lower lip.*** It consists of three parts: the upper submentum, the middle mentum and the lower prementum. A three segmented labial palp, arising from a sclerite called **palpiger,** is present one on each side of the prementurn. It prevents the food from falling, and pushes it into the preoral cavity.

Hypopharynx (Tongue or Lingua): The hypopharynx is a rod like, grooved chitinous structure, hanging in the preoral cavity between the first maxillae. The hypopharynx is also called 'tongue' or **'lingua'.** It bears the opening of the *'efferent salivary duct'*. (Figure 6.2)

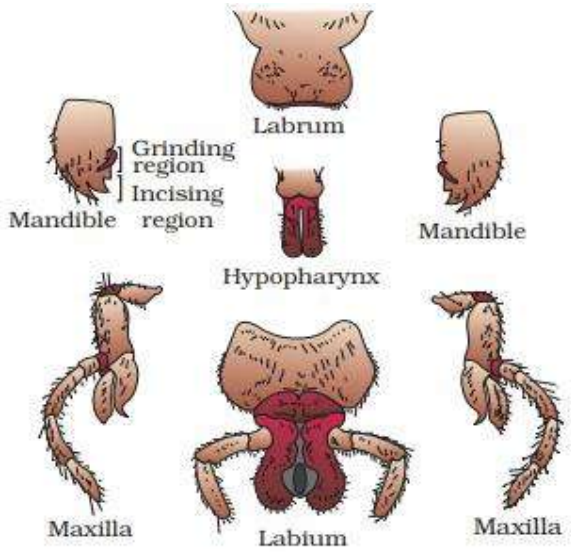


Fig 6.2 *Periplanata* – Mouth parts

Neck (cervicum)

Neck is short, slender, flexible tube that connects the head with the thorax. It is supported by ***four cervical sclerites.*** It is not a 'tagma' of the body. It helps in the movement of the head.

Thorax: The thorax is the second 'tagma' of the body. It consists of three segments: prothorax, mesothorax, and metathorax. Each segment of the thorax is covered by four sclerites -one on the dorsal side (called **tergum** or **notum),** one on the ventral *side* (called **sternum)** and two (called **pleura),** on the lateral sides. The tergum of the prothorax is called **Pronotum**. It is the largest sclerite of the body and covers the neck and a little part of the head. The terga on the mesothorax and metathorax are joiled **mesonotum** and ***metanotum*** respectively. The sclerites of each segment are joined by thin, soft, flexible membranes called arthrodial membranes, which permit movement, between the segments.

Legs: There are three pairs of jointed, walking legs in cockroach, attached one pair to each thoracic segment on the ventral side. The legs are connected with the pleura and sterna of the thoracic segments. According to the segment that bears them, they are called prolegs, mesolegs and metalegs. All the legs are similar in structure. Each leg is made up of five segments or ***podomeres.*** The different podomeres *(from* the base to the tip) are serially: **coxa, *trochanter, femur,* tibia** and **tarsus.**

The coxa connects the leg with the thorax. The trochanter is *movably attached* to the coxa, and *fused* with the femur. The femur and tibia bear chitinous bristles. The joints of tarsus are **tarsomeres** which bear soft pads called **plantulae** on their inner surface. The terminal joint of the tarsus, ends in a pair of ***claws.*** Between the claws there is a soft hairy pad called **pulvillus** or **arolium.**

Wings : Two pairs of wings, the fore, wings and the hind wings, are present in cockroach. The forewings are thick, opaque and leathery. They do not help in flight, but cover and protect the hind wings when they are not in use. They are called **tegmina** (singular: ***tegmen).*** The hind wings are broad, thin, transparent and delicate.

They help in flight and remain folded below the tegmina when not in use. The wings of cockroach contain a network of hollow ***veins*** or ***nervures.***

Abdomen: The abdomen consists of ***ten*** segments. Each segment is covered by the dorsal tergum, the ventral sternum and the two lateral pleura or pleurites. There are ten terga but only nine sterna as the *tenth sternum is absent.* The eighth tergum in the male and both eighth and ninth terga in the female are not visible as they are overlapped by the *seventh tergum.* The tenth tergum extends beyond the posterior end of the body and has a deep notch / groove in the middle of its free end. In the male nine sterna are visible whereas in the female, only seven sterna are visible. The seventh, eighth and ninth sterna together form a ***brood pouch.*** The brood pouch has two parts the anterior genital chamber or ***gynatrium*** and posterior **oothecal chamber.**

The posterior end of the abdomen has a pair **of anal cerci,** a pair **of anal styles** and gonapophyses in the males. Anal cerci are jointed and arise from the lateral sides of the tenth tergum and are found in both the sexes. The anal styles are without joints and arise from the ninth sternum (seen only in the males). The ***gonapophyses*** are small chitinous processes arising from the ninth sternum in the males and eighth and ninth sterna in the females. *They are the external genital organs.* The **anus** is at the posterior end of the abdomen. The genital aperture in male is present just below the anus on one of the **gonapophyses** and in female it is located on the ***eighth sternum.***

Body wall: The body wall consists of three layers: **cuticle,** ***epidermis*** or ***hypodermis*** and ***basement membrane.*** The cuticle is the outer most layer. It is again differentiated into three layers, namely, an outer thin, waxy **epicuticle**, middle thick **exocuticle** made of tough pigmented chitin and an inner much thick **endocuticle**, made of soft layers of **chitin**. The articular membranes lack the exocuticle and so they are flexible. The epidermis lies below the cuticle. It comprises(a single layer of columnar cells resting on the basement membrane. It secretes the cuticle. The basement membrane is the inner most layer of the body wall and it has flattened cells. The cuticle protects the delicate internal organs and prevents the loss of water by evaporation and provides surface for the attachment of muscles.

6.1.3 Digestive System

The digestive system of cockroach consists of an alimentary canal and the associated glands. The preoral cavity, surrounded by the mouth parts, is present in front of the mouth.

The hypopharynx divides it into two chambers called **cibarium** (anterior) and **sallvarium** (posterior).

Alimentary canal

The alimentary canal of cockroach is a long tube and is coiled at some places. It extends between the mouth and the anus. It is divided into three regions, namely, foregut or **stomodaettm** midgut or **mesenteron** and hindgut or **proctodaeum.** The foregut and hindgut are internally lined by ectoderm. The mesenteron is lined by the endodermal cells.

Foregut or stomodaeum

The foregut includes pharynx, oesophagus, crop and gizzard. It is internally lined by a chitinous cuticle. Mouth opens into the **pharynx,** which in turn leads into a narrow tubular oesophagus. The **oesophagus** opens behind into a thin walled distensible sac called **crop.** The crop serves as a reservoir for storing food. Its outer surface is covered by a network of tracheae.

Behind the crop there is a thick walled muscular **proventriculus,** or ***gizzard.*** The chitinous inner lining of the gizzard has six powerful teeth, which form an efficient, grinding apparatus. Behind each tooth is a hairy pad, which bears backwardly directed bristles. Among these plates, food is thoroughly ground into fine particles. These food particles are filtered by the bristles. The gizzard thus acts both as a **grinding mill** and also as a **sieve**. There is a membranous projection of the gizzard in to the mesenteron in the form of a funnel called **stomodeal valve** This valve prevents the entry (regurgitation) of food from the mesenteron back into the gizzard.

Midgut (mesenteron or ventriculus)

The midgut is a short and narrow tube behind the gizzard. It is also called mesenteron or ***ventriculus.*** Between the ventriculus and the gizzard, arising from ventriculus, there are six to eight finger like diverticula called **hepatic caecae.** They are helpful in digestion and absorption of the digested food materials. Ventriculus is functionally divided into an anterior ***secretory part*** and a posterior ***absorptive part.***

The secretory part of the ventriculus has many gland cells and it secretes several enzymes. The 'bolus' of food in the mesenteron is enveloped by a chitinous and porous membrane called **peritrophic membrane,** which is secreted by the funnel like stomodeal valve of the gizzard.

Digested food is absorbed into the blood through the peritrophic membrane in the posterior absorptive region of the ventriculus. The peritrophic membrane protects the wall of the ventriculus from hard food particles in the food. The opening of the ventriculus into the hindgut is controlled by a **sphincter muscle.** It prevents entry of undigested food and uric acid from the hindgut into the midgut.

Hindgut or proctodaeum

The hindgut is a long coiled tube, consisting of three regions namely **ileum, colon** and **rectum.** It is internally lined by chitinous cuticle. The ileum that lies behind the mesenteron is a short tube. Six bundles of fine yellow, blind tubules called **Malphighian tubiales** open into the ileum near the junction of mesenteron and ileum. Malpighian tubules are excretory in function. Ileum collects uric acid from the malpighian tubules and undigested food from the mesenteron. Ileum opens behind into a long coiled tube called colon. Colon leads into a short and wide rectum which opens out through the anus. Rectum bears on its inner side six longitudinal chitinous folds called **rectal papillae.** They are concerned with the reabsorption of water from the undigested food.(Figure 6.3)

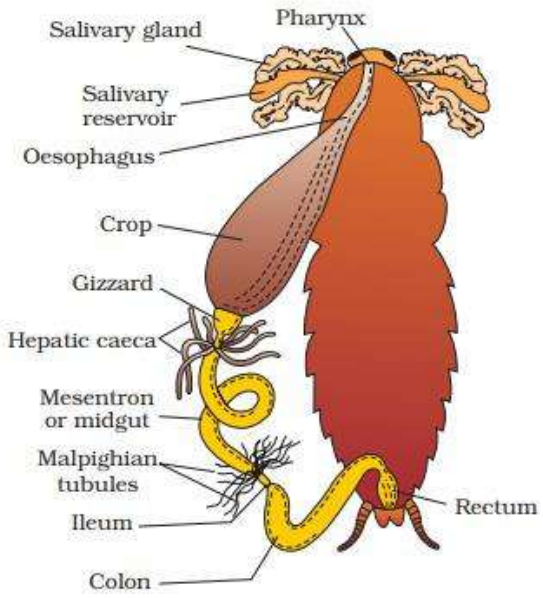


Fig 6.3 *Periplanata* – Digestive system

Digestive glands

The digestive glands associated with the alimentary canal of cockroach are salivary glands, hepatic caecae and glandular cells of the mesenteron.

