1

ORIGIN AND EVOLUTION OF LIFE AND INTRODUCTION TO CLASSIFICATION

The planet earth came into existence sometime between 4 and 5 billion years ago. Life evolved on planet earth about 3.5 billion years ago. Since then, approximately 15 million different species of organisms have evolved. But only about two million have been identified so far. In this lesson we will learn how life of these, at first originated on earth and how such a vast variety of organisms, popularly known as biodiversity, evolved through variation and natural selection.

The study of such a wide variety of organisms becomes convenient only when they are grouped according to similarities and differences, named, and their evolutionary relationships established. We will also learn about the importance and method of classification of organisms in this lesson and understand the position of viruses and viroids vis-a-vis the web of the living world.

OBJECTIVES

After completing this lesson, you will be able to :

- *describe the widely accepted 'theory of origin of life';*
- *explain what is organic evolution;*
- *give morphological, palaeontological, embryological and molecular evidences in favour of organic evolution;*
- *state modern theory of evolution;*
- *explain the sources of organic variations (gene and chromosomal mutations, recombination, gene flow and genetic drift);*
- *explain natural selection with examples;*
- *explain the role of isolation in evolution;*
- *list the various isolating mechanisms;*
- *explain speciation;*
- *understand Hardy–Weinberg Equilibrium to relate genetics and evolution.*
- *define classification;*

- *justify the need for classification of organisms;*
- *list the bases of classification;*
- *trace the changes in bases of classification from morphotaxonomy to systematics.*
- *State the position of virus and differentiate between virus and viroids.*

Notes

1.1 ORIGIN OF LIFE

The earth was formed about five billion years ago. At that time it was extremely hot. The existence of life in any form at that high temperature was not possible. As such, two questions arise pertaining to life:

1. How did life originate on earth?
2. How did primitive organisms evolve into new forms resulting in the evolution of a variety of organisms on earth.

> **Origin of life** means the appearance of simplest primordial life from non-living matter.
>
> **Evolution of life** means the gradual formation of complex organisms from simpler ones.

1.1.1 Chemosynthetic Theory of Origin of Life

Several theories have been put forth to explain the origin of life. The widely accepted theory is the Chemosynthetic theory of origin of life, proposed by A.I. Oparin. Other theories such as the theory of Spontaneous Generation are of historical importance only.

> **Chemosynthetic Theory**
>
> Life might have originated at first on earth through a series of combinations of chemical substances in the distant past and it all happened in water.

- The earth originated about 5 billion years ago.
- It was initially made up of hot gases and vapours of various chemicals.
- Gradually it cooled down and a solid crust was formed.
- The early atmosphere contained ammonia (NH_3), water vapour (H_2O), hydrogen (H_2), methane (CH_4). At that time there was no free oxygen. This sort of atmosphere (with methane, ammonia and hydrogen) is still found on Jupiter and Saturn (Fig. 1.1).
- Heavy rains fell on the hot surface of earth, and over a very very long period the water bodies appeared that still contained hot water.
- Methane and ammonia from the atmosphere dissolved in the water of the seas.
- In this water, chemical reactions occurred and gave rise to amino acids, nitrogenous bases, sugars and fatty acids which further reacted and combined to give rise to biomolecules of life such as proteins and nucleic acids.

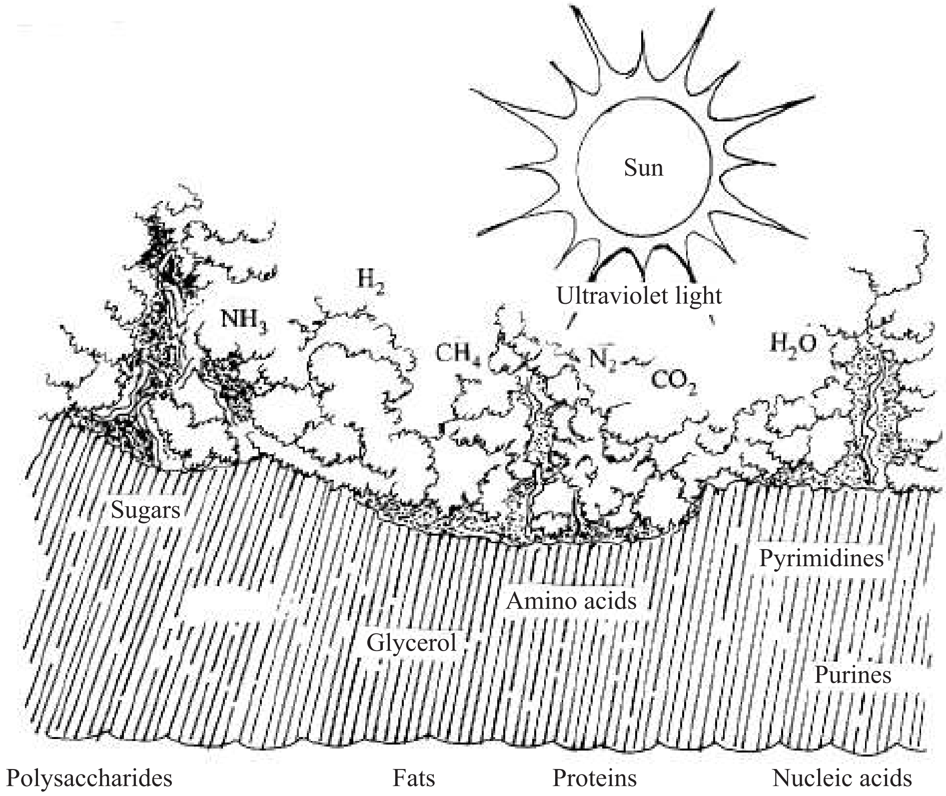


Fig. 1.1 Primitive conditions on earth

1.1.2 Probable stages in the origin of life

First stage

The sources of energy were the ultraviolet rays or electric discharge (lightening) or heat. Either alone or a combination of these energy sources caused reactions that produced complex organic compounds (including amino acids) from a mixture of ammonia (NH_3), methane (CH_4), water (H_2O) and hydrogen (H_2). The amino acids are the building blocks of proteins which are the main components of protoplasm.

> Stanley Miller and Harold C. Urey in 1953 set up an experiment with an air-tight apparatus (Fig. 1.2) in which four gases (NH_4, CH_4, H_2 and H_2O) were subjected to an electric discharge for one week. On analyzing the liquid, they found a variety of organic substances in it, such as amino acids, urea, acetic acid, and lactic acid (Fig. 1.2).

Second Stage

Simple organic molecules combined to form large molecules which included peptides (leading to the formation of proteins), sugars, starch and fat molecules.

Third stage

The large molecules of different kinds combined together to form multi-molecular heaps or complexes. Some simple fat molecules arranged themselves around this molecular complex in a sort of membrane. It was observed in the laboratory experiments that when such complexes reached a certain size they separated from the surrounding solution in the form of what were termed "**coacervate drops**" of microscopic size, moving in the liquid with a definite boundary (**coacervate means "heap"** referring to the combining together of the molecules).

Coacervate like aggregates were probably the precursors of the first living cells.

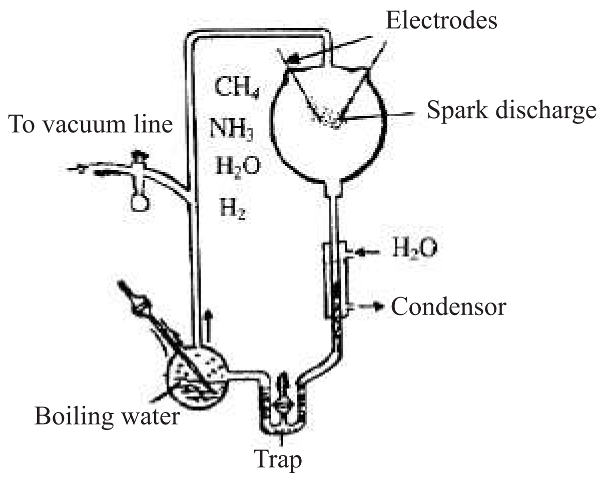


Fig.1.2 The apparatus used by Stanley Miller and Harold C. Urey to demonstrate the synthesis of amino acids under conditions that existed on the primitive earth

Now, some sort of "metabolism" could occur within these coacervates with synthesis of certain substances and breakdown of others. The latter (i.e. breakdown reactions) could provide energy.

Some of the earliest formed proteins might have acted like enzymes and would have affected the rates of reactions. It is also believed that RNA molecules might have shown enzymatic activity in the "primordial soup" of chemical compounds. Such molecules have been termed **ribozymes.**

Fourth stage

Some sort of nucleoproteins or nucleic acids may have evolved by random combinations which have provided two more properties to coacervate–like bodies. These include :

(i) chemical reactions from the nucleic acids, and

(ii) the capacity to reproduce through duplication of the nucleic acids (Fig. 1.3).

Thus, cells were produced that could be called the simplest primordial life. Figure 1.3 depicts the probable stages of origin and evolution of living beings.

The primitive "drop"–like forms of life were all heterotrophs, unable to manufacture their own food but derived it from environment.

One of the innumerable changes in genetic make up of the primitive heterotrophs led to the formation of chlorophyll (green colouring matter of the leaves) molecules.

– The chlorophyll–bearing units of life for the first time started using solar energy for production of food as well as for the first time started liberating free oxygen into the atmosphere.

Early atmosphere of earth had no free oxygen, the forms until then could at best be only “anaerobic”. Chlorophyll–bearing organisms later released free oxygen which gave greater possibilities for life to evolve.

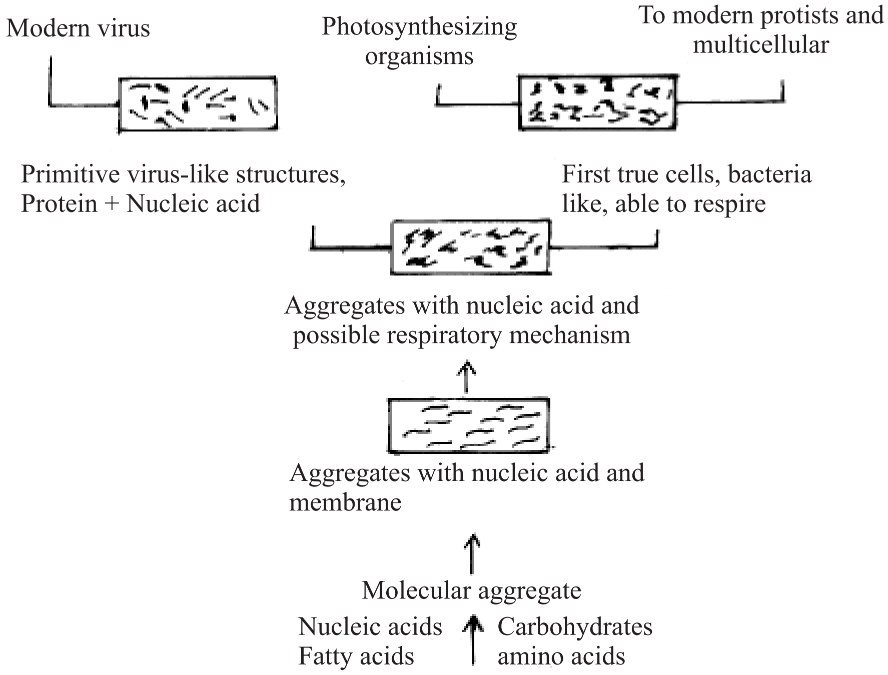


Fig. 1.3 Steps of the events which led to the origin of life

Thus, the simplest form of life originated through four main stages. Thereafter, a wide variety of organisms came into existence through **biological evolution**.

INTEXT QUESTIONS 1.1

1. Approximately how many years ago was the earth formed?

   ....

2. Who gave the Chemosynthetic Theory for origin of life?

   ....

3. Name the four gases present in the primitive atmosphere of the earth.

   ....

4. Name one source of energy which was used for chemical combination in primitive atmosphere.

   ....

5. Where did life originate in water or on land?

   ....

6. What are 'coacervates'?

   ....

7. In the origin of life, first large molecules were formed from inorganic compounds. Name any two such large molecules.

   ....

8. Name the two scientists who experimentally tried to verify Oparin's hypothesis.

   ....

1.2 ORGANIC EVOLUTION

1.2.1 What is Evolution ?

The formation of complex organisms through 'gradual change' from simple ancestral types over the course of geological time is termed Evolution or Organic Evolution.

According to the Theory of Organic Evolution

- The various present day organisms were not created in the same form in which they exist today, but have gradually evolved from much simple ancestral forms from a common ancestor.
- The characteristics of organisms had been changing in the past; they are changing even today, and will continue to do so in the future as well. This is due to the fact that the environment in which organisms live also changes and organisms need to adapt to the changed environment in order to survive.
- Several living organisms of the past have become extinct.
- The origin of the various forms (species) found on earth has been a gradual and extremely slow process, requiring hundreds or even thousands of years. However, the evolution of black peppered moth or polyploid varieties of some crops or pesticide resistant mosquitoes happened in much shorter periods of time.

This process of slow and gradual change is called Organic Evolution.

> The theory of organic evolution states that "All living things on earth are here as a result of descent, with modifications from a common ancestor".

1.2.2 Evidences of organic evolution

The evidences supporting organic evolution are derived from a number of fields of Biology. Those discussed here are :

1. Morphological evidences
2. Embryological evidences
3. Palaeontological evidences
4. Molecular evidences

1. Evidences from Morphology

Though organisms of different species and groups are quite different from each other, they still retain certain common features. Morphological evidences for evolution are derived from -

(i) Homologous and analogous organs (Fig. 1.4 and Fig. 1.5)

(ii) Vestigial organs

(iii) Connecting links

The comparative study of various organs in different groups of vertebrates exhibit common features which show that they evolved from a common ancestor. Take for example the heart of the vertebrates (Fig. 1.4).

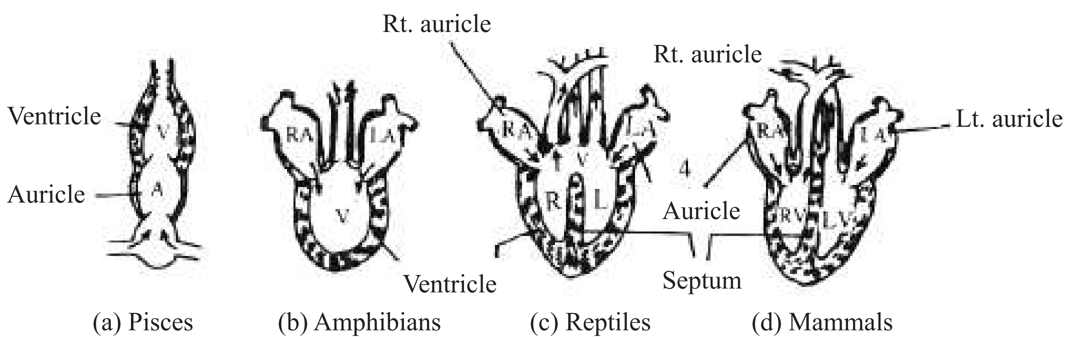


Fig. 1.4 Comparative study of heart of different groups of vertebrates

(ii) Homologous Organs

Homologous organs are the organs which are similar in structure and origin but may look very different and perform different functions.

– Forelimbs of vertebrates are a good example of homologous organs. They are built on the same fundamental plan yet they appear different and perform different functions (Fig. 1.5).

– In each case the forelimb consists of humerus, radius and ulna, carpals, metacarpals and phalanges. This basic similarity in the structure of the apparently different forelimbs of different kinds of vertebrates is due to the fact that all these limbs have evolved from a common type called the **pentadactyl** (five-fingered) limb.