Salivary glands

There is a pair of salivary glands attached to the ventrolateral sides of the crop, one on each side. Each salivary gland has two lobes. Each lobe of salivary gland has many lobules called **acini.** Each acinus is a group of secretory cells called ***zymocells*** with a small ductule. The ductules of both the lobes of a salivary gland unite to form a **common salivaiy duct** on each side.

The two common salivary ducts are joined to form the **median salivary duct.** Between the two lobes of a salivary gland of each side is a sac called **salivary receptacle** that stores saliva. It leads into a **receptacular duct,** or 'reservoir duct'. The receptacular ducts of both the sides are united to form a **common receptacular duct,** or 'common reservoir duct'. The median salivary duct opens into the common receptacular duct. Later these two form an **efferent salivary duct.** The efferent salivary duct opens at the base of the hypopharynx. Acinar cells secrete saliva, which contains starch digesting enzymes such as **amylase**.

Hepatic caecae

The hepatic caecae are also termed 'midgut caecae'. They contain secretory and absorptive cells.

Glandular cells of the mesenteron

The glandular cells of the mesenteron secrete enzymes such as **maltase invertase, Proerases** and **iipase.**

Physiology of Digestion

a) Food collection: Cockroach is an **omnivorous** insect. It feeds on all types of organic matter. It locates the food by the olfactory sensillae of antenna, labial palps and maxillary palps. The food is seized with the help of forelegs, labrum and labium. It is passed to the mandibles for biting and chewing. The laciniae, galeae, glossae and paraglossae hold the food during chewing. The labrum and labium prevent the food from falling down. The food is mixed with saliva during mastication.

b) Digestion: After swallowing, the food passes through the pharynx and oesophagus and reaches the crop. In the crop, food is mixed with digestive juices that are regurgitated into it through the grooves of the gizzard. Hence, most of the food is digested in the crop. The partly digested food is filtered by the bristles of the gizzard and later it passes through the stomodeal valve into the ventriculus.

The enzyme amylase of the salivary juice converts starches into ***disaccharides.*** ***Invertase*** or *sucrase* digests sucrose into ***glucose*** and ***fructose.*** *Maltase* converts maltose into ***glucose.*** The enzyme *Iipase* digests lipids into ***fatty acids*** and ***glycerol.*** Proteases digest proteins into amino acids. Cellulose of the food is digested by the enzyme ***cellulase*** secreted by the microorganisms present in the hindgut of cockroach. Cellulose is converted into glucose.

In the ventriculus, the digested food is absorbed. The undigested food is passed into the ileum, colon, and then reaches the rectum, where water is reabsorbed by rectal papillae. Then the remaining material is finally ***defaecated*** as **dry *pellets*** through the anus.

6.1.4 Circulatory System

The circulatory system helps in the transportation of digested food, hormones etc., from one part to another in the body. *Periplaneta* has an **open *type*** of circulatory system as the blood, or haemohymph, flows freely within the body cavity or haemocoel. Blood vessels are poorly developed and open into spaces. Visceral organs located in the haemocoel are bathed in the blood. The three main parts associated with the blood circulatory system of *Periplaneta* are the haemocoel, heart, and blood.

Haemocoel: The haemocoel of cockroach is divided into three sinuses by two muscular, horizontal membranes, called **dorsal diaphragm** or 'pericardial septum' and **ventral diaphragm.** Both the diaphragms have pores. There is a series of paired triangular muscles, called **alary muscles.** Every segment has one pair of these muscles situated on the lateral sides of the body. These are attached to the pericardial septum by their broad bases and to the terga by their pointed ends or apices. The three sinuses of the haemocoel are known as **pericardial haemocoel** or the **'dorsal sinus'**, the **perivisceral haemocoel** or the **'middle sinus'** and **sternal haemocoel** or **'ventral sinus'** or **'permeural sinus'.** The middle sinus is very large as it contains most of the viscera. The dorsal and ventral sinuses are small as they have only heart and **nerve cord,** respectively.

Heart

The heart lies in the pericardial haemocoel or dorsal sinus. It is a long, muscular, contractile tube found along the mid dorsal line, beneath the terga of the thorax and abdomen. It consists of 13 chambers. Every chamber opens into the other present in front of it. Three of the thirteen chambers are situated in the thorax and ten in the abdomen. Its posterior end is closed while the anterior end is continued forward as the anterior **aorta.** At the posterior side of each chamber, except the last, there is a pair of small apertures called **ostia** one on each

side. Ostia have valves which allow the blood to pass only into the heart from the dorsal sinus.

Blood

The blood of *Periplaneta* is colourless and is called **haemolymph.** It consists of a fluid called plasma, and free blood corpuscles or haemocytes, which are *'phagocytic'*. The phagocytes are large in size and can 'ingest' foreign particles such as bacteria. There is no respiratory pigment in the blood and so it plays no major role in respiration.

The important functions of the blood are:

1. It absorbs digested food from the alimentary canal and distributes it to the rest of the body.

2. It brings nitrogenous wastes from all parts of the body to the excretory organs for their elimination.

3. It carries defensive phagocytes to the places of infection where they engulf the germs and disintegrating tissue parts.

4. It transports secretions of the ductless glands to the target organs.(Figure 6.4)

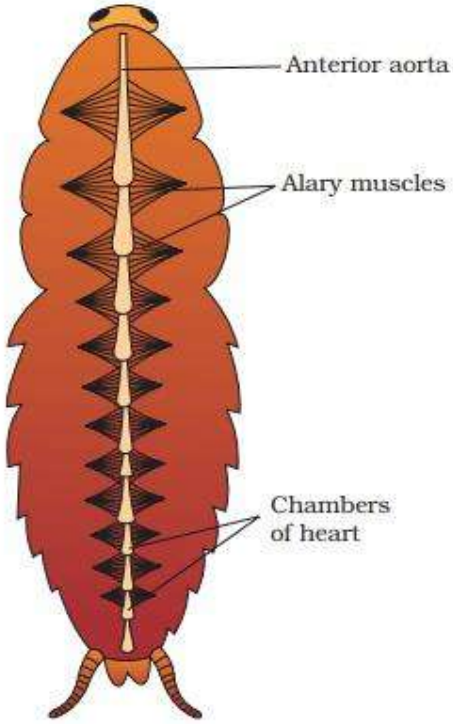


Fig 6.4 *Periplanata* – circulatory system

Circulation of blood

The blood flows forward in the heart by the contractions of its chambers. At the anterior end the heart, the blood flows into the aorta and from there it enters the sinus of the head. From the head sinus, the blood flows into the perivisceral and sternal sinuses. On contraction of the alary muscles the pericardial septum is pulled down. This increases the volume of the pericardial sinus. Hence blood flows from the perivisceral sinus into the pericardial sinus through the appertures of the paricardial spectum. On relaxation of the alary

muscles, the pericardial septum moves upwards to its original position. This forces the blood, to enter the chambers of the heart through the ostia from the pericardial sinus.

GLOSSARY

Abdomen: Third or posterior division of an insect.
Antenna: A sensitive feeler from the animals head: tactile and olfactory in function.
Appendage: A movable projecting part of the body: mouth parts are modified appendages.
Arolium: A soft hairy pad between claws in the leg of cockroach.
Arthropod: A phylum of segmented invertebrates with jointed legs.
Biramous: Possessing two branches.
Cephalic: Relating to head.
Cervix: Neck.
Chitin: A polysaccharide-protein complex; a horny substance.
Cursorial: Swift runner.
Cuticle: External skeletal structure of insect body.
Haemocoel: The body cavity of an arthropod or mollusc filled with haemolymph.
Nervures: Tubular hollow network of the wing of cockroach.
Podomere: A segment of an arthropod leg.
Pulvillus: A soft hairy pad between claws.
Sternum: A ventral sclerite of a body segment of insects.
Tagma: The division of body of an insect into different regions called Tagmatisation.
Tergum: Dorsal sclerite of body segment of an insect.

VERY SHORT ANSWER QUESTIONS

1. Why do you call a cockroach called pest?
2. Name the chitinous tubes that support the wings of cockroach?
3. What is the tegmen?
4. Why is the head in cockroach is called hypognathous?
5. Name the different blood sinuses in cockroach?
6. What are the three regions of the elementary canal in cockroach?
7. Which part of the gut secretes peritropic membrane in cockroach?
8. What are alary muscles?
9. What is heamocoel?
10. Why the blood of periplanata is called heamolymph?
11. Why does not the blood of Periplanata help in respiration?

SHORT ANSWER QUESTIONS

Short answer questions (4 marks)

1. Draw a neat labeled diagram of the mouth parts of cockroach?
2. Draw a neat labeled diagram of the salivary apparatus of cockroach?
3. Describe the physiology of digestion in cockroach?
4. Describe the structure and function of heart in cockroach?

Unit 7

ECOLOGY AND ENVIRONMENT

SUMMARY

The branches of Biology such as 'morphology' and 'anatomy' give us a fairly good picture of organisms. However **Modern Biology** lays stress on studying the habitat, environment - organism relationship ***(Ecology)*** to get a more comprehensive idea of life. Ecology deals with the study of organisms and their interrelationships (biotic factors) and interactions with the surrounding environment (abiotic factors). Interactions between the organisms and the environment limit the distribution of life. The study of ecology encompasses different levels - organism, population, community, ecosystem, etc. An important feature that may not be easily noticeable to the eye of an observer is - the 'steady state' an organism maintains (homeostasis), with reference to its surrounding abiotic factors. This type of homeostasis is achieved by morphological, physiological and behavioural adjustments /mechanisms. Whichever organism is adapted better to its environment 'on a long term basis' is offered **'POSITIVE NATURAL SELECTION PRESSURE'**. Thus ecological adaptations play an important role in **'SPECIATION'**, For example animals such as polar bears grow thicker coat of 'fur' during winter to insulate the body from the cooler environment. Some insects add 'glycerol' (anti-freezing agent) to their blood to avoid freezing in winter. Certain animals show behavioural adaptations to survive -e.g. lizards 'bask' in the sun to warm up their body when sunlight is available and enter shade /burrows when it is very hot out side. Many cold blooded animals are ***'temperature conformers'*** and they change their temperature depending on that of the surroundings. Homeostasis of water *(because water is the most important constituent of protoplasm)* is exhibited by all organisms including the microscopic *protists and* ***bacteria.***

An eminent animal ecologist, **ODUM,** used the ***analogy*** to explain an organism's place and its function thus- IF AN ORGANISM'S HABITAT (place where it lives) IS ITS ***'ADDRESS',*** ITS ECOLOGICAL ROLE/FUNCTION (also called **'niche'**) IS THE ***'PROFESSION'*** OF THE ORGANISM. Underlying all these aspects there are two things that are critically essential to support life on the Earth.

7.0.0 What is Ecology and Ecological Hierarchy

Ecology is a subject which deals with the study of interations among organisms and between organisms and their physical (abiotic) environment. The word ecology was derived from Greek word '*oikos*' which means house and logos means 'study'. Ecology defined by Ernest Haeckel as "the study of the relationships of organisms with their environment". The environmental science ecology has two main braches- **autecology** and **synecology.**

Autecolgy is ecology of single species/ population in relation to environment. It is also known as **species ecology**. Synecology is a branch of ecology that deals with the structure, development, and distribution of ecological communities.

7.1.0 Ecological Hierarchy

Hierarchy means arrangement into a ***'graded series'.*** Ecological organization consists of eleven integrative levels, ranging from Cell to Ecosphere - cell, tissue, organ, organ-system, organism, population, community, ecosystem, landscape, biome and ecosphere (also called Biosphere).

Population

Population is a group of organisms of the same species, living in a specific area at a specific time. For example, the fish belonging to the species *Catta catla* living at a given time, in a pond constitute a 'population'. In the same way, the people (Homo *sapiens)* of India in 2012 form the **Indian population.** Populations are regulated by a set of factors such as **natality, mortality, and population *density.***

Community

It is an association of the interacting members of populations of different autotrophic and heterotrophic species in a particular area. In a community, generally one or a few species dominate with reference to their numbers or size. Generally, a community is named after its dominant population. For example, the Himalayan region (at the altitude of 5000 to 8000 ft.) is dominated by the pine group plants - **deodar trees**. So, it is described as the **Pine-Deodar community**. (Figure 7.1)

Fig 7.1 Pine-deodar community

Ecosystem

It is the next level of organization above the level of *biological* **community. An ecosystem** is a functional unit of the biosphere in which members of the community interact among themselves and with the surrounding environment, involving ***'flow of*** **energy** forming a well defined **trophic structure.** An ecosystem can be as small as an aquarium or a tiny puddle. Ecosystems sometimes may overlap, as the boundaries of an ecosystem are flexible.(Figure 7.2)

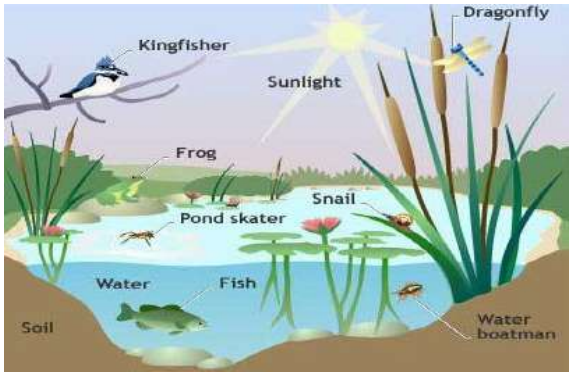


Fig 7.2 Ecosystem

Landscapes

It is the unit of land containing different ecosystems (mosaic of ecosystems) surrounded by natural boundaries. It is the level of organization higher than 'ecosystem'.

Biome

A 'biome' is a ***large community of plants and animals*** that occupies a vast **region.** There are 'terrestrial biomes' and 'aquatic biomes'. Terrestrial biomes are characterized by ***specific climate*** and **dominant *vegetation*** e.g. tropical rain forest, desert, coniferous forest, tundra etc. Aquatic biomes include freshwater biomes and marine biomes.(Figure 7.3)

Fig 7.3 Biomes

Ecosphere (Biosphere)

All the habitable zones on 'the' Earth constitute the ecosphere or biosphere. It is the part of the Earth that supports 'life'. It extends several kilometers above the Earth's surface into the atmosphere and extends several kilometers below the ocean's surface. The biosphere comprises all of the Earth's biomes.

Environment :

Environment is the sum total of biotic and abiotic factors present around the organisms influencing them in various ways. Any component of the environment that

influences the organism is called ***environmental factor.*** The environmental factors are of three types i) climatic, ii) topographical, iii) edaphic.

i) Climate refers to average weather conditions like temperature, humidity, cloud, cover, wind velocity, rainfall, etc.

ii) Topography refers to the surface features (physical features such as elevation / altitude) of a place or region. The topography affects the climatic conditions of the region,

iii) Edaphic factors are related to the soil, and they influence the life of organisms. The main edaghic factors include soil texture, pH, content of organic matter, water, etc.

7.1.1 Habitat and Medium

Ecologically, **habitat** is the place in which an organism lives. It is comparable to the **'address'** of a person (as mentioned in the introduction page to ecology). For instance, the habitat of fish is a pond, lake, sea etc., the habitat of a lion is forest, and the habitat of *Ascaris* is the 'small intestine' of man, and so on. *The **water** surrounding the body of a fish* is *called the **medium*** and the medium of a lion is the **air** around it's body.

7.1.2 Niche

Within a community, each organism occupies a particular biological role or **niche**. Niche is the **functional *role*** of an organism in an ecosystem (comparable to the ***profession'*** of a person, as mentioned in the introduction). It describes the relational position of a species in its ecosystem to each other. For example, the ecological niche of a rose bush growing in the backyard includes absorbing light, water and nutrients for photosynthesis, releasing oxygen into the atmosphere, providing shelter and food for other organisms (e.g. **aphids**) **- in *short the 'rose bush' is a 'producer'.***

7.1.3 Abiotic factors (ecosystem- elementary aspects)

An 'ecosystem' consists of both **structural** components and ***functional*** components. The structural components of ecosystem are of two types - **abiotic** and **biotic** factors. Abiotic factors are again of two types- physical and chemical factors. The physical factors are light, temperature, soil, pressure, etc., Oxygen, carbon dioxide and the various mineral nutrients in the soil /water constitute the chemical factors. These physical and chemical factors affect the life of the organisms present in an ecosystem.

Light

Since plants produce food through photosynthesis, a process which is only possible when sunlight is available as a source of energy, we can easily understand the importance of light for all living organisms, particularly the 'autotrophs'. Many species of small plants (herbs and shrubs) growing in forests are adapted to photosynthesize optimally under very low light conditions because they are constantly overshadowed by tall trees with well spread branches. Many plants are also dependent on sunlight to meet their ***photoperiod requirement*** for flowering.

For many animals, light is important in that they use the diurnal and seasonal variations in the **intensity** and **duration (photoperiod)** of light, as cues (indications) for timing their foraging (collection of food), reproductive and migratory activities. The availability of light on land is closely linked with that of temperature since the sun is the source of both. But, deep in the oceans, the environment is always dark and its inhabitants do not experience light. The spectral quality of solar radiation is also important for life. The UV component of the spectrum is harmful to many organisms. All the colour components of the visible spectrum are not available for marine plants, living at different depths of the seas.

Biological effects of light

Light is an ecological factor that shows its influence on many biological phenomena and activities like pigmentation, movement, vision, metabolism, etc.

Effect of light on pigmentation

Light influences the colour of the skin. The animals which live in regions of low intensity of light such as caves, have less pigmentation than that of the animals exposed to light. For example a cave dwelling amphibian, ***Proteus anguinus,*** has *pale* coloured skin because of less pigmentation. When it is brought into sunlight the skin colour turns *dark.*

Effect of light on direction and rate of movement

Response shown by an organism to changes in light is called **photoresponse.** The major photoresponses of motile organisms include:

1. **Phototoxis** is oriented locomotor movement of an organism towards or away from the direction of light as seen in euglenas (positive response). Cockroaches (negative response) and,
2. **Photokinesis** is the influence of light on non- directional movement of organisms as seen in the larvae *of Pinnotheres macculatus*- the mussel crab, in which intensity of light influences the velocity of the movement of the organism.

Influence of Light on Vision and Behavior.

Light is essential for vision, to procure food, self protection, identification and selection of the mate for sexual reproduction. It also influences the behaviour of organisms. Some animals are active during the 'day time' **(diurnal** animals **e.g.** majority of the birds, reptiles and mammals. Others, which are active during night time are called **nocturnal** animals e.g. earthworms, cockroaches, etc.,

Effect of light on metabolism

The intensity of light influences the rate of metabolism in animals. At lower, intensities of light the rate of metabolism slows down, where as in higher intensities it increases.

Effect of light on biological rhythms

By definition rhythm is a change that is repeated with similar pattern. In the bodies of organisms many behavioural activities are repeated at regular intervals and these are called biological rhythms.

Biological rhythms that occur in a time period of 24 hours are **circadian rhythms,** If the biological rhythms repeat annually (every year), they are called **circannular rhythms.** They are controlled by **'biological clocks'** present in many living organisms. Light has a role in setting or resetting the biological clocks.

Effect of 'photoperiod' on animals (photoperiodism)

The duration of the light hours / exposure to light in a day is known as ***photoperiod.*** The response of organisms for the photoperiod is called **photoperiodism.** The response to photoperiod often centers on reproduction and survival (production of flowers, the migration of birds etc.,). The specific day length, which is essential for the initiation of seasonal events is called **'critical photoperiod'.**

The length of critical photoperiod is not the same in all the species, it varies from species to species and also within the same species inhabiting at various latitudes. For example, when winter sets in Siberia, the light available time in a day decreases, and so some birds migrate all the way to the *new* ***feeding*** and ***breeding grounds*** in various parts of India. When it is summer time back in Siberia they migrate back to their homeland.

Effect of UV Rays

The short wave lengths of light less than 380nm are called ***Ultraviolet rays.*** *UV* radiation is classified into three categories: UVC light (lOOnm to 280 nm), UVB (280nm to 320nm) and UVA (320nm to 380nm). UV radiation kills the microorganisms present on the body surfaces of animals. UV radiation helps in the conversion of sterols present in the skin into vitamin D in mammals. Compared to UVA rays UVB and UVC rays are more harmful to organisms.

7.2.0 Biotic Factors

Producers

The green plants in the ecosystem-terminology are called ***producers.*** They synthesize the food by using solar energy. But certain bacteria such as Iron and Sulphur bacteria are ***chemoautotrophs.*** They fix carbon dioxide by using the energy obtained by the breaking down of certain chemical substances. In a terrestrial ecosystem, the major producers are the herbaceous and woody plants. Likewise, primary producers in an aquatic ecosystem include various species like microscopic phytoplanktonic organisms, algae and some higher plants. The producers form the first trophic level in most food chains. They constitute the main source of food for the organisms of the second/ next higher trophic level-the 'consumers'.