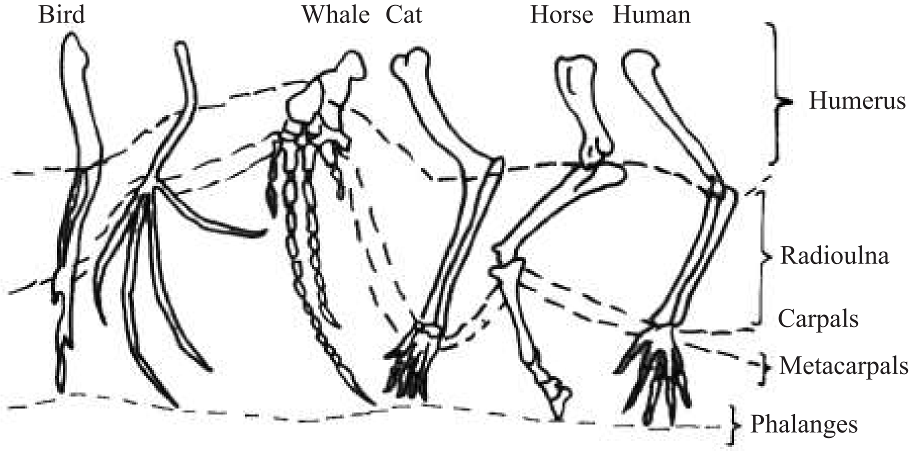


Fig. 1.5 Homology and adaptation in bones of the forelimbs of some vertebrates

The homologous organs, therefore, prove that different kinds of organisms came into existence through evolution.

Analogous organs

The structures which are functionally similar but structurally different are called analogous organs.

The wing of an insect, and that of a bird or bat or pterodactyl are examples of analogous organs (Fig. 1.6). The function of the wing is the same (for flying) but the insect wing has no structural resemblance with that of the vertebrates.

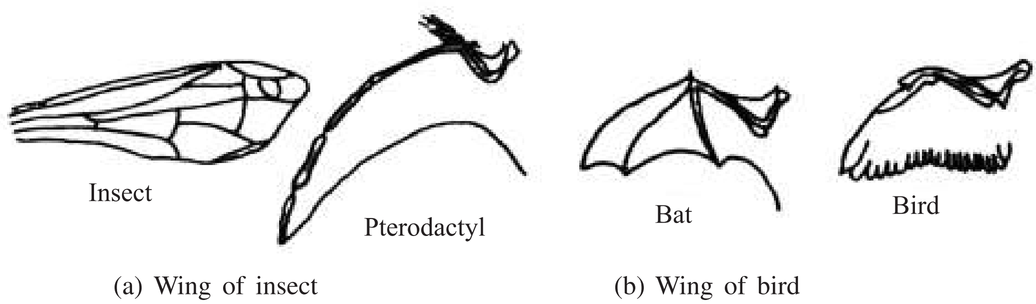


Fig. 1.6 Analogy between wings of insects and of different vertebrates

(iii) Vestigial Organs

Vestigial organ is any small degenerate or imperfectly developed (non-functional) organ or part which may have been complete and functional in some ancestor.

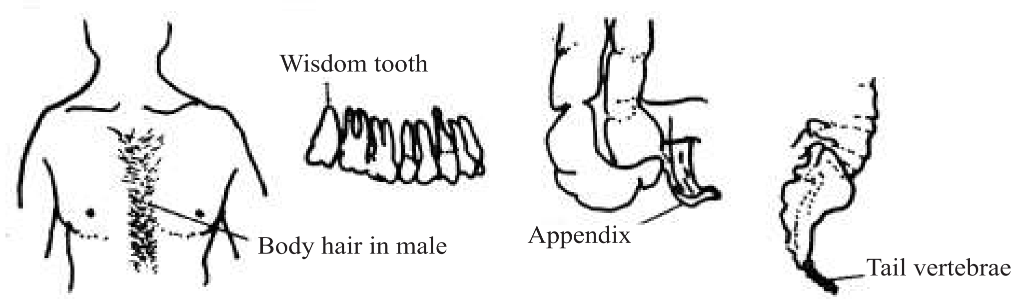
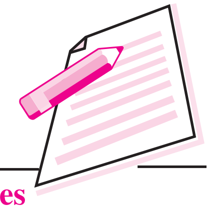


Fig. 1.7 Some vestigial organs in human body



Notes

The only rational explanation for the presence of these non-functional organs is that they have been inherited from ancestors in which they were functional. Fig. 1.7 shows some of the vestigial structures in the human body.

(iv) Connecting Links

The animals or plants which possess characters of two different groups of organisms are known as connecting links. The **connecting links** establish continuity in the series of organisms by proving that one group has evolved from the other. A good example is that of a fossil bird *Archaeopteryx*, which was a connecting link between reptiles and birds. This bird had a beak with teeth and a long tail (with bones) like the lizards. It had feathers on the wings and on the body like the birds. (Fig. 1.8).

Fig. 1.8 An extinct bird - *Archeopteryx*

2. Evidences from Embryology

Embryology is the study of development of an organism

The aspects of embryology which support the doctrine of organic evolution are :

- similar stages of early development (morula, blastula or gastrula) in all the animals;
- the embryos of all vertebrates are similar in shape and structure in their early stages.

This resemblance is so close that it is difficult to tell them apart (Fig. 1.9).

- All the vertebrates start their life from a single cell, the zygote.
- All of them during their life history, pass through two-layered blastula and three layered gastrula stage and then through fish like stage with gill-slits.

All the different aspects of embryology strongly support the fact that the different classes of vertebrates had common ancestors.

3. Evidences from Paleontology

Paleontology is the study of **fossils**. Fossils are the remains or traces of animal and plant life of the past, found embedded in rock either as petrified hard parts or as moulds, casts or tracks.

The fossils of the earliest era in the geological time scale were those of bacteria, then invertebrates and then successively of fishes, amphibians, reptiles and lastly of birds and mammals and among mammals primitive fossils of humans are the most recent.

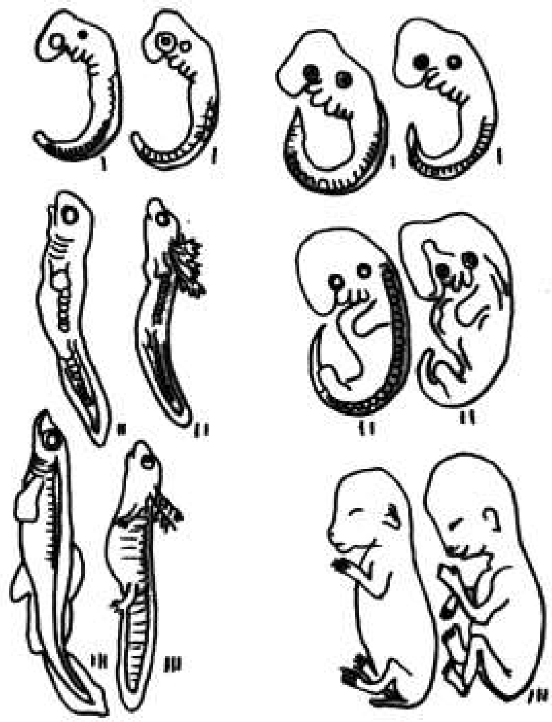


Fig. 1.9 Series of vertebrate embryos in comparable stages of their development a-Fish, b-Chick, c-Man

The discovered fossils of the horse, elephant, camels, and humans provide their ancestral history (Fig. 1.10). The number of toes decreased for greater speed, size gradually increased and teeth adapted to eat grass.

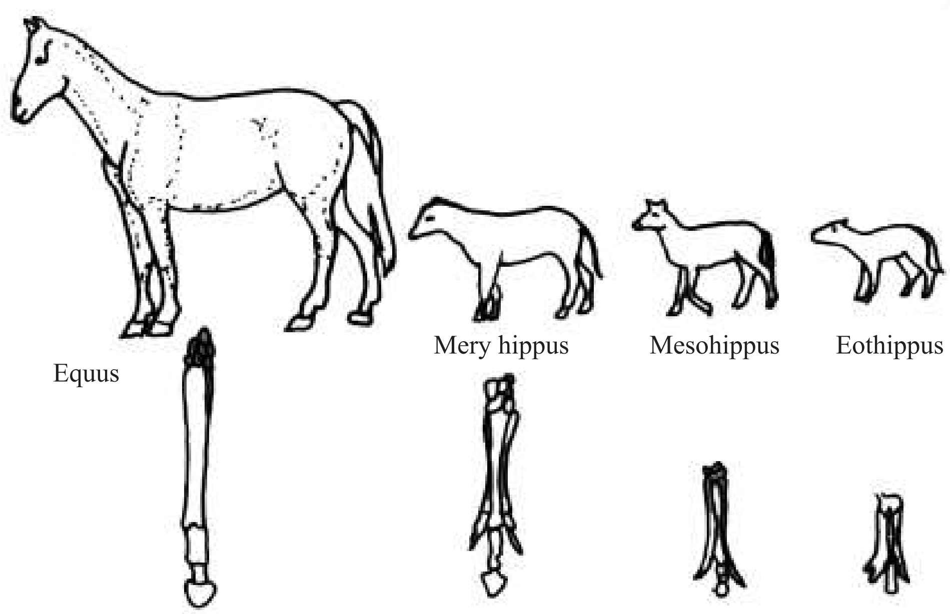


Fig. 1.10 Fossil record of bone of hind legs of horses from *Eohippus* to *Equus* showing decrease in the number of toes

4. Molecular Evidence of Evolution

- All organisms have cell as the basic unit of life. The cell is made of **biomolecules** common to all organisms.
- Ribosomes, the cellular organelles are of universal occurrence in organisms.
- DNA is the hereditary material of all organisms, except for some viruses.
- ATP is the molecule which stores and releases energy for biological processes.
- The same 22 amino acids form the constituents of proteins of almost all organisms.
- The genetic code is universal (exceptions are very few).
- The central dogma which deals with the transfer of genetic information in cells is the same.
- The basic steps of transcription and translation for protein synthesis are similar in all organisms.
- The sequence of nucleotides such as that for the promoter gene (TATA box) is common to all organisms.

However, organisms sharing same chemical characteristics show closer evolutionary relationships. For example (i) human blood proteins are most similar to those of the chimpanzee among all apes, or (ii) only plants and some algae have chlorophyll so they are more closely related. Similarity in chemical constituents between organisms is termed **molecular homology** or **biochemical homology** and are used in recent times, to establish evolutionary relationships and form the basis of systematics.

INTEXT QUESTIONS 1.2

1. Define organic evolution.

   ....

2. Name one fossil animal which forms a connecting link between reptiles and aves.

   ....

3. Which organ of man is homologous to the wings of birds?.

   ....

4. Define vestigial organ.

   ....

5. Give one example of a connecting link among the living beings.

   ....

6. Give two examples from molecular biology which support organic evolution.

   ....

1.2.3 Mechanism of Evolution

Various theories about the mechanism of evolution have been proposed; some of them such as Lamarck's theory of "Inheritance of acquired characters" and De Vries' theory of 'mutation' are now of historical importance only.

Darwin's theory of Natural selection still holds ground but was modified with progress in genetics and developed into the **Modern synthetic theory** which is regarded as the most valid theory of evolution.

Darwin's Theory of Natural Selection

An English Scientist, Charles Darwin (1809-1882) explained the mechanism of evolution through his theory of natural selection. He is still regarded as 'the father of evolution' because of two very significant contributions. He suggested (i) that all kind of organisms are related through ancestry and (ii) he suggested a mechanism for evolution and named it **natural selection.**

According to Darwin, organisms produce more offspring than can survive. Because environmental resources are limited there ensues struggle for existence. Organisms with advantageous variations are protected and allowed to reproduce while the disadvantageous variants are eliminated from nature. This is what was termed **natural selection** by Darwin.

According to Darwin when the environment changes, new adaptations get selected in nature and after many generations sufficient characteristics will have been changed so as to alter the species into a new one (origin of species).

Darwin talked about variation but did not know about the sources of variation. With progress in genetics the sources of variation were discovered and Darwin's original theory of Natural Selection modified. This new theory was termed **Neo-Darwinism** or **Modern Synthetic Theory**.

According to this theory :

1. The unit of evolution is 'population' which has its own gene pool. Gene pool is the group of all different genes of a population.
2. Heritable genetic changes appear in the individuals of a population.
   These heritable changes or variations occur due to small mutations in the genes or in the chromosomes and their recombinations.
3. Natural selection selects the variations which helps in adapting to the environment.
4. A change in the genetic constitution of a population selected by natural selection is responsible for evolution of a new species, since through interaction of variation and **Natural Selection** more offsprings with favourable genetic changes are born. This is called 'differential reproduction'.
5. Once evolved, **Reproductive Isolation** helps in keeping species distinct.

INTEXT QUESTIONS 1.3

1. Who gave the theory of natural selection?

   ....

2. What is the modern interpretation of Darwin's theory of evolution called?

   ....

3. What are the two major contributions of Charles Darwin regarding evolution?

   ....

4. Give two main features of Neo-Darwinism.

   (i) ....

   (ii) ....

5. What do you mean by "differential reproduction"?

   ....

1.2.4 Elemental Forces of Organic Evolution

Evolution is caused by action of forces on **Natural Selection** of **Variation**. Reproductive Isolation keeps the species distinct therefore the elemental forces of Organic Evolution are: (i) Variation (ii) Natural Selection (iii) Isolation.

(i) Sources of organic variation

Variation arises in an individual member of a population, and if favourable, spreads into the population through "differential reproduction" by the action of natural selection. Variations may occur by

1. **Mutation,** which is a sudden genetic change. It may be a change in a single gene (genic mutation or point mutation) or may affect many genes (chromosomal mutation).

2. **Genetic recombination**, which occurs in sexually reproducing organisms at every reproduction. The chromosomes and thus genes of the parents mix at random during zygote formation. That is why offspring of same parents are different from each other as they have different combinations of parental genes. Variation is also brought about when crossing over occurs during gamete formation.

3. **Gene flow** is when there is chance mixing of genes of closely related species through sexual reproduction.

4. **Genetic drift** occurs in small populations when a part breaks off from a large population. Only representative genes of the large population are present which undergo change at a right time and the small population may evolve into a new subspecies or species.

(ii) Natural Selection

Natural selection considered to be responsible for "differential reproduction of genes" which means that more of favourable genes get reproduced in a population.

Many examples of natural selection in action are available now. Given below are three such examples.

Example 1 : DDT resistant mosquitoes

About 50 years back, the mosquito population had been kept in control with the help of DDT. Thereafter, it was found that mosquitoes could not be killed with DDT any longer. There appeared DDT-resistant mosquitoes. What had happened was that a **gene mutation** (variation) had conferred (given) on the mosquito, the ability to resist the effect of DDT. While DDT killed other mosquitoes, those with the gene mutation survived and slowly within a few generations DDT resistant mosquitoes replaced the DDT-sensitive ones. In other words, the DDT resistant mosquitoes 'reproduced differentially' by the action of natural selection.

Example 2 : Metal tolerance in grasses

Certain metal residues sometimes collect in the soil near some industries using heavy metals. Being poisonous they kill the grasses. However, resistant grasses are found to evolve after some time through the action of genetic variation and natural selection.

From the above example, can you explain the evolution of the heavy metal-tolerant grasses?

Example 3 : Industrial melanism

A commonly quoted example of natural selection in action is that of the peppered moth, *Biston betularia*. The moth with its light coloured wings dotted with spots blended well with the lichens growing on the houses and trees on which it rested. Once in a while if a mutated form of the moth which was black in colour appeared, it was eaten up by birds as it was conspicuous because of its black wings. This was observed in the British Isles before the industrial revolution. After the industrial revolution, the genes for black wings proved favourable on the soot covered lichens growing on the walls of houses. Natural selection acted through the agency of the birds which now ate up the conspicuous light coloured winged peppered moth. These were therefore, soon replaced by the black variety (Fig. 1.10).

There are several such examples in which human activities have changed the environment and natural selection has been observed to play its role. But it is an established fact now that all of biodiversity over these millions of years have also evolved through the interaction of variation and natural selection.