I. Consumers

All animals depend on plants (directly or indirectly) for their food needs. They are hence called consumers and also ***heterotrophs.*** If they feed on the producers -(the plants) they are called **primary consumers.** If the animals eat other animals, which eat plants or plant products, they are called ***secondary consumers.*** Likewise, you could have ***tertiary consumers*** too. Obviously the primary consumers are the herbivores. Some common herbivores are insects, birds and mammals in the terrestrial ecosystem and arthropods and molluscs in the aquatic ecosystems. (Figure 7.4)

Figure 7.4 Biotic factors: Producers-consumers

II. Decomposers

You may have heard of the earthworm being referred to as the farmer's 'friend'. This is so because they help in the breakdown of complex organic matter as well as in loosening of the soil (making the soil porous). Similarly, decomposers break down complex organic matter into simple inorganic substances like carbon dioxide, water and nutrients and the process is called **decomposition.** Plant parts such as leaves, bark, flowers and dead remains of animals, including their faecal matter, constitute the **detritus.** Detritus is the ***'raw material*** for **'decomposition'.** The important steps in the process of decomposition are ***fragmentation, leaching, catabolism. humification*** and ***mineralization.***

Detritivores (e.g. earthworm) break down detritus into smaller particles and this process is ***called fragmentation.*** By the process of ***leaching,*** water soluble inorganic nutrients go down into the soil and get precipitated as unavailable salts. Bacterial and fungal enzymes degrade detritus into simpler inorganic substances. This process is called as ***catabolism.***

It is important to note that all the above steps in decomposition operate simultaneously on the detritus. Humification and mineralization occur during decomposition

in the soil. Humification leads to accumulation of a dark coloured amorphous substance called **humus** that is highly resistant to microbial action and undergoes decomposition at an extremely slow rate. Being colloidal in nature it serves as a ***reservoir of nutrients.*** The humus is further degraded by some microbes and release of inorganic nutrients occurs by the process known as **mineralization.**

Decomposition

Decomposition is largely an oxygen-requiring process. The rate of decomposition is controlled by chemical composition of the detritus and climatic *factors.* In a particular climatic condition, decomposition rate is slower if detritus is rich in ***lignin*** and **chitin,** and quicker, if detritus is rich in ***nitrogen*** and water -soluble substances like ***sugars.*** Temperature and soil moisture are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes. Warm and moist environment favours decomposition whereas ***low*** temperature and ***anaerobic environment*** 'inhibit' the decomposition resulting in build up of organic materials. As most of the decomposers are very small microscopic forms, they are also called 'micro-consumers'.

7.3.0 Population interactions

Can you think of any natural habitat on earth that is inhabited just by a single species? There is no such habitat and such a situation is unimaginable. For any species, the minimal requirement is one more species on which it can feed. Even a plant species, which makes its own food, cannot survive alone; it needs soil microbes to break down the organic matter in soil and return the inorganic nutrients for absorption. And then, how will the plant manage pollination without an animal agent? It is obvious that in nature, animals, plants and microbes do not and cannot live in isolation but interact in various ways to form a **biological community** even in minimal communities; many interactive linkages exist, although all may not be readily visible.

7.3.1 Inter-specific Interactions

Inter-specific interactions arise from the interaction of populations of two different species. They could be beneficial, detrimental or neutral (neither harmful nor beneficial) to one of the species or both. Assigning a '+' sign for beneficial interaction, '-' sign for detrimental and '0' for neutral interaction, let us look at all the possible outcomes of inter-specific interactions.

The interactions between species are grouped into four types. They are mutualism, commensalism, parasitism and amensalism. Both the species benefit in **mutualism** and both lose in **competition** in their interactions with each other. The interaction where one species is benefitted and the other is neither benefitted nor harmed is called **commensalism** In **amensalism** on the other hand one species is harmed whereas the other is unaffected. In both **parasitism** and **Predatiori** only one species benefits (parasite and predator, respectively) and the interaction is detrimental to the other species **(host** and ***prey,*** respectively). Predation, parasitism and commensalisms share a common characteristic - the interacting species live closely together.

Population Interactions-Types

Name of Interaction	Species A	Species B
Mutualism	+	+
Competition	-	-
Predation	+	-
Parasitism	+	-
Commensalism	+	0
Amensalism	-	0

7.3.2 Predation

What would happen to all the energy fixed by autotrophic organisms if the community has no animals to eat the plants? You can think of predation as nature's way of transferring the energy fixed by plants to higher trophic levels. When we think of predator and prey, most probably it is the tiger and the deer that readily come to our mind, but a sparrow eating any seed is also a type of predator (a seed predator-also called ***granivor.*** Although animals eating plants are categorized separately as herbivores, they are, in abroad ecological context, not very different from predators.

Besides acting as 'conduits'/ 'pipelines' for energy transfer across trophic levels, predators play other important roles. They keep the prey populations under control. In the absence of predators, the prey species could achieve very high population densities and cause instability in the ecosystem. Predators have different types of functions to play in nature. They include:

A. Predator as a biological control

The prickly pear cactus introduced into Australia in the early 1920s caused havoc by spreading rapidly into millions of hectares of rangeland (vast natural grass lands). Finally, the invasive cactus was brought under control only after a cactus-feeding predator (a moth) was introduced into the country. **Biological control** methods adopted in agricultural pest control are based on the ability of the predators to regulate prey populations.

B. Predators maintain 'species diversity'

Predators also help in maintaining species diversity in a community, by reducing the intensity of competition among competing prey species. In the rocky intertidal communities of the American Pacific Coast, the starfish *Pisaster* is an important predator. In a field experiment, when all the starfish were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year, because of increased ***inter - specific competition.***

C. Predators are prudent (practical) pertaining to preys

If a predator is too efficient and overexploits its prey, then the prey might become extinct and following it, the predator will also become extinct due to lack of food. This is the reason why predators in nature are *"prudent.*

Prey species have evolved various defences to lessen the impact of predation.

They include:

a) Preys *fool (deceive) or avoid their predators:* Some species of insects and frogs are cryptically-coloured ***(camouflaged),*** to avoid being detected easily by the predator. Some are poisonous and therefore avoided by the predators.

b) Preys defend by becoming distasteful to predators: The **Monarch *butterfly*** is highly distasteful to its predator (bird) because of a special chemical present in its body. Interestingly, the butterfly acquires this chemical during its ***caterpillar stage*** by feeding on a **poisonous *weed.***

c) Plants too have their defensive mechanisms: For plants, herbivores are the predators. Nearly 25 per cent of all insects are known to be **phytophagous** (feeding on plant sap and other parts of plants). The problem is particularly severe for plants because, unlike animals, they cannot escape from their predators. Plants therefore have evolved a variety of morphological and chemical defences against herbivores.

i) **Thorns** (Acacia, Cactus, etc.,) are the most common morphological means of defense. Many plants produce and store chemicals that make the herbivore sick when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it.

ii) You must have seen the weed Calotropis growing in abandoned fields. The plant produces highly poisonous ***cardiac glycosides*** and that is why you never see any cattle or goats browsing on this plant.

iii) A wide variety of chemical substances that we extract from plants on a commercial scale (**nicotine, *caffeine, quinine, strychnine, opium,*** etc.,) are produced by them actually as defences against grazers and browsers.

7.4.0 Competition *(interspecific competition0*

When Darwin spoke of the struggle for existence and survival of the fittest in nature, he was convinced that ***interspecific competition*** is a 'potent force' in the process of organic evolution, involving Natural Selection. It is generally believed that competition occurs when closely related species compete for the same resources that are limited, but this is not entirely true.

I. Competition among *Unrelated Species*

Firstly, unrelated species could also compete for the same resource (Interspecific competition). For instance, in some **shallow** South American lakes visiting **FIamingos** and residentjishes compete for their common food, the suspended **zooplankton** in the shallow waters. Secondly, resources need not be limiting for competition to occur. In ***interference competition,*** the feeding efficiency of one species might be reduced due to the interfering and inhibitory presence of the other species, even if resources (food and space) are abundant. Therefore, *competition is best defined as a process in which the fitness of one species (measured in terms of its* **'r'***- the intrinsic rate of increase) is significantly lower in the presence of another species.*

II. Competitive exclusion

It is relatively easy to demonstrate in laboratory experiments, as **Gause** and other experimental ecologists did. When the resources are limited, the competitively superior species will eventually eliminate the other species e.g. the Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, actually due to the greater browsing efficiency of the goats.

III. Competitive release

Another evidence for the occurrence of competition in nature comes from what is called **'competitive release.** Competitive release occurs when one of the two competing species is removed from an area, thereby releasing the remaining species from one of the factors that limited its population size. A species, whose distribution is restricted to a small geographical area because of the presence of a competitively superior species, is found to expand its distributional range dramatically when the ***competing species*** is experimentally removed. This is due to the phenomenon called ***'competitive release'.*** **Counell's** 'field experiments' showed that, on the rocky sea coasts of Scotland, the larger and competitively superior barnacle *Balanus* dominates the intertidal area, and excludes the smaller barnacle Chathamalus from that zone. When the dominant one is experimentally removed, the populations of the smaller ones increased. In general, herbivores and plants appear to be more adversely affected by competition than the carnivores (Ref: **ncert** text book).

IV. Coexistence, rather than exclusion

Gause's *principle of 'Competitive Exclusion'* states that two closely related species competing for the same resources cannot co-exist indefinitely and the ***competitively inferior one*** will be eliminated in due course of time. This may be true if resources are limiting, but not otherwise.

More recent studies point out that species facing competition might evolve mechanisms that promote **co-existence** rather than competitive exclusion. One such mechanism is **'resource partitioning',** if two species compete for the same resource, they could avoid competition by choosing, for instance, *different times for feeding* or *different foraging (food collecting) patterns.* **MacArthur** showed that five closely related species of

warblers (a kind of birds) living on the same tree was able to *avoid competition* and *co-exist* due to behavioural differences in their foraging activities.