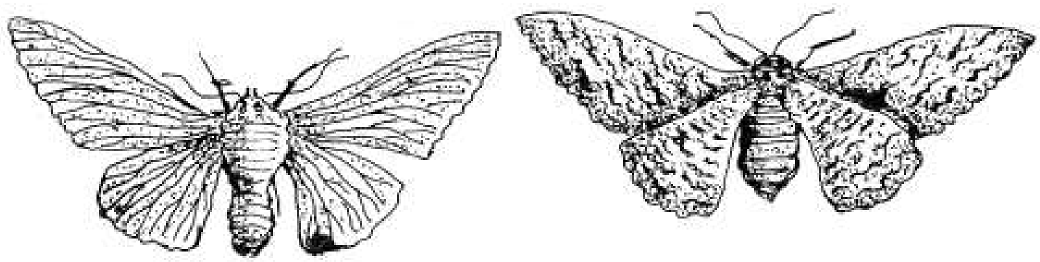


Fig. 1.11 Light and dark forms of *Biston betularia*

(iii) Role of Reproductive Isolation

Once new species arise from the parental species due to the effect of variation and natural selection, reproductive barriers prevent the two species from exchanging genes through reproduction.

Thus two related species cannot mate with each other and remain distinct. Isolation means separation and reproductive isolation simply means that the two species are prevented from successful reproduction and kept genetically distinct from each other. Reproductive isolation operates in the following ways:

Ecological isolation	:	The two species are unable to mate as they live in geographically different areas.
Seasonal isolation	:	Mating is prevented because the reproductive organs mature at different times.
Ethological (Behavioural) isolation	:	The songs in birds of two species or the colouration of two fishes are so different that female of one species is able to recognise only the male of its own species.
Mechanical isolation	:	The male and female organs for mating differ in different species and prevent their union.
Physiological isolation	:	The sperms of one species are not able to survive in the female tract of another species.
Zygotic and developmental Isolation	:	If all the above mechanisms fail and a “hybrid zygote” (zygote from mating of two different species) is formed, it dies after some time. If the hybrid zygote survives it dies during development.

Hybrid sterility : Mule, the offspring of a female horse and male donkey is a good example. It leads a normal life but is sterile and cannot reproduce.

F_2 breakdown : In rare cases, all the above mechanisms fail and a hybrid (offspring of parents belonging to different species) is fertile, it can reproduce only for one generation.

1.2.4 Speciation

The evolution of new species is termed **speciation.** Speciation occurs in the following ways and is termed accordingly.

Allopatric speciation takes place when a part of the population becomes geographically separated (geographical isolation) from the parental population. For example a group of birds lives at the base of the mountain, some members fly up and get geographically isolated. Variation and natural selection act differently on the two because the environment in which the two live is different. Gradually genetic changes render them to be reproductively isolated.

Sympatric speciation

Sometimes a genetic barrier (reproductive barrier) prevents reproduction between a section of a population of a species with other members. Such a section of population usually arises in plants because of polyploidy. **Polyploidy** is a mutation in which the normal diploid number of chromosomes become doubled or trebled (2n becomes 3n, 4n, 5n etc) in a section of the population of a species due to certain irregularities during cell division. The polyploid section of the population is then unable to interbreed (mate and reproduce) with their diploid ancestors and becomes a new species.

Models of speciation

There are two accepted models of speciation that have given rise to the biodiversity

1. Phyletic Gradualism model

Two species from common ancestor gradually become more and more structurally different acquiring adaptations unique to each other (Fig. 1.12a). Darwin also believed that evolution is a slow and gradual process.

2. Punctuated equilibrium

A new species arises through major changes in the beginning and then remain constant for long periods before changing again. (Fig. 1.12b). This model was suggested by palaeontologists (scientists who study fossils), Niles Eldredge and Stephen Jay Gould.

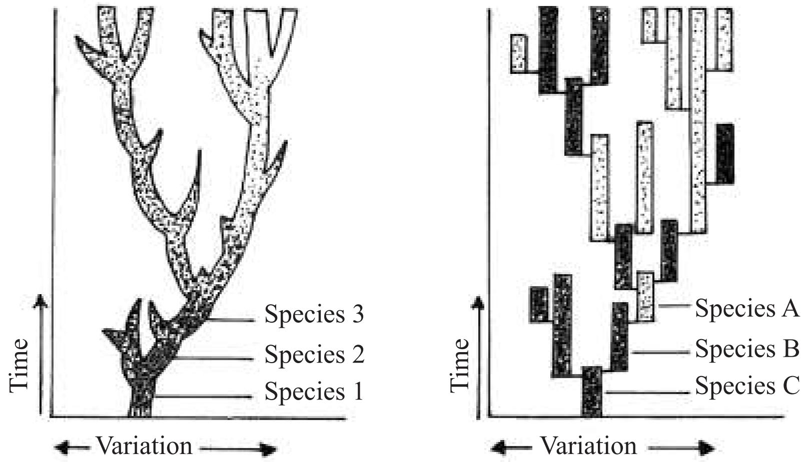


Fig. 1.12 Models of speciation (a) Phyletic gradualism, (b) Punctuated equilibrium

1.2.5 Hardy-Weinberg Equilibrium

This is a concept related to both genetics and evolution and was proposed by G. H. Hardy and W. Weinberg.

A population of sexually reproducing organisms in which genes combine at random due to random mating is called **panmictic**. In other words, a panmictic population is one in which mating partners are not specifically selected. For example, we humans usually do not look for specific blood group when a marriage is arranged so we are panmictic with respect to blood types.

The Hardy Weinberg Principle states that in a panmictic population if there is no pressure of mutation, selection, genetic drift etc. then the relative frequency of any pair of genes remains constant, generation after generation. For example, a gene has two alleles, p and q in the population and no mutation or selection etc. takes place, then the frequency of these two alleles will remain constant generation after generation. This can be mathematically represented as:

$$(p+q)^2 = 1 \text{ or } p^2 + 2pq + q^2 = 1$$

INTEXT QUESTIONS 1.3

1. List the sources of organic variation.

   ....

2. What is 'industrial melanism' about? Answer in one or two sentences.

   ....

3. State one point of difference between (a) allopatric & sympatric speciation (b) Ecological and Ethological Isolation

   ....

4. What is a panmictic population?

   ....

5. According to Hardy Weinberg Principle, $(p + q)^2 = 1$. Explain this mathematical expression.

....

1.3 CLASSIFICATION

1.3.1 Meaning of Classification

Classification means identifying similarities and differences between different kinds of organisms and then placing similar organisms in one group and different kinds of organisms in different groups.

Taxonomy, may thus be defined as the science of classification of organisms into categories, maintaining certain rules. Early taxonomists classified organisms according to **morphological features** only. Once the concept of organic evolution was accepted, taxonomists began to draw evolutionary relationships between different kinds of organisms. This was termed **systematics.** Today taxonomy and systematics are treated as synonymous, since for classification, both morphological and biochemical resemblances and even those between molecules such as DNA and RNA are studied to establish evolutionary relationships.

1.3.2 Taxonomic categories

While classifying an organism, it is assigned to categories which show its evolutionary relationship with other groups of organisms. Each level or category is termed **taxon** (plural-taxa). The lowermost category of classification or taxon is **species**. Other categories are arranged above the species so that there is a hierarchy of categories. The various taxonomic categories are given below :

Species : Group of individuals of one kind which can interbreed to produce fertile offsprings.

Genus : Group of species resembling each other in several features indicating common ancestry.

Family : Group of genera (singular-genus) resembling each other. e.g. *Felis domestica* (the cat) and *Panthera tigris* (the tiger), both belong to the family Felidae.

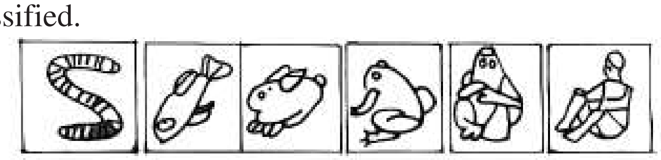
Order : Includes families showing similar characteristics.

Class : Includes related orders.

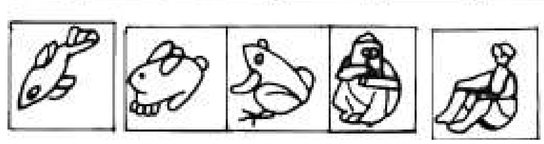
Phylum : Includes related classes. (See Fig. 1.13)

The various phyla belong to their respective **kingdoms**. There are **five kingdoms** about which you will learn later. Humans belong to the kingdom Animalae and classification of humans is given as an example to describe the manner in which living organisms are classified.

Kingdom : Animalae (Animals)



Phylum : Chordata (Animals with notochord/ backbone)



Class : Mammalia (Animals that suckle their young ones.)

Order : Primates (Mammals with larger brains and binocular vision)

Family : Hominidae (Humans and human like ancestors)

Genus : *Homo* (Fossilmen and modern man)

Species : *H.sapiens* (Modern man)

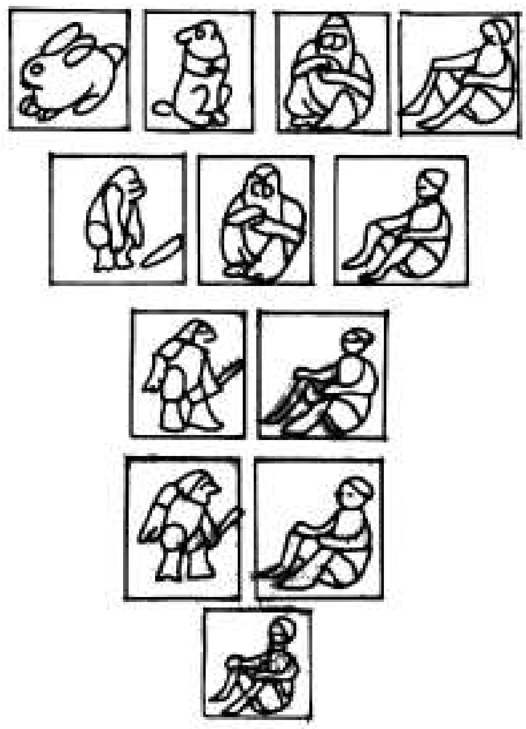


Fig. 1.13 Classification of Human species

1.3.3 Scientific naming of organisms

Different plants and animals have different common names. A cat is called 'billi' in Hindi, 'biral' in Bengali, 'punai' in Tamil and 'manjar' in Marathi. There are different words for cat in French or German. Thus, there arose the need to give organisms names which could be understood throughout the world. Therefore, scientific names which are understood all over the world were given to organisms.

A simplified system of naming organisms called **binomial nomenclature** has been the standard for more than two centuries now. It was proposed by the Swedish biologist, **Carolus Linnaeus (1707-1778)**. Binomial nomenclature simply means **two-name** system of naming. The name of every category of organism has two parts, that of the **genus** followed by that of **species**. The generic name is written with a capital letter and the specific name with a small letter. e.g. ***Homo sapiens*** is the scientific name of modern man, ***Mangifera indica*** is the boctnical name of mango.

Three main features of biological naming are as follows :

1. A scientific name, by convention, is printed in **italics** or **underlined** when hand written.
2. Scientific naming is according to a set of scientific rules of nomenclature.
3. Scientific names are mostly in *Greek* and *Latin*. They are uniformely understood all over the world and have made communication about organisms easier.

1.3.4 Prokaryotes and Eukaryotes

The organisms that are most primitive or the first to evolve on earth are the bacteria. They do not possess a nuclear membrane around their single chromosome. Absence of a well-defined nucleus or in other words a primitive nucleus terms them **prokaryotes** (pro = primitive, karyon = nucleus). **All bacteria including blue-green algae (Cyanobacteria) are prokaryotes**. As a constrast, **organisms other than bacteria** possessing a well-defined nucleus are **eukaryotes** (eu = true; karyon = nucleus). There are other differences between prokaryotes and eukaryotes which are given below in Table 1.1.

Table 1.1 Differences between Prokaryotes and Eukaryotes

Characteristics	Prokaryotes	Eukaryotes
1. Size	0.1-10 µm	10-100 µm (larger volume)
2. Genetic material	Circular DNA, no linear DNA, no histones associated with DNA, nucleoid form, no nuclear membrane	Histones present on which DNA molecule wrapped, well defined linear chromosomes, with free terminal end nuclear membrane present
3. Site of nuclear material	DNA in cytoplasm	DNA inside distinct nucleus
4. Organelles	No membrane bound organelles	Mitochondria, golgi body, lysosomes present in the cell
5. Cell wall	Always present, Contains peptidoglycan	None in (animals) and made of cellulose/chitin in plants and fungi
6. Respiration	By mesosomes	By mitochondria
7. Reproduction	Mostly asexual e.g. bacteria and cyanobacteria (blue-green algae)	Asexual and sexual e.g. Protoctista, fungi, plants Animals

1.3.5 The Five Kingdoms of Organisms

Till recently there were only two kingdoms for classification - **Plantae** and **Animalae**. Such a two kingdom classification had several drawbacks, e.g. bacteria and fungi were kept alongwith plants although they are very different.

R.H. Whittaker in 1969 suggested the five kingdom classification which is based on the following three criteria.

(i) The presence or absence of a well-defined nucleus.

(ii) Unicellular or multicellular

(iii) Mode of nutrition

The five kingdoms are Monera, Protista or Protoctista and Fungi, Plantae and Animalae. Based on the three criteria mentioned above, (Fig. 1.13) the five kingdom classification is explained as under.

Table 1.2 The five kingdom classification of organisms

Names of Kingdoms	Nature of nucleus	Whether unicells or multicells	Kinds of nutrition
1. **MONERA** (Blue green algae and bacteria)	Prokaryotic	Unicellular (except some cyanobacteria that are filamentous or multicellular and sometimes branched.	Diverse types of nutrition
2. **PROTOCTISTA** (some Algae and Protozoa)	Eukaryotic	Unicellular	Diverse kinds of nutrition
3. **FUNGI** (Moulds, etc.)	Eukaryotic	Unicellular or Multicellular	**Saprophytic** (Feed on dead, organic matter)
4. **PLANTAE** (All green plants)	Eukaryotic	Multicellular	**Autotrophic** (Synthesize food by photosynthesis)
5. **ANIMALAE** (Animals)	Eukaryotic	Multicellular	**Heterotrophic** (Depend on other organisms for food)

The five kingdoms are shown below in Fig. 1.14

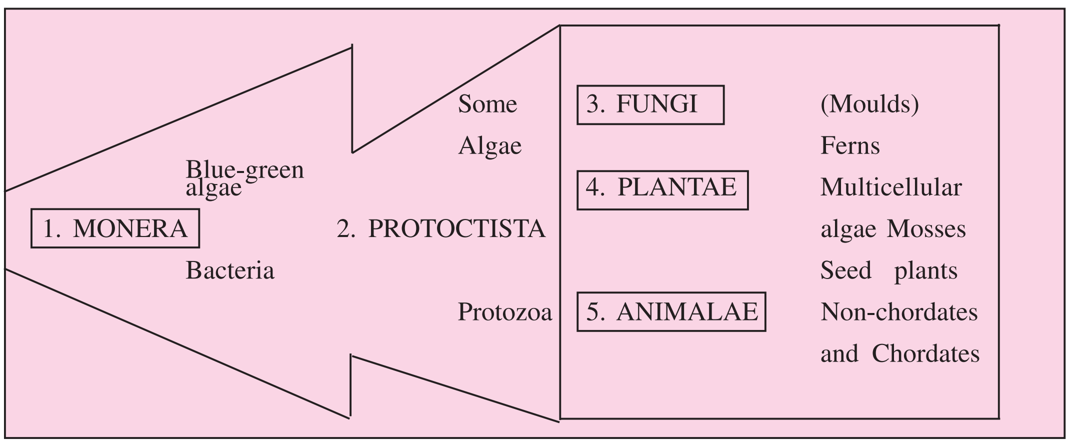


Fig. 1.14 The Five Kingdoms of Life

INTEXT QUESTIONS 1.4

1. Name the scientists who proposed :

   (a) Binomial nomenclature ....

   (b) Five Kingdom Classification ....

2. Which were the first organisms to appear on earth?

   ....

3. Name the taxonomic categories which come before and after family.

   ....

4. Name the categories above order level in a correct sequence.

   ....

5. Rewrite the following in correct form –

   (a) Mangifera Indica ....
   (b) Homo Sapiens ....
   (c) Felis leo ....

6. Place the following in their respective kingdoms

   (a) Bacteria which curdle the milk ....
   (b) Cow ....
   (c) Grass ....
   (d) Amoeba ....
   (e) Bread mould ....

1.4 VIRUSES - AN INTRODUCTION

- You have heard about diseases such as influenza, polio, mumps, rabies, small-pox, AIDS and dengue are caused by viruses.
- They are non-living and made up of DNA or RNA surrounded by a protein coat. They can replicate. However, they cannot reproduce on their own. They reproduce when inside a living cell. Therefore viruses pose a special classification problem.
- Logically, therefore, they cannot be placed in any of the five kingdoms because they can multiply in their host cells, and can mutate – like living organisms but, can be crystallised exhibiting a non-living feature.

Discovery of Viruses

In 1892, the Russian botanist Iwanowsky prepared an extract from tobacco plants suffering from tobacco mosaic disease. The extract was filtered to keep back bacteria in the residue. The filtrate was still infectious. Dutchman Beijerinck gave the term virus in 1898 (Virus - poison in Latin) to these infective particles.

Size

- Viruses are extremely small and can be seen only under the electron microscope.
- They are smaller than the smallest bacteria.
- Can pass through fiters which retain bacteria.
- Their size is indicated in nanometres (nm). Their size ranges from 10 nm to 300 nm in diameter.

Nanometre (nm)

It is a unit of microscopic measurement, equal to 10^{-9} m. It was formerly called millimicron

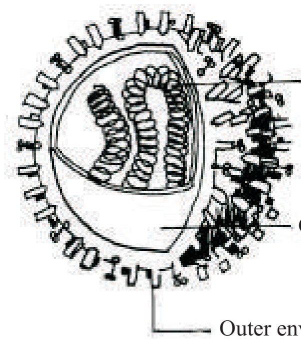


Fig. 1.15(a) Influenza virus

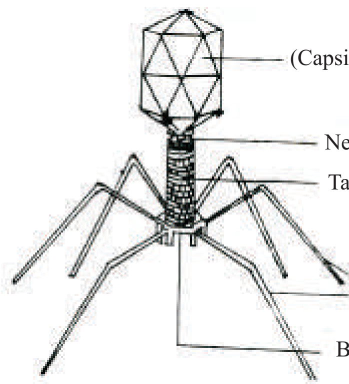


Fig. 1.15(b) T. Bacteriophage

1.4.1 Structure of virus

Virus has a simple structure consisting of a core and a cover. The core particle is the genetic material, either DNA or RNA. The cover is a protein coat called **capsid** (Fig. l.16).

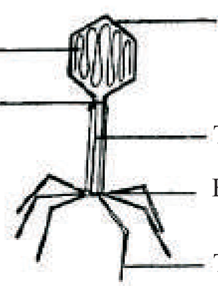


Fig. 1.15 Structure of Virus

Virus can reproduce only when inside the living cells.

A virus cannot reproduce by itself. For its reproduction it needs to enter the cell of some organism. From the host cell, it uses the raw material and enzymes and energy generating machinery of the host cell to produce its own DNA. A number of virus particles are thus formed inside the host cell. The host cell bursts to release the new virus particles.

Virus — living or non-living?

Though viruses possess nucleic acids as genetic material like the living organisms, they cannot make copies of DNA for reproduction on their own. They can make copies of themselves to reproduce only inside a living cell. And because their genetic material is DNA or RNA, they exhibit mutations followed by variations in their infective properties. Further, they are considered non-living because they are non-cellular, they have no enzymes of their own and they can be crystallised

1.4.2 Infective properties of virus

Viruses are known to attack bacteria, plants or animals. Viruses which invade bacteria are called **bacteriophages.**

Viruses are highly specific in their relationship with the host and tissue. For example – Polio virus attacks particular nerves; mumps virus attacks the particular pair of salivary glands (parotid glands) of humans.

Viruses keep on 'mutating'!

Mutation means change in genetic material. For example – Influenza virus which has RNA as its genetic material, mutates and so every year flu is caused by a different virus and scientists find it difficult to find a cure for influenza or flu.

1.4.3 Viruses and diseases

Table 1.3 indicates the names of certain viruses, their hosts and diseases and modes of their transmission

Certain cancers are also known to be caused by viruses. These viruses have RNA as genetic material and are called ***retroviruses***.

Table 1.3 Certain viruses, their hosts, diseases caused by them and mode of transmission.

	Virus	Host	Disease	Mode of Tranmission
Plants	Potato roll virus	Potato	Potato leaf roll	Air borne contact
	Tomato stunt virus	Tomato	Tomato bushy stunt	Air borne, contact
	Tobacco mosaic virus	Tobacco	Mosaic	Air borne, contact
Human	Herpes virus	Humans	Herpes	Air borne,, contact
	Pox virus	Humans	Small Pox	Air borne, contact
	HIV	Humans	AIDS	(i) Sexual contact (ii) Lactating mother to child (iii) Blood transfusion
	Dengue	Humans	Dengue	Bite of infected *Aedes* mosquito
	Hepatitis B	Humans	Hepatitis	Infected water

1.4.4 Viroids

Viroids are circular RNA molecules, consisting of several hundred nucleotides. They infect plants and even kill them. In plants, they use enzymes of the plant cells to replicate like the viruses do. When they infect plants, these RNA molecules cause defects in the regulatory systems controlling plant growth. Hence viroid infected plants show stunted growth and abnormal development.

INTEXT QUESTIONS 1.6

1. With reference to viruses fill in the blanks (1, 2 and 3) in the following table :

1. ...	Tobacco	Tobacco Mosaic Disease
HIV	2. ...	AIDS
Herpes	human	3. ...

2. Give one feature because of which viruses are considered non-livng.

   ....

3. Name one chemical common to viruses and all other organisms.

   ....

4. Complete the following :

   (a) Core particle of virus contains ....

   (b) Coat of virus is made of ....

5. In what way is viroid structurally different from a vrius?

   ....

   (Refer Module 1, Lesson 1 page 22)

6. Why are viroids considered a menace for plants that they attack?

   ....

WHAT YOU HAVE LEARNT

- The most accepted theory about origin of life is the chemosynthetic theory.
- Earth's early environment was favourable for the formation of organic molecules from simple inorganic materials.
- Coacervates are believed to have been membrane–bound molecular aggregates capable of growth and budding.
- It is believed that life originated some 3.5 billion years ago on this earth.
- The environment and the forms of life of the past were quite different from those of today.
- Evolution is the gradual unfolding of living forms from the earlier simpler forms into the complex ones. It was in operation in the past, it is operating at present and will continue do so in the future.
- Chief evidences in favour of organic evolution come from comparative anatomy, embryology, palaeontology and molecular biology.

- Darwin's theory of 'Origin of Species' by natural selection', explains the process of evolution through useful variation and natural selection.
- Neo-Darwinism is the modern interpretation of Darwinism based on natural selection, mutation and reproductive isolation. This is also called the modern synthetic theory.
- Sources of variation are mutation, recombination, geneflow and genetic drift.
- Natural selection acts upon variation through "differential reproduction" which means greater reproduction of favourable genes.
- Isolation helps in formation of new species and also in keeping species distinct.
- The reproductive isolating mechanisms are ecological isolation, seasonal, ethological, mechanical and physiological isolation, zygote inviability, hybrid sterility and F_2 breakdown.
- Evolution of new species is termed speciation.
- Speciation occurs through (a) geographical isolation, or (b) polyploidy.
- Gradualism and punctuated equilibrium are suggested modes of speciation.
- Hardy Weinberg equilibrium relates to genetic variation during evolution. According to this theory, 'in a panmictic population, frequency of two alleles remains same for generations in the absence of Mutation and Natural Selection.
- Classification is essential for studying organisms and communicating about them. Classification means grouping on the basis of similarities and differences.
- There are hierarchical taxonomic categories which reveal evoulutionary relationships of an organism.
- The scientific naming of organisms is according to the Linnaean system of binomial nomenclature.
- The five kingdoms of life are Monera, Protoctista, Fungi, Plantae and Animalae.
- Viruses are nucleoprotein particles which have DNA or RNA molecules present as core particles, surrounded by a protein coat.
- Viruses were discovered by Ivanowsky and named by Beijerinck.
- Viruses are very small and can be observed only through electron microscope.
- Viruses cannot reproduce except when inside living cells.
- Viruses share properties of living and nonliving.
- Viruses infect bacteria, plants and animals.
- Viruses attacking bacteria are called bacteriophages.
- Viruses cause several human diseases like herpes, small pox, AIDS, dengue and influenza.
- Viroids are RNA particles that attack plants.

TERMINAL EXERCISES

1. Explain the most valid theory about origin of life on earth. How did Miller and Urey verify the chemosynthesis theory of evolution?
2. Differentiate between Darwinism and Neo-darwinism.
3. Explain the synthetic theory of evolution.

5. Substantiate the idea of evolution through molecular evidence.
6. Classify the following animals : earthworm, roundworm, frog and human-beings.
7. Write the scientific names of

   (i) Mango (ii) Man (iii) Cat (iv) Tiger

8 How does a virus increase in number? Show only by explanatory diagrams.
9. Give a schematic diagram of the five Kingdom classification.
10. State the criteria on which the five kingdom classification is based.

ANSWERS TO INTEXT QUESTIONS

1.1 1. 5 billion years 2. A.I. Oparin

3. NH_3, CH_4, CO_2, water vapour
4. Lightening/geothermal energy/UV rays (any one)
5. Water
6. aggregates of (life-like) molecules
7. amino acids, fatty acids, sugars (any two)
8. Miller and Urey

1.2 1. The process of slow and gradual change as a result of descent with modification, from a common ancestor.

2. *Archaeopteryx*
3. Fore-limb/arm
4. Functionless organs of the body
5. (i) Lungfish between fish and amphibia

   (ii) Egg laying mammals between reptiles and mammals.
6. See sub-section on evidence of evolution from molecular biology

1.3 1. Mutation, Recombination, gene flow, genetic drift,

2. It is about the evolution of a variety of peppered moth during industrial revolution, through mutation and Natural Selection.
3. Allopatric speciation leads to differences in population of a species due to physical isolating barriers. Reproductive barriers separate sympatric species which may live in the same geographical area.
4. Both are isolating mechanisms, Ecological Isolation by barriers of season or habital and Ethological Isolation by barriers of behavioural differences.
5. Randomly mating population.
6. $(q + q)^2 = 1$ means frequencies of allelic genes p + q remain same for generation after generation if there is no force of evolution like variation, natural selection etc.

1.4
1. Charles Darwin
2. Neo-Darwinism/synthetic theory
3. All organisms are related through ancestry he suggested natural selection as the probable mechanism for evolution.
4. (i) Variation in population forms the basis of evolution
   (ii) Differential reproduction
5. Reproduction of favourable genes is greater

1.5
1. (a) Carolus Linnaeus
   (b) R.H. Whittaker
2. Bacteria
3. Genus
4. Kingdom, phylum, class, order
5. (i) *Mangifera indica* (ii) *Homo sapiens* (iii) *Felis leo*
6. Kingdom, phylum, class, order, family, genus, species
7. (i) Monera (ii) Animalae (iii) Plantae (iv) Protoctista (v) Fungi

1.6
1. 1. Tobacco mosaic virus, 2. humans, 3. Herpes.
2. They cannot reproduce on their own / they can be crystallised (any one)
3. Nucleic acid/protein (any one)
4. (a) DNA or RNA (b) Protein
5. A virus has a DNA or RNA molecule surrounded by a protein coat, whereas a viroid is only an RNA molecule.
6. They infect plants and when inside the plant cells, use the host plants' enzymes to replicate & increase in number resulting in stunted and abnormal growth of plant.

2

THE KINGDOMS MONERA, PROTOCTISTA AND FUNGI

The Kingdom Monera which includes all the bacteria including blue-green algae (cyanobacteria) and the Protoctista which includes the protozoa, the diatoms and some algae are in a way the simplest among the living world. All bacteria, majority of protoctists and many fungi are microscopic and generally referred to as micro-organisms. You will learn about the three kingdoms in this lesson.

OBJECTIVES

After completing this lesson, you will be able to :

- *state the basis for classifying certain organisms as members of kingdoms Monera, Protoctista and Fungi;*
- *emphasize the fact that Kingdom Monera is the only prokaryotic kingdom and also that it is the most primitive;*
- *describe the generalized structure of a bacterium and cyanobacterium;*
- *describible economic importance of bacteria with examples;*
- *recognize the status of cyanobacteria and justify its inclusion in kingdom Monera;*
- *describe the characteristics of Kingdom Protoctista (protista);*
- *describe the structure of Amoeba, Paramecium, Euglena and Plasmodium;*
- *describe the structure of diatoms;*
- *list the uses of protists to humans and mention the diseases caused by protozoa;*
- *list the general characteristics of fungi with examples;*
- *describe the strucutre and reproduciton of yeast, Rhizopus,* mushroom, *Penicillium and its utility for humans;*
- *explain what are mycorrhizae;*
- *describe the economic importance of fungi.*

2.1 KINGDOM MONERA

- Includes the bacteria and cyanobacteria (commonly called blue-green algae).
- Since only bacteria are prokaryotic (lacking a true nucleus, that is without a nuclear membrane), Monera is the only **prokaryotic** kingdom.
- Bacteria were the first cellular organisms to evolve on the planet earth after life originated around 3.5 billion years ago and were the **only** cellular organisms on earth for almost the next two billion years.
- Most bacteria are single celled or **unicellular** (monere : single) but actinomycetes and some cyanobacteria are multicellular and filamentons wherein filaments may be branched.
- Monerans are also the most numerous of all living cellular organisms.

2.1.1 Structure of a bacterial cell

The single celled bacterium has a cell wall made of the compound peptidoglycan covering the cell membrane; and a single circular (upring-like) chromosome. The cell has ribosomes but no membrane bound organelles. Let us get to know some details of these parts (Fig. 2.1).

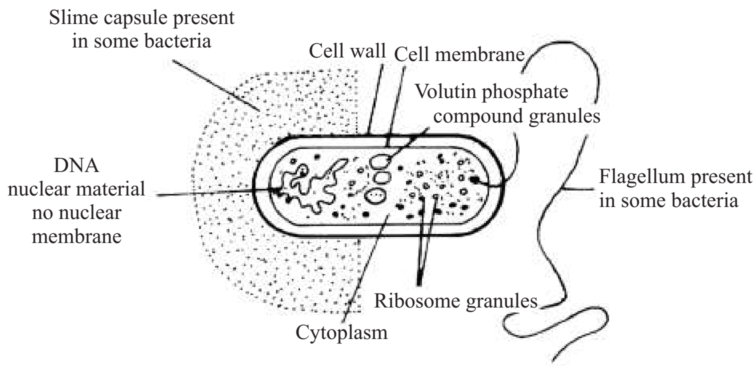


Fig. 2.1 Structure of a bacterium.

Note the following parts of a bacterium in the figure (Fig. 2.1). The outermost covering is the cell wall.

Cell wall

All prokaryotes have a rigid cell wall, which protects and gives shape to the cell. The cell wall is made up of a chemical, **peptidoglycan,** unique to bacteria, lipids, polysaccharides and some proteins.

Pili (Singular : pilus)

Pili are short and thin thread like tubular structures projecting out from the cell wall in some bacteria.

Flagella

Some bacteria move with the help of one or more flagella. Flagella are longer and thicker than pili. Their structure is different from flagella of eukaryotes.

Plasma Membrane

Plasma membrane, present below the cell wall, encloses the cytoplasm and other cell contents. It is made up of lipids and proteins, as in eukaryotes.