7.4.1 Parasitism

Considering that the parasitic mode of life ensures free 'lodging' and 'meals', it is not surprising that parasitism has evolved in so many taxonomic groups from plants to higher vertebrates. Many parasites have evolved to be ***host-specific*** (they can parasitize only a specific species of host) in such a way that both host and the parasite tend to ***co-evolve;*** that is, if the host evolves special mechanisms for rejecting or resisting the parasite, the parasite has to evolve mechanisms to *'counteract'* and *'neutralize'* them, in order to continue successful parasitic relationship with the same host species. In order to lead successful parasitic life, parasites evolved special adaptations, such as:

a. Loss of sense organs (which are not necessary for most parasites).
b. Presence of adhesive organs such as suckers, hooks to cling on to the host's body parts.
c. Loss of digestive system and presence of high reproductive capacity.
d. The life cycles of parasites are often **complex,** involving one or two intermediate hosts or vectors to facilitate parasitisation of their *primary* hosts.

e.g.-l: The human liver fluke depends on two ***intermediate*** *(secondary)* ***hosts*** (a **snail** and a **fish)** to complete its life cycle.

e.g.-2: The malaria parasite needs a vector (mosquito) to spread to other hosts.

Majority of the parasites harm the host; they may reduce the survival, growth and reproduction of the host and reduce its population density. They might render the host more vulnerable to predation by making it physically weak.

The Types of Parasites

I. Ectoparasites: These parasites feed on host organism while remaining outside the body of the host. The most familiar examples of this group are the ***lice*** on humans and ***ticks*** on dogs. Many marine fish are infested with ectoparasitic copepods.

II. Endoparasites: Endoparasites are those that live inside the host's body at different sites (liver, kidney, lungs, red blood cells, etc.,). The life cycles of endoparasites are more complex because of their extreme specialization. Their morphological and anatomical features are greatly simplified while emphasizing (stressing on) their reproductive potential.

III. Brood Parasites: Certain birds are fascinating examples of a special type of parasitism, in which the parasitic bird lays its eggs in the nest of its host and lets / allows the host incubates them. During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest.

Try to follow the movements of the cuckoo (koel) and the crow in your neighborhood park during the breeding season (spring to summer) and watch brood parasitism in action.

7.4.2 Commensalism .

This is the interaction in which one species benefits and the other is neither harmed nor benefited. Barnacles growing on the back of a whale benefit while the whale derives no noticeable benefit.

7.4.3 Mutualism

This type of interaction benefits both the interacting species.

The most common examples of mutualism are found in plant-animal relationships. Plants need the help of animals for **pollinating** their flowers and **dispersing** their seeds. Animals obviously have to be paid **'fees'** for the services that plants derive from them. Plants offer rewards in the form of **pollen** and **nectar** for pollinators and juicy and nutritious ***fruits*** for seed dispersing animals.

Now you can see why plant-animal interactions often involve **co-evolution** of the mutualists, that is, the evolutions of the flower and its pollinator species are tightly linked with one another.

The 'cattle egret' (a kind of bird) and 'grazing cattle' living in close association, is a classic example of commensalism. The egrets always forage close to where the cattle are grazing because the cattle, as they move, stir up and drive out insects, from the vegetation thus helping the egrets to find and catch the insects. Another example of commensalism is the interaction between **sea anemon** that has tentacles with **Stinging cells** and the '**Clown Fish**' that lives among them. The fish gets protection from predators, as the predator stays away from the stinging tentacles of the anemone. The anemone does not derive any visible benefit by 'hosting' the clown fish.

In many species of fig trees, there is a one-to-one relationship with the pollinator species of **wasp** It means that a given **fig species** can be pollinated only by its **'partner' wasp** species and no other species. The female wasp uses the fruit not only as a site for oviposition **(egg-laying site),** but also uses the developing seeds within the fruit for nourishing its larvae. The wasp pollinates the flowers of the fig plant while searching for suitable egg-laying sites. In return for the favour of pollination the fig offers the wasp some of its developing seeds, as food for the developing wasp larvae.

Orchids show a high degree of diversity of floral patterns. Many of them have evolved to attract the right pollinator insect (bees and bumblebees) and ensure pollination by it. Not all orchids offer rewards. The Mediterranean orchid *Ophrys* employs **'sexual deceit'** to get pollination done by a specific species of bee. One petal of its flower resembles the female of the bee in size, colour and markings. The male bee is attracted to the 'petal' as it presumes it to be the female, **'pseudocopulates'** with the flower, and during that process, it is dusted with pollen from the flower. When the same bee 'pseudocopulates' with another flower, it transfers the pollen to it. Here you can see how ***co-evolution*** operates in nature. If the female bee's colour patterns change even slightly, for any reason in the course of evolution, pollination success will be reduced, unless the orchid flower ***co-evolves*** and alters the resemblance of its petal to the changed female bee.

7.5.0 The Food Chains

Energy flows into biological systems (ecosystems) from the Sun. The biological systems of environment include several food levels called **trophic levels.** A trophic level is composed of those organisms which have the same source of energy and having the same number of steps away from the sun. Thus a plant's trophic level is ***one***. while that of a herbivore - ***two,*** and that of the first level carnivore - ***three.*** The second and third levels of the carnivores occupy ***fourth*** and ***fifth*** trophic levels respectively.

A given organism may occupy more than one trophic level simultaneously. One must remember that the trophic level represents a functional level. A given species may occupy more than one trophic level in the same ecosystem at the same time; *for example, a sparrow is a primary consumer when it eats seeds, fruits, and a secondary consumer when it eats insects and worms.*

The food energy passes from one trophic level to another trophic level mostly from the lower to higher trophic levels. When the path of food energy is 'linear', the components resemble the 'links' of a chain, and it is called ***'food* chain'.** Generally a food chain ends with decomposers. The three major types of food chains in an ecosystem are *Grazing Food Chain, Parasitic Food Chain and Detritus Food Chain.*

I. Grazing Food Chain

It is also known as *predatory food chain.* It begins with the green plants (producers) and the second, third and fourth trophic levels are occupied by the *herbivores,* primary

carniuores and secondary *carnivores* respectively.(Figure 7.5) In some food chains there is yet another trophic level - the climax carnivores. The number of trophic levels in food chains varies from 3 to 5 generally. Some examples for *grazing food chain* **(GFC)** are given below.

I Trophic level	II Trophic level	IIITrophic level	IV Trophic level	V Trophic level
Rosebush →	Amphids →	Spiders →	Small birds →	Hawk
Grass →	Grasshooper →	Frog →	Snakes →	Hawk
Plants →	Caterpiller →	Lizard →	Snake	
Phytoplanktons →	Zooplankton →	Fish →	Bird	
Grass →	Goat →	Man		

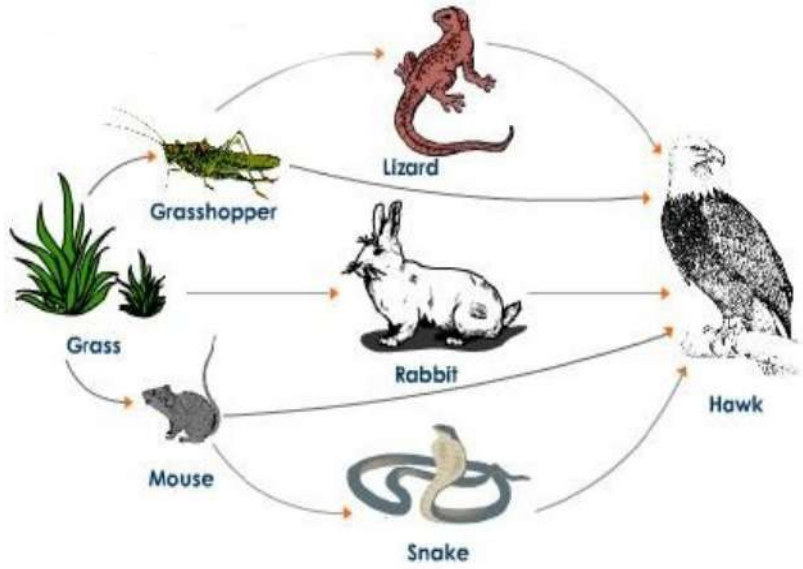


Fig 7.5 Grazing food chain

II. Parasitic food chain

Some authors included the 'Parasitic Food Chains' as a part of the GFC. As in the case of GFCs, it also begins with the producers, the plants (directly or indirectly). However, the food energy passes from large organisms to small organisms in the parasitic chains. For instance, a tree which occupies the 1st trophic level provides shelter and food for many birds. These birds host many ***ecto-parasites*** and ***endo-parasites.*** Thus, unlike in the predator food chain, the path of the flow of energy includes fewer, large sized organisms in the lower trophic levels, and numerous, small sized organisms in the successive higher trophic levels.

III. Detritus Food Chain

The detritus food chain (**DFC**) begins with dead organic matter (such as leaf litter, bodies of dead organisms). It is made up of ***decomposers*** which are ***heterotrophic organisms,*** mainly the 'fungi' and 'bacteria'. They meet their energy and nutrient requirements by

degrading dead organic matter or detritus. These are also known as ***saprotrophs*** (sapro: to decompose).

Decomposers secrete digestive enzymes that breakdown dead and waste materials (such as faeces) into simple absorbable substances. Some examples of detritus food chains are:

1. Detritus (formed from leaf litter)-Earthworms -Frogs -Snakes
2. Dead animals -Flies and maggots -Frogs -Snakes

In an aquatic ecosystem, GFC is the major 'conduit' for the energy flow. As against this, in a terrestrial ecosystem, a much larger fraction of energy flows through the detritus food chain than through the **GFC**. Detritus food chain may be connected with the grazing food chain at some levels. Some of the organisms of **DFC** may form the prey of the **GFC** animals. For example, in the detritus food chain given above, the earthworms of the **DFC** may become the food of the birds of the **GFC.** It is to be understood that food chains are not 'isolated' always.(Figure 7.6)

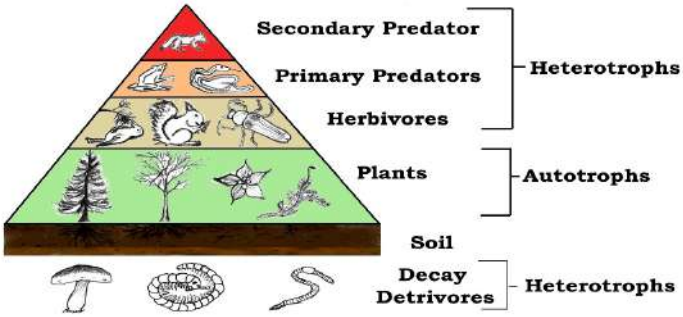


Fig 7.6 Detritus food chain

7.5.1 Food Web

In a simple GFC the food energy flows through in ***linear trophic levels.*** However, in an ecosystem the feeding relationships are never that simple. The feeding interrelationships become more complex because of the omnivores present in the ecosystem. For instance man, birds and some other animals are **'omnivores',** by their feeding habits. In such cases it is difficult to place an animal in a simple / single food chain as they have many interconnections with the animals of other food chains. These natural interconnections of food chains form a 'net-work' called **'food web'**. (Figure 7.7)