Genetic Material

One circular chromosome made of a double helical molecule of DNA is located in a region of the cytoplasm called **nucleoid**. Since the chromosome is not lodged within a true nucleus, bacteria are termed as prokaryotes. Hence Monera is the prokaryotic kingdom. Apart from the chromosome as several species of bacteria possess one or more additional rings of DNA called **plasmids**, which replicate along with bacterial chromosome and bear genes for antibiotic resistance and act as the sex factor or F-factor providing the property of male sex to the cell that bears the sex-factor or the F-factor.

Cell Organelles

Membrane bound organelles like endoplasmic reticulum, mitochondria, chloroplast, and golgi complex are **absent**. Only 70s *ribosomes* are present, which are different from those of eukaryotes (see lesson 1 and 4).

> Prokaryotes have no nuclear membrane around genetic material and no membrane bound cell organelles except mesosomes. They have only the 70s ribosomes.

2.1.2 Monera - General body functions

A. Nutrition

The four nutritional categories found in bacteria are :

(i) Autotrophs - synthesize their own organic food.

(ii) Saprotrophs - feed on dead organic matter.

(iii) Symbionts - use food from other living organisms with which they are associated for mutual benefit.

(iv) Parasites - absorb food from living organisms and cause harm to them

B. Respiration

Respiration in bacteria may be either

(i) aerobic i.e. using oxygen for respiration or

(ii) anaerobic i.e. respiration in the absence of oxygen.

Cellular respiration or breakdown of food to release energy occurs in **mesosomes** which are the inner extensions of the cell membrane.

C. Reproduction

(i) **Asexual Reproduction**

Bacteria reproduce asexually by **binary fission** (Fig. 2.2). Under favourable conditions it takes about 20 minutes for one bacterium cell to divide into two by binary fission.

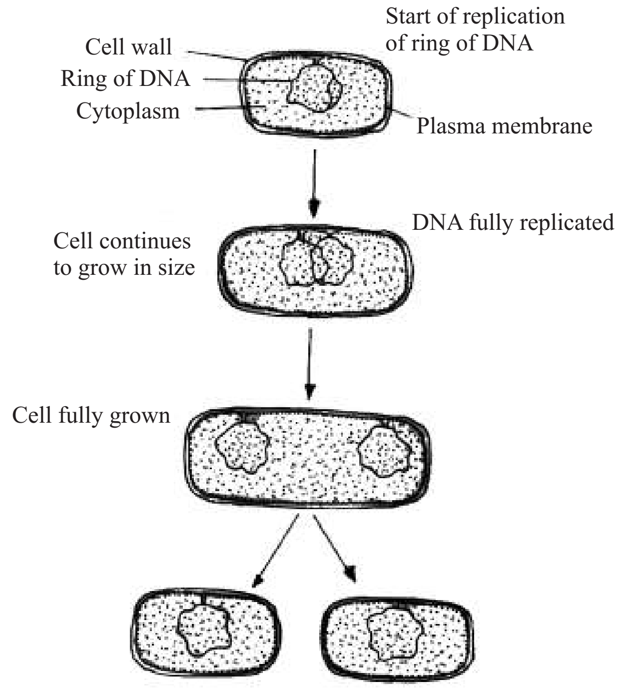


Fig. 2.2 Binary Fission in Bacteria

(ii) **Sexual Recombination (=Genetic Recombination)**

Some bacteria show a primitive mode of sexual reproduction. It is different from sexual reproduction in higher forms. The steps are:

(a) Two conjugating (lie very close for transfer of genes) bacteria are held together by pili.

(b) A segment of DNA strand is transferred from one bacterium to another bacterium. (Fig 2.3) or F-factor = sex-factor (fertilisty factor) is transferred from male donor cell to female (recipient) cell.

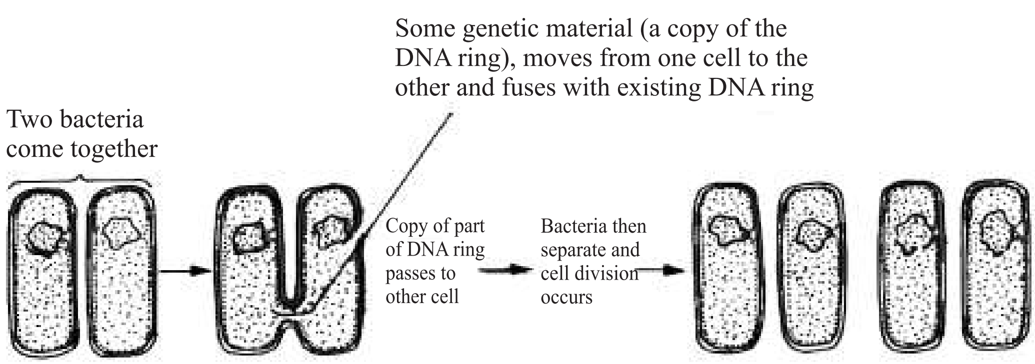


Fig. 2.3 Conjugation in Bacteria

INTEXT QUESTIONS 2.1

1. What is the chemical nature of the circular single chromosome of a bacterium?

   ....

2. Name the special region in the bacterial cell where genetic material lies.

   ....

3. What is the main component of cell wall in prokaryotes?

   ....

4. State one point of difference between flagella and pili.

   ....

5. Give one difference between aerobic and anaerobic bacteria

   ....

6. What is transferred during sexual recombination in a bacterium?

   ....

2.1.3 Beneficial and harmful bacteria

Many bacteria harm us by causing many diseases. On the other hand some bacteria are very useful.

Diseases Caused By Bacteria

	Name of Bacterium	Disease Caused
1.	*Vibrio cholerae*	Cholera
2.	*Salmonella typhi*	Typhoid
3.	*Clostridium tetani*	Tetanus
4.	*Corynebacterium diphtheriae*	Diphtheria
5.	*Mycobacterium tuberculosis*	Tuberculosis

Beneficial Activities of Bacteria

	Name of bacteriun	Activities
1.	*Rhizobium*	Found in roots of legumes, like Peas, grams, Pulses etc, where it fixes atmospheric nitrogen as ammonia, which is then converted into useful amino acid.
2.	*Azotobacter*	Makes the soil fertile. It fixes atmospheric nitrogen in the soil.
3.	*Streptomyces*	Produces Streptomycin antibiotic.
4.	*Lactobacillus*	Ferments lactose (milk sugar) to lactic acid. This helps in setting of milk into curd.
5.	Methanogenic bacteria	Sewage treatment

2.1.4 Cyanobacteria

These were earlier called the blue-green algae. (Fig. 2.4a) A very successful group on primitive earth, they could carry out photosynthesis and the oxygen released during the process changed the earth's atmosphere and gradually the level of oxygen increased in the earth's atmosphere.

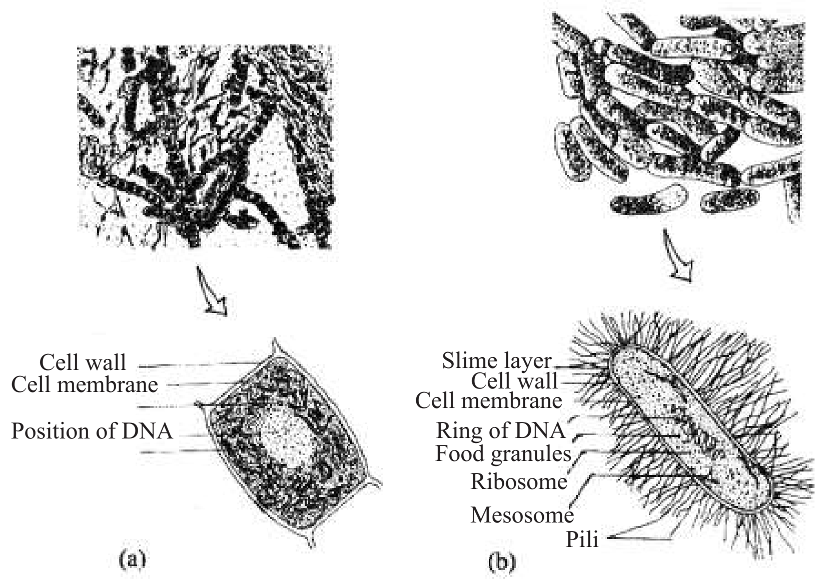


Fig. 2.4a-b Cyanobacteria (blue green algae)

Differences between Bacteria and Cyanobacteria

Bacteria	Cyanobacteria
1. Smaller cells	1. Comparatively larger cells
2. May have flagella	2. Do not have flagella.
3. Some bacteria (green) carry out photosynthesis in a different way and do not release oxygen (anoxygenic)	3. They all carry out photosynthesis in the usual manner as in green plants and release oxygen (oxygenic)
4. Sexual recombination by conjugation in some bacteria	4. Sexual recombination has been observed in some cyanobacteria.

INTEXT QUESTIONS 2.2

1. Name the bacteria that :

   (i) fix atmospheric nitrogen in the soil ....

   (ii) set milk into curd ....

(iii) cause tuberculosis ....

(vi) cause tetanus ....

2. Approximately how many bacteria may be obtained from one bacterium in an hour?

....

3. Give any three differences between bacteria and cyanobacteria.

....

2.1.5 Monera

Kingdom Monera includes three groups, viz.

1. Archaebacteria
2. Eubacteria, and
3. Cyanobacteria

Archaebacteria includes bacteria that live in unusual environments particularly at low levels of oxygen. Main types of Archaebacteria are

- **Methanogenic** bacteria that live in sewage and intestinal tracts of animals
- **Thermoacidophilic** bacteria that live in hot springs.
- **Halophilic** bacteria which live in salty conditions where hot sun concentrates sea water. Eubacteria include all other bacteria excluding cyanobacteria. All cyanobacteria are oxygenic photoautotrophs.

2.2 KINGDOM PROTOCTISTA (UNICELLULAR EUKARYOTES)

- Protoctista are **unicellular eukaryotes**. Protozoa, diatoms and unicellular algae are included in it.
- They have membrane bound organelles such as nucleus with chromosomes enclosed in nuclear membrane, mitochondria, chloroplast (in photosynthetic protoctists only), golgi bodies and endoplasmic reticulum.
- Mitochondria are the respiratory organelles.
- Protoctists are either photosynthetic, parasitic or saprotrophic.
- For locomotion, protoctists may have cilia or flagella (Fig. 2.5) having 9 + 2 microtubules unlike those of bacteria, which consist of only one spirally coiled protein, called flagellin.
- They reproduce both asexually and sexually.
- Some protoctists are beneficial to humans whereas the others are harmful.

2.2.1 Classification of Protoctista

The kingdom protoctista includes –

1. **Phylum Protozoa** which has the following four classes :

   (i) Rhizopoda : Example, *Amoeba*

(ii) Flagellata : Example, *Euglena*

(iii) Ciliata : Example, *Paramecium*

(iv) Sporozoa : Example, *Plasmodium*

The protistan algae belong to

1. Phylum Bacillariophyta : Example diatoms
2. Phylum Chlorophyta : Example *Chlorella*

2.2.2 Some examples of Protoctists

1. *Amoeba*

Amoeba is commonly found in the mud, in freshwater ponds and ditches containing decaying leaves.(Fig. 2.5a)

– It has blunt pseudopodia for locomotion.

– It captures food by pseudopodia to form a food vacuole.

– It has a contractile vacuole for osmoregulation

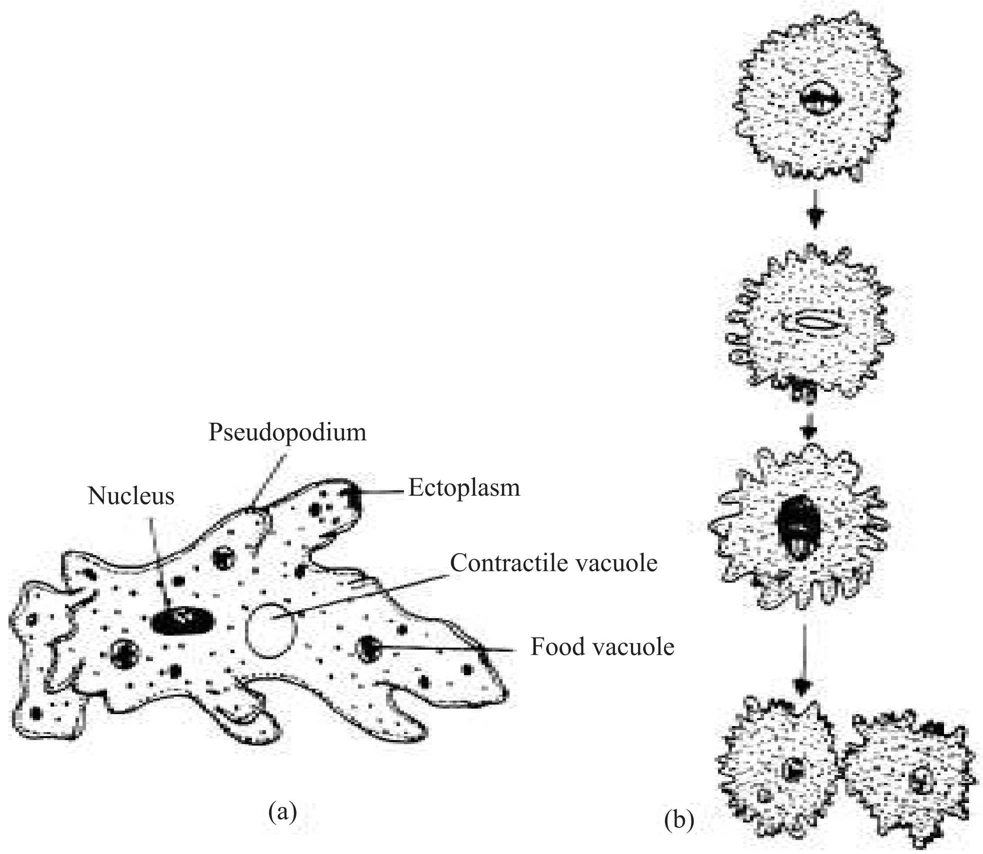


Fig. 2.5 Amoeba : (a) General Structure, (b) Amoeba showing binary fission.

Reproduction : Sexual reproduction is uncommon in *Amoeba*.

Asexual reproduction is by binary fission. (Fig. 2.5b)

2. *Entamoeba*

One common species is *Entamoeba histolytica* which caues amoebic dysentery in humans. It is amoeboid in form. The new host gets infected when the cyst is swallowed along with contaminated food or water. The cyst bursts and releases *Entamoeba* in the intestines where it causes local abscesses (open injury). The symptoms of amoebic dysentery are abdominal pain, nausea and presence of blood and mucus with stool.

3. *Plasmodium* (The malarial parasite)

The life cycle of *Plasmodium* has both asexual and sexual phases.

– The asexual phase is spent in the human blood.

– Sexual phase is spent in the female *Anopheles* mosquito Fig. 2.6.

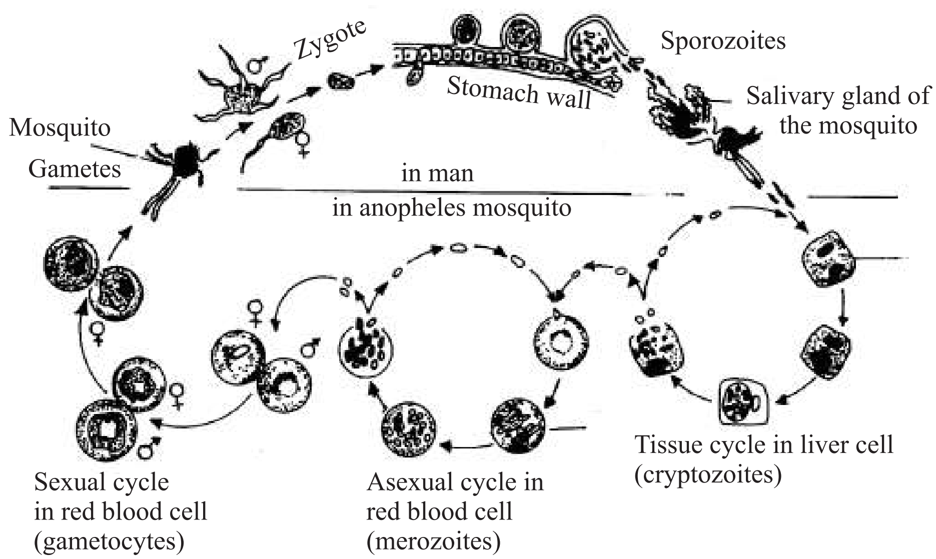


Fig. 2.6 The life cycle of Plasmodium in mosquito and man.

> **Male** *Anopheles* cannot cause malaria as it feeds on plant juices and not the human blood.

4. *Euglena* – A freshwater Flagellate

Euglena is abundantly found in stagnant waters such as pools, ponds and ditches containing decaying organic matter. (Fig. 2.7)

As seen in the Fig. 2.7, the organism has the following parts.

Pellicle - elastic body covering made up of protein.

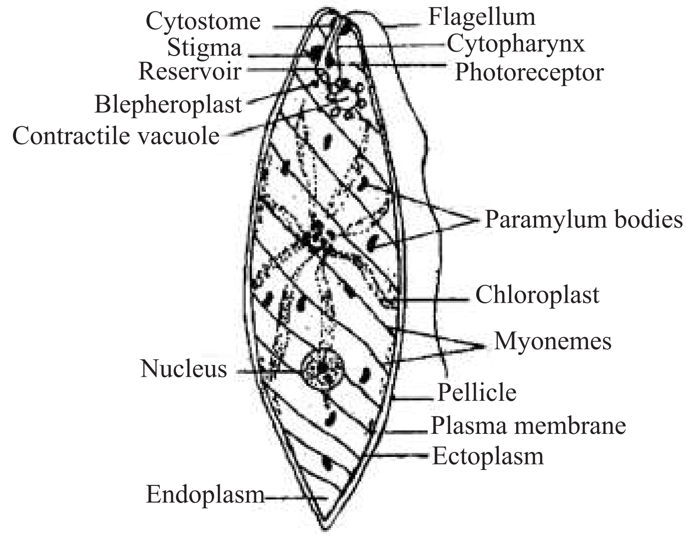


Fig 2.7 *Euglena* - General Structure

Cytostome and Reservoir - the cell mouth leading into a tubular cytopharynx which opens into a vesicle called reservoir.

Stigma or eyespot - a prominent red pigment spot. It is sensitive to light.

Contractile Vacuole - for osmoregulation.

Flagellum - for propulsion in water.

Chloroplast - contain green coloured chlorophyll for photosynthesis.

Reproduction - is by binary fission.

5. The Diatoms

- The diatoms are found in both fresh and salt water and in moist soil.
- Thousands of species of diatoms act as food for aquatic animals.
- Diatoms are either unicellular, colonial or filamentous and occur in a wide variety of shapes (Fig. 2.8).
- Each cell has a single prominent nucleus and plastids. They produce shells (cell walls) containing silica.

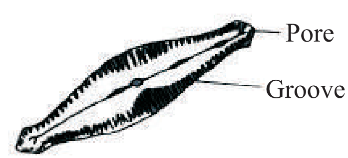


Fig. 2.8 Diatoms

6. Other Algae

- Algae can be unicellular e.g. *Chlamydomonas* (2.9a) or multi-cellular like *Spirogyra* (Fig. 2.9b)

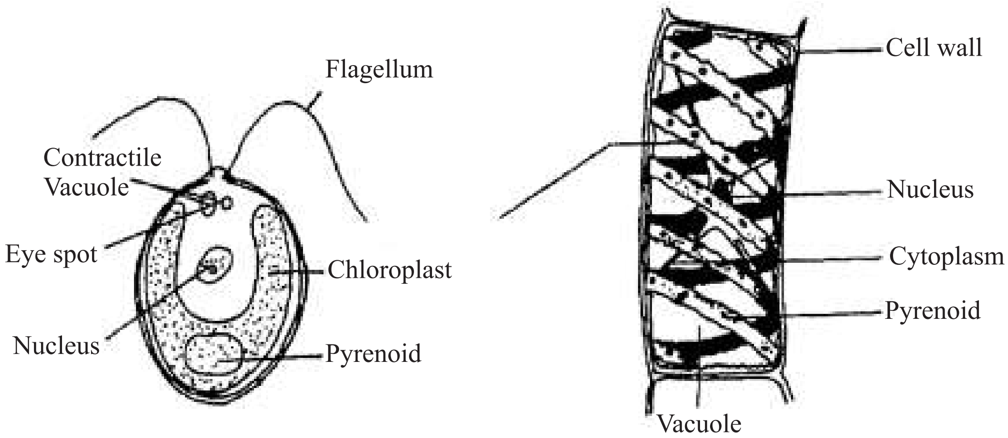


Fig. 2.9 (a) *Chlamydomonas* (b) *Spirogyra*

– Algae can prepare their own food by photosynthesis as they contain chlorophyll. Some algae have other pigments also e.g. blue pigment (Phycocyanin), a brown pigment (Fucoxanthin) or a red pigment (Phycoerythrin). Depending on the pigment present, the algae are called blue, green, brown or red algae.

> Colour of the Red Sea is due to the dominant occurrence of a blue-green alga, *Trichodesmium erythraeus*

– Structurally the algae have a definite cell wall, cell membrane, a nucleus, cytoplasm and choloroplast. The chloroplast is cup-shaped in *Chlamydomonas* and ribbon-shaped in *Spirogyra*. Pyrenoids, the starch containing bodies are integral part of chloroplasts in green algae.

2.2.3 Usefulness of Algae

– Provide food for fish as part of phytoplankton (organisms floating on the water surface)

– These are rich sources of vitamins A and E.

– Many marine forms are important sources of iodine, potassium and other minerals.

– Blue-green algae increase the soil fertility by fixing atmospheric nitrogen.

– Blue-green algae that fix atmospheric nitrogen, are a source of natural fertilizer for the crop plants.

– A group of algae (diatoms) deposit silica in their walls. After their death these algae are preserved as fossils. Their siliceous deposits in large amounts result in the formation of diatomaceous earths that are used as filters, and for lining of furnaces.

INTEXT QUESTIONS 2.3

1. Protoctists are single celled like most of the Monerans. Why have they been put in a separate kingdom? Answer in one short sentence.

   ....

2. Name the protozoan which causes

   (i) Amoebic dysentery ....

   (ii) Malaria ....

3. Which is the kind of asexual reproduction found in Protoctista?

   ....

4. Through which organelle of the protoctists does respiration occur?

   ....

5. Name the organelle responsible for regulating water content (osmoregulation) in amoeba.

   ....

6. Name two kinds of locomotion found in protoctista.

   ....

2.3 KINGDOM FUNGI

2.3.1 Position of Fungi

During warm humid days slices of bread, chapati, leather belts or shoes, develop a powdery layer on them. In lawns and flower beds, mushrooms come out. These are all fungi.

Fungi were earlier classified as plants without chlorophyll and without differentiation of their body into root, stem and leaves. They are now included, in a separate Kingdom called **Fungi.**

2.3.2 Characteristics of Fungi

- Fungi are heterotrophic unicellular or **multicellular eukaryotes**
- Fungi exist as slender thread like filaments called hyphae. Hypha may be one celled or multicelled and has, one or more nuclei. Yeast, however, is single celled, and uninucleate.
- Their cell walls are made of chitin
- A hypha may be divided into cells by partitions called septa.

- Septa have pores through which cytoplasm streams freely.
- A group of hyphae forming a network is called mycelium (mycetos meaning fungus; Fig. 2.10).
- Mycelia spread out on the substrate, or on the ground and even extend upto several kilometers.
- They do not possess chlorophyll as their nutrition is by absorption or feeding on dead organic matter.
- Aquatic fungi have flagellate gametes or flagellate spores
- Higher fungi do not have flagellum at any stage of life cycle.
- Reproduction in fungi is both asexual by means of flagelalte or non-flagellate spores and sexual through conjugation (refer to Fig. 2.13, 2.14).

Fungi are eukaryotic, unicellular or multicellular saprotrophs having filaments which grow through soil, wood and other substrates.

2.3.3 Five main kinds of Fungi

The fungi are of five main kinds

1. Myxomycetes, the **Slime moulds**, which have irregular shape.
2. Phycomycetes, are unicellular, filamentous and branched e.g. *Rhizopus and Phytophthora*.
3. Ascomycetes, are one celled (e.g. yeasts) or multicellular branched e.g. *Aspergillus, Penicillium,* and *Neurospora*.
4. Basidiomycetes, are multicellular, branched, and are represented by rusts, smuts, **Mushrooms** and **toadstools**, which are large enough to be seen by naked eyes.
5. Deuteromycetes, are multicellular filamentous branched fungi which reproduce only by asexual means e.g. *Alternaria*.
6. **Lichens and mycorrhizae** which exist in symbiotic associations.

1. Yeasts

Yeasts are fungi which do not produce any hyphae. These are generally in the form of single oval cells.

Fig. 2.10 shows the general structure of a yeast cell. Note the followmg features in it:

– ovoid cell.
– distinct cell wall and nucleus.
– one or more vacuoles in the cytoplasm.
– cytoplasm is granular and has glycogen and fat (oil) globules.

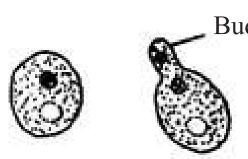


Fig. 2.10 A single cell of yeast

Nutrition

Yeast is saprotrophic. It can directly absorb simple sugar (glucose) but for obtaining sucrose (cane sugar) it gives out the enzyme invertase or sucrase which breaks down sucrose into simple sugars. The simple sugars are then simply absorbed into the cell.

Yeast respires anaerobically to yield energy as follows

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} \longrightarrow \underset{\text{(ethyl alcohol)}}{2C_2H_5OH} + 2CO_2 + \underset{\text{(energy)}}{2ATP}$$

Reproduction

Yeast reproduces asexually by budding (Fig. 2.11).

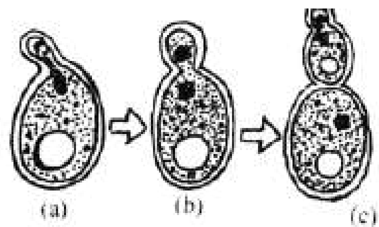


Fig. 2.11 Budding in yeast (a) A bud is forming and the nucleus is dividing; (b) Bud formed and the nucleus gets divided; (c) Further budding forms a chain

Sexual reproduction may also occur by conjugation between two yeast cells. The fused contents divide by one meiosis followed by one mitosis to produce eight cells with a thick wall around each. The 8-celled structure is called **ascus** and each cell is called **ascospore**. The ascospores may be carried by wind and germinate under suitable conditions to produce new yeast cells.

2. Myxomycetes (Slime Moulds)

These consist of a naked, creeping multinucleate mass of protoplasm sometimes covering up to several square metres. The nuclei are diploid

3. Basidiomycetes (Mushrooms and Toadstools)

The vegetative part of the mycelium lies embedded in the substratum (in ground or in wood) When conditions are favourable the umbrella like mushrooms grow out with a stalk and a cap. (Fig. 2.12)

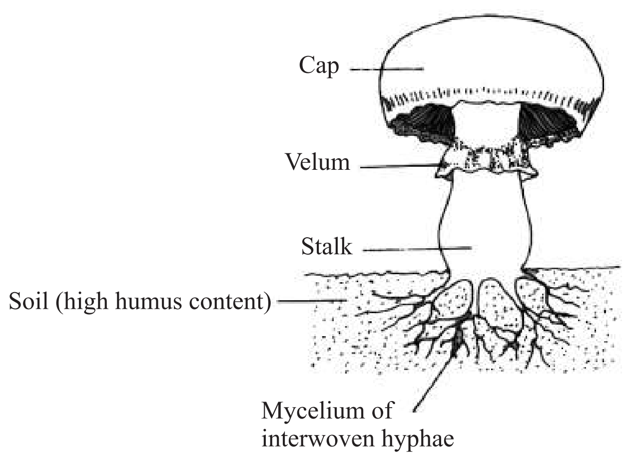


Fig. 2.12 A Mushroom

4. Lichens

These are a combination of a certain fungus and a green or blue green alga which live in a symbiotic (mutually beneficial) association : the green or blue green alga prepares food while the fungus gives protection, and absorbs water and minerals from the surroundings.

INTEXT QUESTIONS 2.4

1. Name the slender filaments that form the body of a fungus.

   ....

2. Which are the types of reproduction found in fungi?

   ....

3. Draw two small figures to show asexual reproduction in yeast.

   ....

4. Which are the four main kinds of fungi?

   1. .... 2. ....

   3. .... 4. ....

2.3.4 Economic importance of Fungi

A. Harmful Fungi

Several agricultural plants like sugarcane, maize, cereals and vegetables suffer from diseases caused by fungi.

1. *Puccinia graminis* (Wheat Rust)

It causes brown patches on leaf and stem of wheat plants. It decreases the yield of wheat and makes it unfit for human consumption.

2. *Rhizopus* or (Bread Mould) grows on bread (Fig. 2.13).

If the bread is exposed to warm and humid conditions a cottony mass develops in few days. This white cotton mass later develops a greyish black colour, because of black coloured spores.

– The whitish network is called mycelium.

– The mycelium contains thread like structures called *hyphae*.

– The root-like sturctures growing out of the hyphae penetrate the bread, and secrete digestive enzymes (extracellular digestion) and absorb the digested food.

– Greyish black colour of the mould develops due to formation of sporangium which after rupturing release dark coloured spores. The spores scatter by wind and germinate after falling on a suitable substractum. **This is asexual reproduction**.

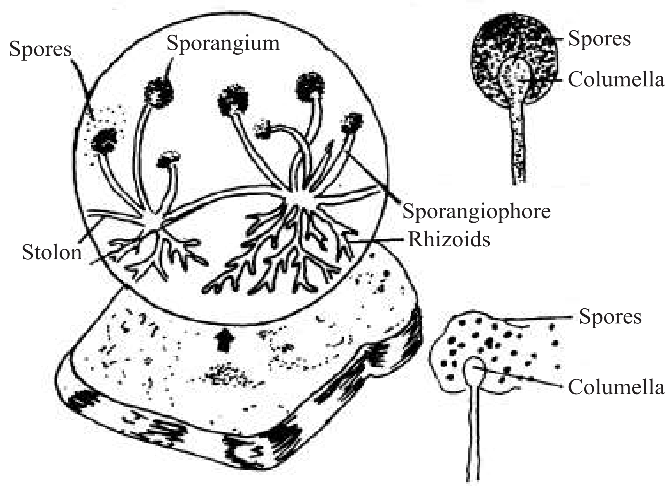


Fig. 2.13 Asexual reproduction in *Rhizopus*

Sexual reproduction (Fig. 2.14) takes place by conjugation between two neighbouring hyphae to produce a zygospore which after a period of rest undergoes meiosis followed by several mitotic cell divisions to produce a germ sporangium having a large number of haploid unicellular spores. The germ sporangium differs from asexual sporangium, as it does not have columella. When mature, the germ sporangium bursts to release spores which germinate on meeting favourable conditions and produce a new mycelium

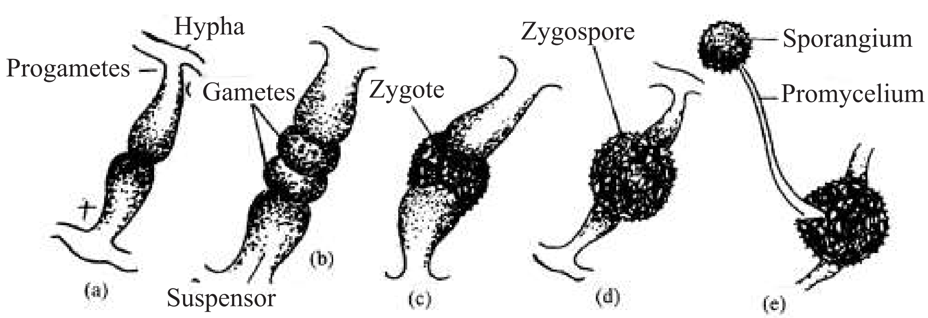


Fig. 2.14 Sexual reproduction in *Rhizopus*

3. In **human,** skin diseases like ringworm and athlete's foot are caused by fungi. Some ear infections are also caused by fungi.