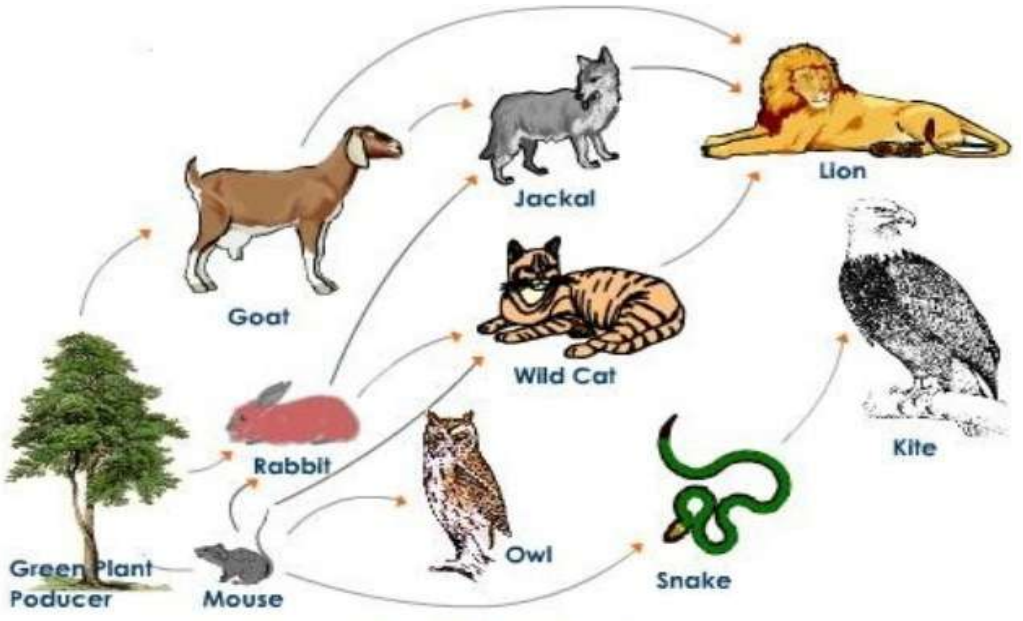


Fig 7.7 Food web

7.5.2 Energy Flow

Except for the deep sea ***hydro-thermal ecosystem,*** sun is the only source of energy for all ecosystems on Earth. Of the incident solar radiation less than 50 per cent of it is ***photosynthetically active radiation*** (PAR). We know that plants and photosynthetic bacteria (autotrophs), fix Sun's radiant energy to synthesise food from simple inorganic materials. Plants capture only 2-10 percent of the PAR and this small amount of energy sustains the entire living world. So, it is very important to know how the solar energy captured by plants flows through different organisms of an ecosystem. All heterotrophs are dependent on the producers for their food, either directly or indiretly. The law of conservation of energy is the ***first law of thermodynamics.*** It states that energy may transform from one form into another form, but it is neither created nor destroyed. The energy that reaches earth is balanced by the energy that leaves the surface of the earth as invisible heat radiation.

The energy transfers in an ecosystem are essential for sustaining life. Without energy transfers there could be no life and ecosystems. Living beings are the natural proliferations that depend on the continuous inflow of concentrated energy.

Further, ecosystems are not exempted from the Second *Law of* thermodynamics. It states that no process involving energy transformation will spontaneously occur unless there is degradation of *energy.* As per the second law of thermodynamics -the energy dispersed is in the form of unavailable heat energy, and constitutes the ***entropy*** *(energy lost or not available for work in a system).* The organisms need a constant supply of energy to synthesize the molecules they require. The transfer of energy through a food chain is known as ***energy flow.*** A constant input of mostly solar energy is the basic requirement for any ecosystem to function. The important point to note is that the amount of energy available decreases at successive trophic levels. When an organism dies, it is converted to detritus or dead biomass that serves as a source of energy for the decomposers. Organisms at each trophic level depend on those at the lower trophic level, for their energy demands.

Each trophic level has a certain mass of living material at a particular time, and it is called the **standing crop.** The standing crop is measured as the **mass** of living organisms **(biomass)** or the number of organisms per unit area. The biomass of a species is expressed in

terms of fresh or dry weight (dry weight is more accurate -because water contains no usable energy).

The 10 percent Law

The 10 percent law for the transfer of energy from one trophic level to the next was introduced by Lindeman (the Founder of the modern Ecosystem Ecology). According to this law, during the transfer of energy from one trophic level to the next.only about 10 percent of the energy is stored/ converted as body mass / biomass. The remaining is lost during the transfer or broken down in catabolic activities (Respiration). Lindeman's rule of trophic efficiency/ Gross ecological efficiency is one of the earliest and most widely used measures of ecological efficiency. For *example, if the NPP (Net primary production) in a plant is 100 kJ, the organic substance converted into* ***body*** **mass** *of the herbivore whichfeeds on it is 10 kJ only.* Similarly the **body mass** *of the carnivore-I is 1 kJ only. .*

7.5.3 Productivity ;

The *rate of production* of biomass is called ***productivity.*** It can be divided into **primary** and ***secondary*** productivities.

I. Primary productivity is defined as the amount of biomass or organic matter produced per unit area over a period of time by plants, during photosynthesis. It can be divided into gross primary productivity (GPP) and net primary productivity (NPP).

a) *Gross Primary* productivity of an ecosystem is the rate of production of organic matter during photosynthesis. A considerable amount of GPP is utilized by plants for their catabolic process (respiration).

b) Net primary productivity Gross primary productivity minus respiratory loss (R), is the net primary productivity (NPP). On average about 20-25 percent of GPP is used for the catabolic (respiratory) activity.

GPP - R = NPP

The net primary productivity is the biomass available for the consumption of the heterotrophs (herbivores and decomposers).

II. Secondary productivity is defined as the rate of formation of new organic matter by consumers.

7.6.0 Population Growth

The size of a population for any species is not a static parameter. It keeps changing in time, depending on various factors including availability of food, 'predation pressure' and **'environmental resistance**'. These changes in population density provide information whether it is *'flourishing* or *declining'*. Whatever might be the ultimate reasons, the density of a population in a given habitat during a given period, fluctuates due to changes in four basic processes/ factors. **Natality** and **immigration** contribute to an increase in population density where as **mortality** and **emigration** lead to a decrease.

(i) Natality refers to the number of births during a given period in the population that are added to the initial number of individuals.

(ii) Mortality is the number of deaths in the population during a given period,

(iii) Immigration is the number of individuals of the same species that have come into the habitat/ population from elsewhere/ another population during the time period under consideration.

(iv) Emigration is the number of individuals of the population who left the habitat / population, during the time period under consideration.

So, if **"N"** is the population density at time **'t'**, then its density at time **t + 1** is

$N_{t+1} = N_t + \{(B + I) - (D + E)\}$

It can be seen from the above equation that population density will increase if the number of births plus the number of immigrants **(B +I)** is more than the number of deaths plus the number of emigrants **(D + E),** otherwise it will decrease. Under normal conditions,

births and deaths are the most important factors influencing population density, the other two factors assuming importance only under special conditions. For instance, if a new habitat is just being colonised, immigration may contribute more significantly to the population growth than birth rate.

Growth Models

Does the growth of a population with time show any specific and predictable pattern? Uncontrolled growth of human population and resultant problems in our country are seriously concerning our planners. Therefore naturally we are curious to know whether different animal populations in nature behave the same way or show some restraints on growth. Perhaps we can learn a lesson or two from nature on how to control population growth.

(i) Exponential growth: Resource **(food** and **space)** availability is essential for the unhindered growth of a population. Ideally, when resources in the habitat are unlimited, each species has the potential ability to grow in number, as Darwin observed while developing his theory of Natural Selection. In such conditions, the population grows in an **'exponential'** or **'geometric'** fashion. If in a population of size **N**, the birth rates (not total number but *per* capita births) are represented as **b** and death rates (again, *per capita* death rates) as ***d,*** then the increase or decrease in **N** during a unit time period **t (dN/dt)** will be:

Let

The **'r'** in this equation is called the **'intrinsic rate *of* natural increase'** and is a very important parameter chosen for assessing impacts of any biotic or abiotic factor on population growth.

To give you some idea about the magnitude of **r** values, for the Norway rat, the r is 0.015, and for the flour beetle- it is 0.12. In 1981, the **r** value for human population in India was **0.0205.**

The above equation describes the exponential or geometric growth pattern of a population (Figure) and results in a J-shaped curve when we plot **N** in relation to time. Using the principles of calculus, we can derive the integral form of the exponential growth equation as

$N_t = N_o e^{rt}$ where

N_t = Population density after time **t** ;

N_o = Population density at time zero:

r = Intrinsic rate of natural increase

e = The base of natural logarithms (2.71828)

Any species growing exponentially under unlimited resource conditions can reach enormous population densities in a short time. Darwin showed how even a slow growing animal like elephant could reach enormous numbers in the absence **of 'natural checks'.**

(ii) Logistic growth: No population of any species in nature has at its disposal unlimited resources to permit exponential growth. This leads to competition between individuals for limited resources. Eventually, the 'fittest' individual will survive and reproduce. The governments of many countries have also realised this fact and introduced various control measures to limit growth of human population. In nature, any given habitat will have enough resources to support a maximum possible number, beyond which no further growth is possible. Let us call this limit as nature's **carrying capacity (K)** for that species in that habitat.