B. Beneficial Fungi

– Certain Mushrooms (such as *Agaricus campestris*) are edible.
Yeast is used for fermentation during manufacture of bread, beer, soya sauce, cheese and wine.

– **Mycorrhizae** are fungi associated with roots of plants. Roots benefit in getting minerals from the environment while fungi get food from the plant in return through such association.

– *Neurospora* has been a favourite experimental material in Genetics.

– Various antibiotics are derived from fungi. Penicillin is obtained from *Penicillium notatum* (Fig. 2.15). Its antibiotic effect was discovered by chance by Alexander Flemming in 1927.

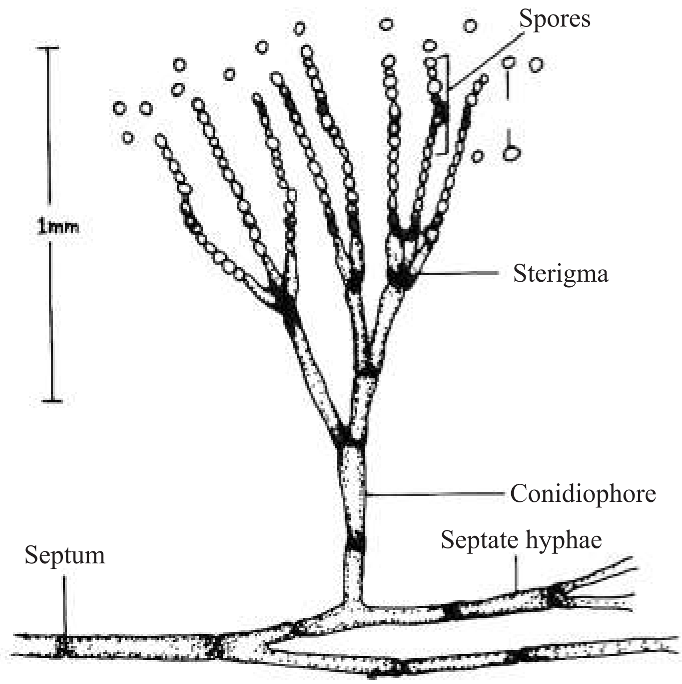


Fig. 2.15 *Penicillium*

INTEXT QUESTONS 2.5

1. Name
   (i) the fungus from which Penicillin is extracted ....
   (ii) a unicellular fungus. ....
   (iii) The fungus which causes wheat rust ....
   (iv) The whitish cottony mass, growing on stale bread. ....
   (v) Two common human diseases caused by fungi ....
2. Who discovered antibiotic properties of *Penicillium*?

   ....

WHAT YOU HAVE LEARNT

- Protoctista includes protozoa, diatoms and other unicellular algae.
- They are unicellular eukaryotes and possess organelles like mitochondria, golgi, bodies, chloroplast, endoplasmic reticulum
- Protoctists ae autotrophic, saprotrophic or parasitic.
- Protozoans may have pseudopodia, cilia and flagella for movement.

- They reproduce asexually as well as sexually.
- Examples of protoctists are *Paramecium*, *Amoeba*, malarial parasite, *Chlorella*, *Euglena*, *Chlamydomonas* and diatoms.
- Some protoza cause diseases. Algae provide food for fish, and are rich sources of some minerals and vitamins. Blue green algae fix atmospheric nitrogen. Walls of diatoms which have silica get deposited to form diatomaceous earths, which is used as filters and for lining the furnaces.
- Diatoms form bulk of plankton in ponds lakes and oceans, and are food for many aquatic organisms.
- Prokaryotes lack true nucleus. Genetic material in Prokaryotes is in the form of single circular DNA.
- DNA is placed in special region in a bacterial cell called nucleoid. A small ring of extra DNA present in some bacteria, is called plasmid or sex factor or F-factor (F = fertility)
- Bacteria exhibit four different kinds of nutrition - autotrophic, saprotrophic, symbiotic and parasitic.
- Cyanobacteria possess chlorophyll that helps in oxygenic photosynthesis.
- Some bacteria fix atmspheric nitrogen to enrich soil, some help in sewage treatment.
- Certain bacteria cause diseases like cholera, typhoid, tetanus and tuberculosis.
- There are bacteria that survive in extreme environments like high temperature, high salinity, and presence of methane.
- Fungi are eukaryotic, unicellular or multicellular saprotrophs.
- Fungi are of several kinds such as yeasts, slime moulds, mushrooms, lichens and mycorrhizae.
- Yeasts are unicellular, which commonly reproduce asexually by budding. Sexual reproduction occurs by conjugation.
- Slime moulds are naked, creeping multinucleate mass of protoplasm.
- Lichens are symbiotic combinations of fungi and algae.
- *Rhizopus* is the common bread mould that produces whitish network (mycelium) on stale bread, in warm humid weather.
- *Rhizopus* reproduces asexually by spores, and sexually by producing zygospore which in turn produces haploid spores after meiosis and repeated mitotic divisions.
- Wheat rust (*Puccinia graminis*) causes brown patches on leaf and stem of wheat plants.
- Ringworm and athelete's foot are two common fungal diseases of humans.
- Certain mushrooms are edible.
- Yeast is used for making bread and beer.

- *Neurospora* is used in experiments on genetics.
- *Penicillium notatum* yields penicillin.
- Various other fungi produce other antibiotics.

Notes

TERMINAL EXERCISES

1. Draw a labelled diagram of a typical bacterial cell.
2. List the different nutritional categories of bacteria and protoctists.
3. Draw the labelled diagrams to show binary fission in bacteria.
4. How does amoeba normally reproduce ? Draw diagrams to represent the process.
5. Draw a labelled diagram of *Euglena*.
6. What are the common features of diatoms which justify their inclusion in protoctists?
7. Write a paragraph on economic importance of the protoctists.
8. List any three characteristics of fungi.
9. What are mycorrhizae?
10. Name three harmful fungi mentioning their harmful effects.
11. Write a note on beneficial fungi.
12. Draw labelled diagrams of the following :
    (i) A series of stages in the budding of yeast.
    (ii) Magnified view of the bread mould growing on bread.

ANSWERS TO INTEXT QUESTIONS

2.1
1. DNA
2. Nucleoid
3. Peptidoglycan
4. Flagella are thicker and longer than pili/used in movement, used in conjugation.
5. Aerobic bacteria respires in presence of oxygen/the anaerobic bacteria respires in the absence of oxygen.
6. A fragment of DNA strand.

2.2 1. (i) *Azotobacter*

(ii) *Lactobacillus*

(iii) *Mycobacterium tuberculosis*

(iv) *Clostridium tetani*

2. Eight

3. Bacteria - smaller cells, flagella present, sexual recombination by conjugation. Cyanobacteria - large cells, no flagella, rare sexual recombination.

2.3 1. Protoctista are Eukaryotes/ possess true nucleus.

2. (i) *Entamoeba histolytica*

(ii) Malarial parasite or *Plasmodium*.

3. Binary fission

4. Mitochondria

5. Contractile vacuole

6. Flagellar, Pseudopodial or amoeboid (any two).

2.4 1. (i) mycelium

2. asexually, sexually

3. Refer diagram 2.12

4. (i) Yeast

(ii) Slime moulds

(iii) Mushrooms and Toadstools

(iv) Lichens

(v) *Aspergillus/Penicillium/Neurospora*

2.5 1. (i) *Penicillium notatum*

(ii) Yeast

(iii) *Puccinia graminis*

(iv) mycelium, *Rhizopus*

(v) spores

(vi) Ringworm, Athelete's foot

2. Alexander Flemming

3

KINGDOMS PLANTAE AND ANIMALIA

In the previous lessons you have learnt about the basic aspects of classifying organisms and about the three lower kingdoms: **Monera** (*prokaryotic, unicellular rarely multicellular and filamentous*), **Protoctista** (*eukaryotic, unicellular*), and **Fungi** (*eukaryotic, uni- or multicellular, and heterotrophic*). In this lesson, you will study about the remaining two kingdoms, **Plantae** (*eukaryotic, multicellular and autotrophic*) and **Animalia** (*eukaryotic, multicellular and heterotrophic*).

OBJECTIVES

After completing this lesson you will be able to

- *give the basis of inclusion of certain organisms in Kingdom Plantae;*
- *classify Kingdom Plantae upto divisions;*
- *give the typical characteristics of Algae, Bryophyta, Pteridophyta and Spermatophyta;*
- *classify the division Spermatophyta upto classes- Gymnospermae and Angiospermae;*
- *give the typical features of dicot families such as Malvaceae and Fabaceae;*
- *give the typical features of the monocot families such as Liliaceae and Poaceae;*
- *justify the inclusion of certain organisms in Kingdom Animalia;*
- *classify Kingdom Animalia upto Phyla;*
- *give the characteristics of various animal phyla with examples;*
- *classify Arthropoda and Chordata upto classes with examples;*
- *classify Mammalia upto major orders with examples.*

3.1 MAIN DIVISIONS OF KINGDOM PLANTAE (PLANTS)

Both plant and animal kingdoms include a wide variety of organisms which contribute towards the biodiversity on the planet earth. We shall now learn the classification of plants and animals.

> Plants are multicellular, eukaryotic, photosynthetic autotrophs rarely heterotrophs having cellulosic cellwalls. All are embryophytes.

Plantae are classified as follows :

Kingdom Plantae (Embryophyta) is classified into the following divisions:

1. **Bryophyta :** Amphibians of plant kingdom, non-vascular.
2. **Pteridophyta :** True root, stem and leaves, vascular tissue present.
3. **Spermatophyta :** Seed producing, vascular tissues present.

Spermatophyta are further divided into:

(a) Gymnospermae : naked seeded plants. Seeds not enclosed in an ovary.

(b) Angiospermae : seeds enclosed in the ovary wall; are divided into :

- (i) Dicotyledons : embryo with two cotyledons.
- (ii) Monocotyledons : Single cotyledon in the embryo.

3.2 BRYOPHYTA (BRYOPHYTES)

Bryophytes are amphibians of plant kingdom as they complete their life cycle in both water and on land. These mainly grow in damp, shady places, especially in the hills.

- They are embryophytes that do not have vascular tissues (neither xylem nor phloem), where multicellular sporophytes are always borne on the gametophytes.
- No true leaves and roots, as their independent plant body is gametophytic (haploid).
- Sex organs are jacketed as they are always surrounded by one or several layers of sterile cells.

There are three main types of bryophytes

1. Flat, ribbon-like – Liverworts (*Marchantia*) Fig. 3.1(a)
2. Small, leafy plant body – Mosses (*Funaria*) Fig. 3.1(b)
3. Flat, thalloid plant body bearing a horn-like sporophyte – Hornworts or *Anthoceros*

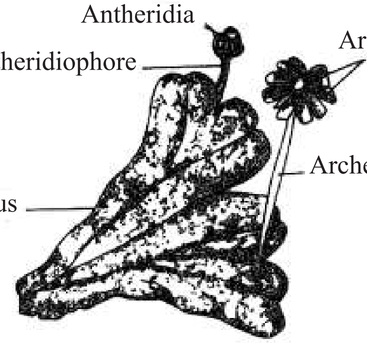


Fig 3.1(a) Liverworts (*Marchantia*)

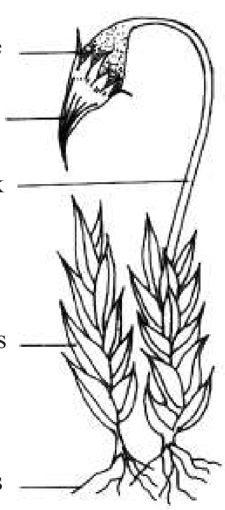


Fig 3.1(b) Moss plant (*Funaria*)

In all types of bryophytes, the main plant body is **gametophyte**, larger and more persistent and photosynthetically active which bears the sex organs. In mosses, the gametophytic plant body is a leafy stem called '**gametophore**' but in liverworts and hornworts the plant body is usually a thallus, that is ribbon-like or heart-shaped and bilaterally symmetrical. The body is without roots, stems and leaves. The plants are anchored to soil by rhizoids, which are unicellular in liverworts and hornworts and multicellullar in mosses. Rhizoids help in anchorage and also in absorption of water and minerals from the substratum. The male sex organs are **antheridia** and female sex organs are **archegonia**. The gametes are produced in the sex organs. Male and female gametes fuse to give rise to a zygote which develops into a **sporophyte**. Sporophyte remains attached to gametophyte and depends on it for food and minerals. The sporogenous tissue in the sporophyte undergoes meiosis to produce haploid spores. The spores, on dispersal, germinate to give rise to a gametophyte again.

Gametophyte (Undergoes Mitosis): Gamete producing phase of plants

Sporophyte (Undergoes Meiosis): Spore producing phase of plants

In all three types of bryophytes, the life cycle shows **Alternation of generations**.

Comparison of gametophytic and sporophytic phases of Bryophytes

Gametophytic phase	Sporophytic phase
1. Haploid phase, generally autotrophic	Diploid phase, heterotrophic or partially autotrophic
2. Has multicellular sex organs called antheridia and archegonia bearing sterile jacket surrounding the gametes	Has spore-producing structure
3. Produces gametes	Produces spores
4. Gametes are produced by mitosis	Spores are produced by meiosis
5. Dominant phase occupies most of the life period	Short-lived phase which remains attached to the gametophyte

- The bryophytes are pioneers of vegetation, i.e. they are the first ones to grow on various habitats like rock, lava, sand, water and act as soil binders.
- The mosses hold water better than the soil thus improve the microhabitat for seeds of other plants to grow.
- These are the sources of food for fish and birds and their dried plant body is used as nesting materials by birds.

INTEXT QUESTIONS 3.1

1. Mention one unique feature of bryophytes.

   ....

2. Define alternation of generations.

   ....

3. Name the male and female sex organs of bryophytes.

   ....

4. List the habitat most suitable for the growth of bryophytes.

3.3 PTERIDOPHYTA (PTERIDOPHYTES)

A fern plant is a pteridophyte. (Fig. 3.2)

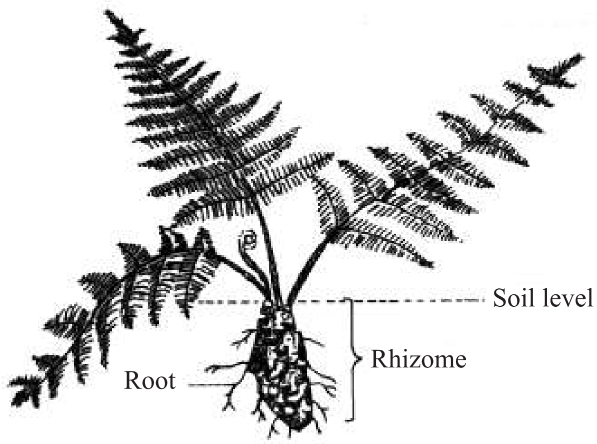


Fig. 3.2 A garden fern plant

1. Ferns are lower vascular plants. They contain vascular tissue. Which is made up of xylem and phloem and helps in conduction of water and nutrients to all parts of the plant body. Pteridophytes are usually found in damp, shady places or in the gardens, and on the hills where temperature is low.
2. The main plant body represents a sporophytic (diploid) generation and has roots which penetrate the soil to absorb water, and minerals.
3. The leaves (**fronds**) of sporophyte grow on thick, horizontal underground stem or **rhizome** which bears adventitious roots. The young leaves and the base of **fronds** are covered by dry brown scales (ramenta).
4. The young leaves and leaflets are characteristically circinately coiled structures (see Fig. 3.2*a*). The axis of the leaves is called **rachis** and leaflets on both sides of rachis are called **pinnae**. The divisions of pinnae are known as pinnules.
5. On the under surface of the leaves, develop spore-producing bodies called **Sporangia** in groups, called **sori** (singular - **sorus**) which may or may not be covered by multicellular structure called **indusium**. The sporogenous tissue in the sporangia undergoes meiosis to produce haploid spores.
6. The spores on dispersal germinate into an independent, small thallus–like body, the gametophyte, called **prothallus**. The prothallus bears antheridia and archegonia which produce male and female gametes respectively. The gametes fuse and the zygote develops into a diploid sporophyte.
7. The young embryo absorbs nutrients and water from the gametophyte until its roots and leaves are formed. The gametophyte then dies.
8. Gametophyte grows independent of sporophyte, and it lives for a short period of time but a new sporophyte is temporarily dependent upon a tiny gametophyte.