A population growing in a habitat with limited resources show initially a **lag phase,** followed by phases of **acceleration** and **deceleration** and finally an **asymptote / stability,** when the population density reaches the carrying capacity. A plot of **N** in relation to time **(t)** results in a **sigmoid curve.** This type of population growth is called **Verhulst-Pearl Logistic Growth** (Figure) and is described by the following equation:

Where
N = Population density at time **t**
r = Intrinsic rate of natural increase
K = Carrying capacity

Population Growth curves; Curve **'a'** shows the exponential *growth* in population when resources are unlimited; Curve **'b'** shows the logistic growth in population when resources are a limiting factor where **K** is the *carrying capacity.*

7.7.0 Environmental issues

Pollution

With an enormous increase in human population over the last 100 years, there is a heavy demand for food, water, clothing, home, roads, transport facilities and other innumerable commodities needed by man. To meet the demand man is exerting tremendous pressure on natural resources, thereby causing **environmental pollution.**

Pollution is an undesirable change in the physical, chemical or biological characteristics of the environment due to natural causes and human activities. *Any deviation from the natural composition of the environment which causes adverse effects is also described as* pollution. *The agents which cause* pollution *are called* **pollutants.**

Types of pollution

More commonly pollution is classified according to the type of environment that is affected. Mainly there are three types. 1. Air Pollution 2. Water Pollution and 3. Soil Pollution.

7.7.1 Air Pollution and its control

Earth is surrounded by an envelope of air consisting of various gases which is called atmosphere. As a blanket of gases atmosphere acts as a thermal insulator and regulates the temperature on the earth by selectively absorbing U.V.rays of solar radiation. The composition of the main gases in dry air by volume is Nitrogen **78.09%,** Oxygen **20.94%,** Argon **0.93%,** Carbon dioxide **0.03%.** Life cannot exist on earth without oxygen. Air pollutants cause injury to all living organisms. They reduce growth and yield of crops. They are harmful to the respiratory system of humans and animals. Increase in the concentration of pollutants or duration of exposure increase the harmful effects on the organisms.

The major air pollutants

1. Carbon monoxide (CO)

It is produced mainly due to incomplete combustion of fossil fuels. Automobiles are a major cause of CO pollution in larger cities and towns. Automobile exhausts, fumes from factories, emissions from power plants, forest fires and even burning of fire-wood contribute to CO pollution. Haemoglobin has greater affinity for CO and so CO competitively interferes with oxygen transport. CO causes symptoms such as **headache** and **blurred vision** at lower concentrations. In higher concentrations, it leads to coma and death.

2. Carbon Dioxide (CO_2) :

Carbon dioxide is the main pollutant that is leading to **global *warming.*** Plants utilize CO_2 for photosynthesis and all living organisms emit carbon dioxide in the process of respiration. With rapid urbanization, automobiles, aeroplanes, power plants, and other human activities that involve the burning of fossil fuels such as gasoline, carbon dioxide is turning out to be an important pollutant of concern.

3. Sulphur Dioxide (SO_2) :

It is mainly produced by burning of fossil fuels. Melting of sulphur ores is another important source for SO_2 pollution. Metal smelting and other industrial processes also

contribute to SO_2 pollution. Sulfur dioxide and nitrogen oxides are the major causes of **acid rains,** which cause acidification of soils, lakes and streams, and also accelerated corrosion of buildings and monuments. High concentrations of sulphur, dioxide (SO_2) can result in breathing problems in asthmatic children and adults. Other effects associated with long-term exposure to sulphur dioxide, include respiratory illness, alterations in the lungs' defenses and aggravation of existing cardiovascular problems.

To control SO_2 pollution, the emissions are filtered through scrubbers. Scrubbers are devices that are used to clean the impurities in exhaust gases. Gaseous pollutants such as SO_2 are removed by scrubbers*.

4. Nitrogen Oxides

Nitrogen oxides are considered to be major primary pollutants. The source is mainly automobile exhaust. The air polluted by nitrogen oxides is not only harmful to humans and animals, but also dangerous for the life of plants. Nitrogen oxide pollution also results in **acid rains** and formation of **photochemical *smog.*** The effect of nitrogen oxides on plants include the occurrence of necrotic spots on the surface of leaves. Photosynthesis is affected in crop plants and the yield is reduced. Nitrogen oxides combine with volatile organic compounds by the action of sunlight to form secondary pollutants called **Peroxyacetyl nitrate** (PAN) which are found especially in photochemical smog*. They are powerful irritants to eyes and respiratory tract

5. Particulate matter / Aerosols

Tiny particles of solid matter suspended in a gas or liquid constitute the 'particulate matter'. Aerosols' refer to particles and/or liquid droplets and the gas together **(a system *of colloidal particles dispersed in a gas*)**. Combustion of 'fossil fuels' (petrol, diesel, etc.,), fly ash produced in thermal plants, forest fires, cement factories, asbestos mining and manufacturing units, spinning and ginning mills etc., are the main sources of particulate matter pollution. According to the **Central Pollution Control Board (CPCB)** particles of 2.5 micrometers or less in diameter are highly harmful to man and other air breathing organisms.

Measures to control Air Pollution caused by automobiles

1. Proper maintenance of automobiles along with use of diesel or unleaded petrol.
2. Fitting **'catalytic *converters'*** to the automobiles having expensive metals namely platinum, palladium and rhodium as catalysts which reduce emission of poisonous gases.(Figure 7.8)

Fig 7.8 air pollution

7.7.2 Water pollution and its control

Ancient civilizations flourished along river banks. Primitive life evolved in water only. The bodies of organisms contain water to the extent of nearly 90% of their body weight. Sea water constitutes 97% of water available on the planet. Fresh water which *is* required for our utility constitutes only about 3%.

Inferior quality of water, caused by pollution of natural waters is a major problem world is facing today. It is posing a serious threat in developing countries and India, of course, is riot an exception. Many water bodies in general and almost all the rivers in India are grossly polluted either by sewage or discharge of industrial effluents.

Ganga Action Plan

The holy river Ganga along with its 2500 kms. stretch, has been receiving for decades, millions of gallons of untreated domestic sewage from many cities and towns and also toxic industrial effluents from thousands of industries. As a result, it is becoming a **stinking dump** of various toxic substances. The water is becoming unfit for drinking and cultivation. Kanpur, Allahabad, Varanasi, Patna, and Kolkata are identified to be the main centres for causing pollution. Government of India launched a plan in 1985 with the aim of purifying the waters of river Ganga **(Ganga Action Plan).** Due to change of scope of river pollution control works, the Govt. of India renamed the programme as **National *River Conservation Project* / Plan,** instead of Ganga Action Plan, which is now spread in 165 towns of 17 different states.

The major water pollutants

1. Domestic Sewage

Sewage is the major source of water pollution in large cities and towns. It mainly consists of human and animal excreta and other waste materials. It is usually released into freshwater bodies or sea directly. As per the regulations the sewage has to be passed through **treatment plants** before it is released into the water courses. Only 0.1 percent of impurities from domestic sewage are making these water sources unfit for human consumption. In the treatment of sewage, solids are easy to remove. Removal of dissolved salts such as nitrates, phosphates and other nutrients and toxic metal ions and organic compounds is much more

difficult. Domestic sewage primarily contains biodegradable organic matter, which will be readily decomposed by the action of bacteria and other microorganisms.

Biological Oxygen Demand (BOD)

BOD is a measure of the content of biologically degradable substances in sewage. The organic degradable substances are broken down by microorganisms using oxygen. The demand of oxygen is measured in terms of the oxygen consumed by microorganisms over a period of 5 days **(BOD 5)** or seven days **(BOD 7)**. BOD forms an index for measuring ***pollution load*** in the sewage. Microorganisms involved in biodegradation of organic matter in water bodies consume a lot of oxygen, and as a result there is a sharp decline in dissolved oxygen causing death of fish and other aquatic animals.

Algal blooms

Presence of large amounts of nutrients in waters also causes excessive growth of planktonic algae and the phenomenon is commonly called 'algal blooms'. Algal blooms impart distinct colour to the water bodies and deteriorate the quality of water. It also causes mortality of fish. Some algae which are involved in algal blooms are toxic to human beings and animals.

Excessive growth of aquatic plants such as the common *water hyacinth (Eichhornia crassipes),* the world's most problematic aquatic weed which is also called ***'Terror of Bengal'*** causes blocks in our water ways. They grow faster than our ability to remove them. They grow abundantly in ***eutrophic*** water bodies (water bodies rich in nutrients) and lead to imbalance in the ecosystem dynamics of the water body.

Sewage arising from homes and hospitals may contain undesirable pathogenic microorganisms. If it is released untreated into water courses, there is a likelihood of outbreak of serious diseases, such as dysentery, typhoid, jaundice, cholera etc.,

2. Industrial -Effluents

Untreated industrial effluents released into water bodies pollute most of the rivers, fresh water streams, etc., Effluents contain a wide variety of both inorganic and organic pollutants such as oils, greases, plastics, metallic wastes, suspended solids and toxins. Most of them are non-degradable. Arsenic, Cadmium, Copper Chromium, Mercury, Zinc, and Nickel are the common heavy metals discharged from industries.

EFFECTS : Organic substances present in the water deplete the dissolved oxygen content in water by increasing the **BOD** (Biological oxygen demand) and **COD** (Chemical oxygen demand). Most of the inorganic substances render the water unfit for drinking. Outbreaks of dysentery, typhoid, jaundice, cholera etc., are caused by sewage pollution.(Figure 7.9)

Fig 7.9 Water pollution

Biomagnification

Increase in the concentration of the pollutant or toxicant at successive trophic levels in an aquatic food chain is called **Biological Magnification** or **Bio-magnification.** This happens in the instances where a toxic substance accumulated by an organism is not metabolized or excreted and thus passes on to the next higher trophic level. This phenomenon is well known regarding DDT and mercury pollution.

As shown in the above example, the concentration of **DDT** is increased at successive trophic levels starting at a very low concentration of **0.003 ppb** (ppb = parts per billion) in water, which ultimately reached an alarmingly high concentration of **25 ppm** (ppm = parts per million) in fish-eating birds, through bio-magnification. High concentrations of DDT disturb **calcium metabolism in birds,** which causes thinning of egg shell and their premature breaking, eventually causing decline in bird populations.

Eutrophication

Natural **ageing** of a lake by nutrient enrichment of its water is known as **eutrophication.** In a young lake, the water is cold and clear, supporting little life. Gradually nutrients such as nitrates and phosphates are carried into the lake via streams, in course of time. This encourages the growth of aquatic algae and other plants. Consequently the animal life proliferates, and organic matter gets deposited on the bottom of the lake. Over centuries, as silt and organic debris piles up, the lake grows shallower and warmer. As a result, the aquatic organisms thriving in the cold environment are gradually replaced by warm-water organisms. Marsh plants appear by taking root in the shallow regions of the lake. Eventually, the lake gives way to large masses of floating plants (bog) and finally converted into land.

Depending upon the climatic conditions, size of the lake and other factors, the natural ageing of a lake may span thousands of years. However, pollutants from human activity **(anthropogenic)** radically accelerate the aging process. This phenomenon is called **'Cultural** or **Accelerated eutrophication'.**

During the past century, lakes in many parts of the earth have been severely eutrophied by sewage, agricultural and industrial wastes. The prime contaminants are nitrates and phosphates, which are the **'chief plant nutrients'.** The dissolved oxygen which is vital to other aquatic life is depleted. At the same time, other pollutants flowing into the lake may poison the whole population of fish, whose decomposing remains further deplete the dissolved oxygen content in the water.

GLOSSARY
Autecology: Ecology of individual species.
Biomass: The total mass of living material within a specified area.
Brakish water: An intermediate zone between fresh water and marine water.
Camouflage: Concealing coloration and morphology as defence against predators. (Eg. Stick insects)
Chemoautotrops: These comprise bacteria that obtain energy from the oxidation of simple inorganic compounds and can use the energy released to assimilate CO2 and transfer the energy into organic compounds.
Climate: The climate of an area can be described by its mean values of temperature, rain fall, wind speed etc.
Community: The total living biotic component of an ecosystem, including plants, animals and microbes.
Detritus: Non living organic matter of plant origin.
Estuary: It is a place where river joins sea.
Osmotrophic nutrition: Intake of pre digested food material through the body surface.

Standing crop: The mass of vegetation in the given area at one particular time.
Decomposer: decomposers are organisms that break down the dead or decaying organisms.
Asymptote: A line which approaches near to some curve than assignable distance, but, though infinitely extended, would never meet it.
Chemo-autotroph: An organism that obtain energy through chemical process.
Mortality: Death rate or the number of individuals that died in a population in unit time.
Natality: Birth rate or number of individuals produced in population in a unit time.
Algal bloom: An algal bloom is a rapid increase or accumulation in the population of algae in an aquatic system.
Biological oxygen demand (BOD): The amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.
Chemical oxygen demand (COD): A test procedure based on the chemical decomposition of organic and inorganic contaminants dissolved or suspended in water.
Chloro fluoro carbons (CFC): Any of various halocarbon compounds consisting of carbon, hydrogen, Chlorine, once used widely as aerosol propellants and refrigerants. CFCs are believed to cause depletion of the atmospheric ozone layer.
Deforestation: The removal of a forest or standing trees where the land is there after converted to non-forest use.
Eutrophication: A process whereby the water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth.
Sewage: Domestic waste water containing various solid and liquid waste materials.

VERY SHORT ANSWER TYPE QUESTIONS

1. Define the term ecology?
2. What is autecology?
3. Define community?
4. What is an ecosystem?
5. Distinguish between ecosystem and Biome?
6. Define the term habitat?
7. Explain the 'niche' of an organism?
8. What is a biome? Name any two biomes you studied?
9. What is effect of light and body pigmentation?
10. Distinguish the terms phototaxis and photokinesis? What are the biological rhythms?
11. What are the circadians rhythms?
12. Explain the bioluminescence?
13. Define commensalism? Give one example?
14. Define mutualism? Give one example?
15. Define parasitism? Give one example?
16. Define amensalism? Give one example?
17. What is predation? Give one example?
18. Distinguish between predation and parasitism?
19. Distinguish between GFC and DFC?
20. Distinguish between food chain and food web?
21. What is the effect of CO pollution on human beings?
22. Which air pollutants are chiefly responsible for acid rains?

SHORT ANSWER TYPE QUESTIONS

1. Write about ecological hierarchy?
2. Write notes on habitat and medium?
3. Predation is not an association. Support the statement?
4. Write short notes on parasitic adaptations?
5. Explain GFC?
6. Wrote a note on DFC?
7. List out any four major air pollutants? Describe their effect on human beings?
8. Explain BOD?

VOCATIONAL BRIDGE COURSE

ZOOLOGY – FIRST YEAR – I

(w.e.f. 2018-19)

Blue Print

S.No.	Topic	No.of periods	Weightage of marks
		Weightage of marks	
1.	Diversity of living world	05	02
2.	Structural organization in animals	06	05
3.	Animal diversity-I(Invertebrate phyla)	07	05
4.	Animal diversity-II(chordata phylum)	06	05
5.	Biology in human welfare	08	09
6.	*Periplanata Americana* (Cockroach)	06	05
7.	Ecology and environment	10	09
	Total	48	40

REVISED SYLLABUS for VOCATIONAL BRIDGE COURCE

ZOOLOGY – FIRST YEAR (w.e.f 2018-19)

Question Bank

Unit I: Diversity of living world

Very short answers(1 mark)

1. List out any four sacred grooves in India?
2. What does ICZN stands for?
3. Define species richness?
4. What is meant by Tautonemy ? Give one example?
5. Define the term Histology? what is it otherwise called?
6. Write the fullform of IUCN? In which book threatened species are enlisted?
7. Distinguish between Embyology and Ethology?

Unit-II: **Structural organization in animals**

Very short answers (1 mark)

1. What is cephalization ? how is it useful to its possessors?
2. Why is the true coelom considered a secondary body cavity?
3. What is haematocrit value?
4. What is the strongest cartilage? In which region of human body, do you find it?
5. Define osteon?
6. What is a sesamoid bone? Give an example?
7. What is Lymph? How does it differ from plasma?

Short answer questions (4 marks)

1. Give an account of glandular epithelium?
2. Explain haversian system?
3. Describe three types of cartilage?

Unit-III: **Animal Diversity – I** (Invertbrate Phyla)

Very short answers (1 mark)

1. What are the functions of canal system of sponges?
2. What is metagenesis? Animals belonging to which phylum exhibit metagenesis?
3. What are the excretory cells of flat worms called? What is the other important functions of these specialized cells?
4. What is botryoidal tissue?
5. What are the respiratory structures of Limulus and Palamnaeus respectively?
6. Which Arthropod, you have studied, is called a living fossil? Name its respiratory organs?
7. What is the function of the radula ? Give the name of group of Molluscs which do not produce radula ?
8. What is Aristotle's lantern ? Give one example of an animal possessing it ?

Short answer questions (4 marks)

1. Write a short notes on salient features of the Anthozoans ?
2. Write a short notes on salient features exhibited by Polychaetes?
3. What are the chief characters of the Crustacians?
4. What are salient features of the Echinoids?

Unit-IV: **Animal Diversity – II** (Phylum: Chordata)

Very short answers (1 mark)

1. What is the importance of air bladder in fishes?
2. How does the heart of an Amphibian differ from that of a reptile?
3. How do you distinguish a male frog female frog?
4. Name one poisonous and one non poisonous snake found in South India?
5. What is Jacobson's organ? What is their function?
6. What is a pneumatic bone? How do they help birds?
7. Distinguish between Altricial and Precocial hatchlings ?

Short answer questions (4 marks)

1. Compare and contrast cartilaginous and bony fishes ?
2. Write eight salient features of the class Amphibia ?
3. What are modifications that are observed in birds that help them in flight?
4. What are the features peculiar to raite birds ? Give two examples ?

Unit-V: **Biology in human welfare**

Very short answers (1 mark)

1. Define parasitism and justfy this term?
2. What is a hyperparasite? Mention the name of one hyperparasite?
3. What do mean by parasitic castration ? give one example?
4. Define neoplasia? Give one example/
5. What are heamozoin granules ? what is their significance?
6. Define prepatent period ?what is its duration in life cycle of *Plasmodium vivax* ?
7. Define incubatin period? what is its duration in life cycle of *Plasmodium vivax* ?
8. Distinguish between Lymphadenities and Lymphangitis?

Short answer questions (4 marks)

1. Describe the structure of a tropozoite of *Entamoeba histolytica?*
2. Describe the cycle of Golgi in the life history of *Plasmodium vivax* ?
3. Explain the pathogenisity of *Wuchereria bancrofti* in man?

4. Write a short notes on typhoid fever and its prophylaxis?
5. What are the adverse effects of tobacco ?
6. Write a short notes on Opioids ?
7. “prevention is better than cure”. Justify with regard to TDA abuse?

Unit-VI: ***Periplanata Americana*** (Cockroach)

Very short answers (1 mark)

1. Why is the head in cockroach is called hypognathous ?
2. Name the different blood sinuses in cockroach ?
3. What are the three regions of the elementary canal in cockroach?
4. What are alary muscles ?
5. What is heamocoel?
6. Why is the blood of periplanata called heamolymph?
7. Why does not the blood of Periplanata help in respiration?

Short answer questions (4 marks)

1. Draw a neat labeled diagram of the mouth parts of cockroach?
2. Draw a neat labeled diagram of the salivary apparatus of cockroach?

Unit-VII: **Ecology and Environment**

Very short answers (1 mark)

1. Define the term ecology?
2. Define the term habitat?
3. What is a biome? Name any two biomes you studied ?
4. What is effect of light and body pigmentation?
5. Define commensalism? Give one example?
6. Define mutualism? Give one example?
7. Define parasitism? Give one example?
8. Define amensalism? Give one example?
9. Distinguish between food chain and food web?
10. What is the effect of CO pollution on human beings?
11. Which air pollutents are chiefly responsible for acid rains?

Short answer questions (4 marks)

1. Write about ecological hierarchy?
2. Explain GFC?

MODEL QUESTION PAPER

VOCATIONAL BRIDGE COURSE

ZOOLOGY 1st YEAR (w.e.f. 2018-19)

Time: 1 ½ Hours Max.Marks:25

Section-A 5x1=5

Note: 1) Answer any five of the following
2) Each question carries one mark

1. What does ICZN stands for?
2. Define species richness?
3. What is cephalization ? how is it useful to its possessors?
4. What is botryoidal tissue?
5. What is the importance of air bladder in fishes?
6. Define neoplasia? Give one example
7. What are alary muscles
8. Define the term ecology?

SECTION-B 5x4=20

Note: 1) Answer any five of the following
2) Each question carries four marks
3) Draw a neat labeled diagram wherever necessary

1. Give an account of glandular epithelium?
2. Write a short notes on salient
3. features of the Anthozoans ?
4. Compare and contrast cartilaginous and bony fishes ?
5. Describe the structure of a tropozoite of *Entamoeba histolytica?*
6. Describe the cycle of Golgi in the life history of *Plasmodium vivax* ?
7. Draw a neat labeled diagram of the mouth parts of cockroach?
8. Write about ecological hierarchy?
9. Explain GFC?