The gametophytic and sporophytic phases alternate as in bryophytes

INTEXT QUESTIONS 3.2

1. Name the dominant generation of pteridophytes.

   ....

2. The stage of pteridophytes which produces spores for continuing rest of the life cycle is.

   ....

3. Why do you classify pteridophytes under Trachaeophyta?

   ....

4. Name the male and female reproductive organs in pteridophytes?

   ....

5. Write the name of gametophyte of fern.

   ....

3.4 GYMSOSPERMAE (GYMNOS; NAKED, SPERMA; SEED)

Together with flowering plants Angiosperms, the Gymnosperms form the group Spermatophyta (sperma; seed, phyte; plant) i.e. seed-producing plants.

The gymnospermae bear naked ovules on flat scale leaves called ovuliferous scales which are not enclosed in carpels (ovary). The ovuliferous scales are arranged in cones.

Characteristics of Gymnosperms

1. The adult plant (sporophyte) is a tall, woody, perennial tree or shrub mostly evergreen. The stem is usually branched, but rarely unbranched as in, ***Cycas***.
2. Leaves may be simple (as in ***Pinus***) (Fig. 3.3a) or compound (as in ***Cycas*** Fig. 3.3b).
3. Leaves may be dimorphic or of one kind only. Foliage leaves are large green simple or pinnately compound, needle-like and grow on dwarf shoot as in, *Pinus*, or directly borne on the main trunk as in ***Cycas.*** Scale leaves are brown and simple.
4. Vascular bundles in stem are arranged in a ring and show secondary growth.
5 Gymnosperms bear cones which are usually unisexual (either male or female, Fig. 3.3c), rarely bisexual as in *Gnetum*.
6. Pollen grains are haploid produced in microsporangia of the male cones. In *Pinus*, each pollen grain has two large sacs, called wings to help in the dispersal by wind. Pollen grains produce two male gametes.
7. Ovules are not enclosed in ovary as in Angiosperms, but are borne naked on leafy megasporophylls of female cone, so the term gynmosperms or 'naked seeds' for this group. Ovules are produced side by side, inside which female gamete or egg is produced. The male gamete fuses with female gamete in the ovule. The fertilised ovule then develops into a seed (winged in case of *Pinus*).

Some common Gymnosperms are

Pine (*Pinus*), Redwood (*Sequoia*), Juniper (*Juniperus*), Cedar (*Cedrus*) and sagopalm (Cycas). Many gymnosperms yield timber, resins, turpentine, and several other products like the dry fruit chilgoza. Sago (sabutdana) is obtained from old stems of **Cycas**.

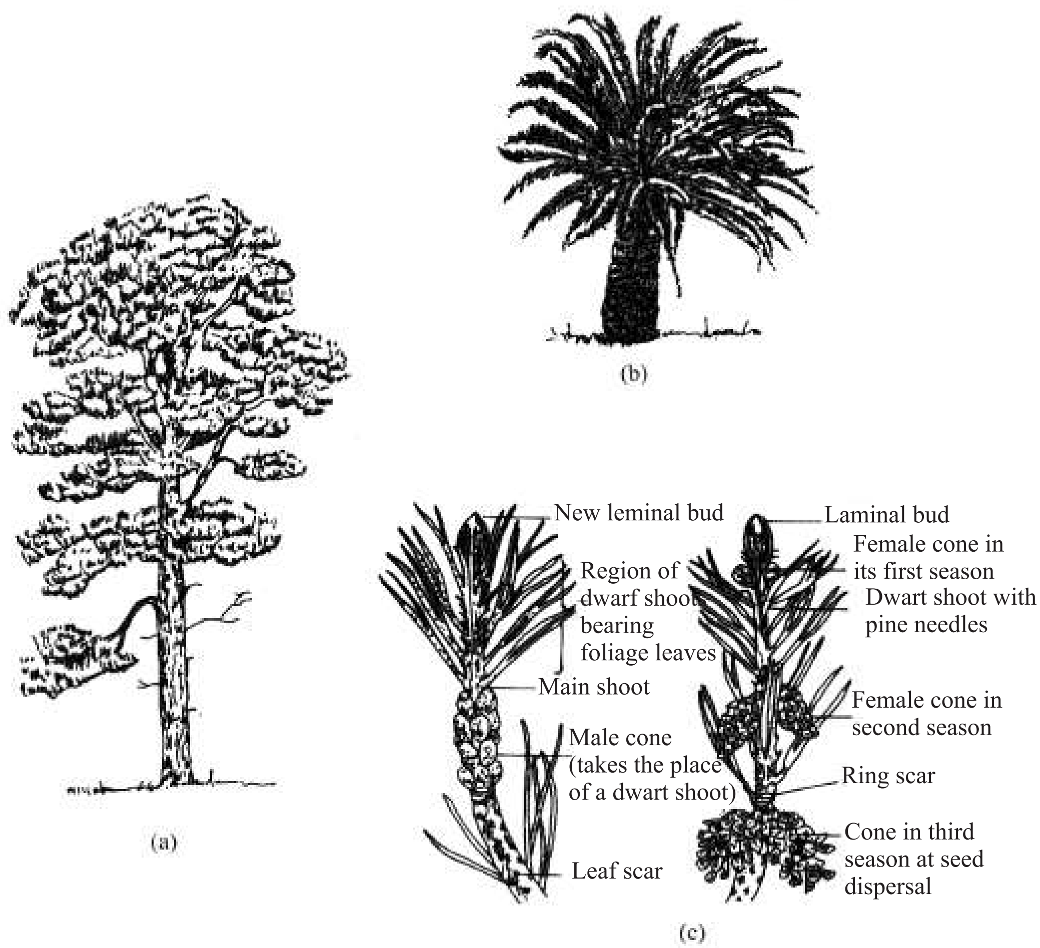


Fig. 3.3 Some examples of phylum Gymnosperm ae (a) *Pinus* tree (b) *Cycas* tree (c) tree with male and female cone

INTEXT QUESTIONS 3.3

1. What does the term gymnosperm mean?

   ....

2. Give any two common examples of gymnosperms.

   ....

3. List two commercial products of gymnosperms.

   ....

3.5 ANGIOSPERMAE

3.5.1 Angiosperms

A typical flowering plant

Our most familiar plants like pea, mango, coconut, wheat and rice come under the group called **Angiosperms**. Their seeds are always enclosed in the fruit. Which is a mature, fertilized ovary.

Look at an angiosperm plant in Fig. 3.4.

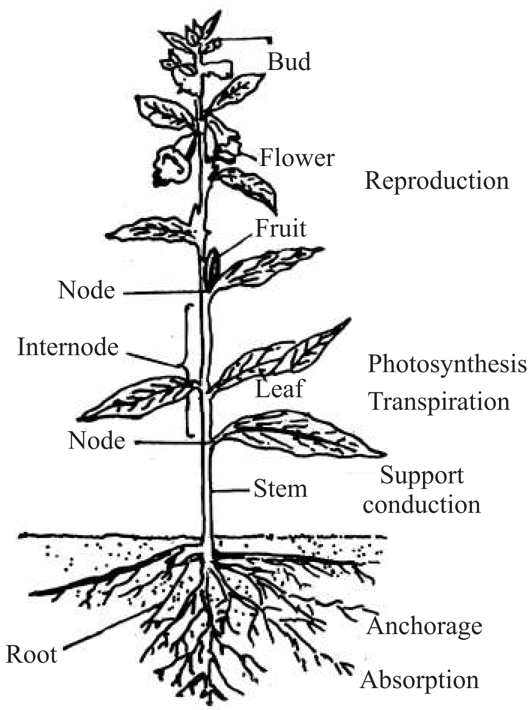


Fig. 3.4 The parts of an angiosperm our plant

The angiosperms are divided into two groups or classes:

1. Dicotyledons. 2. Monocotyledons.

Look at Fig 3.5 to study the differences between the two groups.

Angiosperms bear seeds enclosed in the fruits.

Dicot plants have two cotyledons in seeds whereas **Monocots** have only one cotyledon within the seeds.

Differences between angiosperms and gymnosperms

Gymnosperms	Angiosperms
1. Seeds naked as not enclosed in ovary.	Seeds enclosed in fruit (a mature, fertilized ovary).
2. Independent plants are sporophytes which bear cones where spores develop, that in turn give rise to gametophytes which in turn bear gametes.	Independent plants are sporophytes which bear flowers where reproductive spores develop, which produce gametophytes that in turn, bear gametes.
3. Xylem has mainly tracheids usually absent.	Xylem has both vessels as well as tracheids.

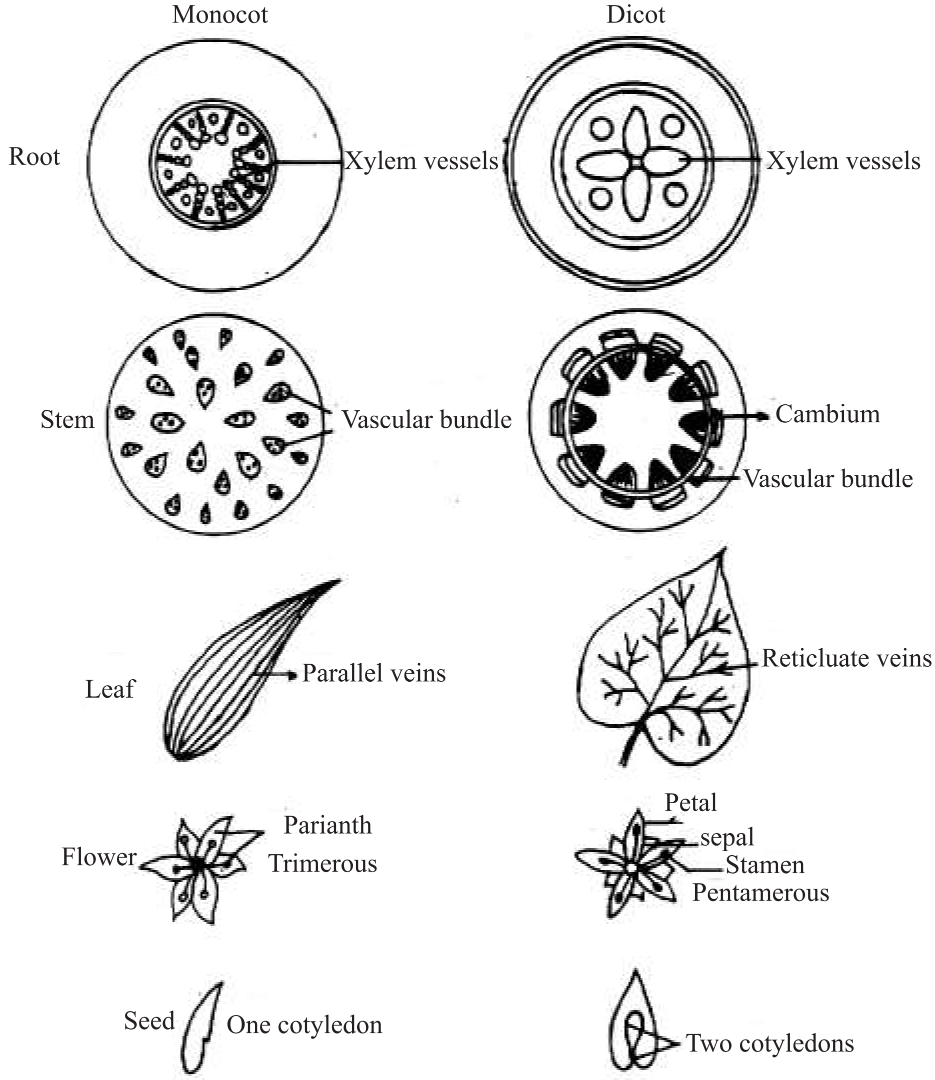


Fig. 3.5 Comparison of Monocots and Dicots

3.5.2 Some families of Angiosperms

Angiosperms include the most diverse and widespread members of the Kingdom Plantae.

Flowers offer a large number of characters which are constant and as such these are used for grouping of angiosperms into different families.

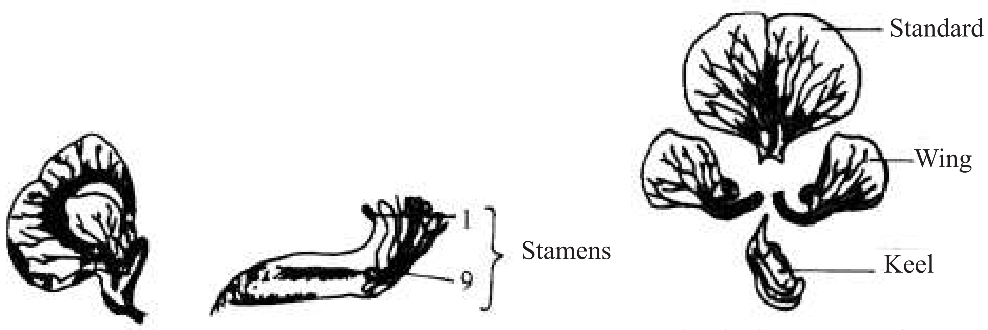
Within each family are included plants which show similarities in organization of various parts of the flower.

We shall study only four families: Two of dicots and two of the monocots

1. Fabaceae – Pea family : includes all the pulses
2. Malvaceae – China rose family
3. Liliaceae – Lily family
4. Poaceae – Grass family : includes cereals

Fabaceae Family (Papilionaceae) : A dicotyledonous family

The plants are herbs or shrubs and rarely trees. Flowers are zygomorphic (means a flower can be cut into two equal halves only through one radius), bisexual, complete, calyx consists of 5 sepals, jointed. Corolla comprise of 5 petals, polypetalous (papilionaceous in shape or butterfly shaped). There is a large petal called standard', two smaller ones called as 'wings and two interior small ones, more or less jointed forming the 'keel'. Androecium gas 10 stamens, arranged in two whorls (9+1) that is diadelphous condition (Fig. 3.6a). Gynoecium is superior, monocarpellary, unilocular with many ovules arranged on a marginal placenta. Fruit is



A flower

Petals of a flower opened out

Fig. 3.6a A pea flower

Some examples of useful plants of Fabaceac

Common Names	Botanical Name
Pea (Matar)	*Pisum sativum*
Pigeon pea (Arhar)	*Cajanas cajan*
Green gram (Moong)	*Phaseolus aureus*
Soyabean	*Glycine max*
Lentil (Masoor)	*Lens culinaris*
Groundnut (Moong-phali)	*Arachis hypogea*
Chickpea (Chana)	*Cicer arietinum*

2. Malvaceae

The plants may be herbs, shrubs or trees.

Hibiscus rosa-sinensis (china-rose/shoe flower, vernacular; gurhal) is one of the best examples of this family. The flowers are large and attractive usually solitary axillary (See Fig. 3.6b).

Flowers are pentamerous (all whorls have members that are five or multiples of five), and actinomorphic (means that it can be divided into two equal halves through any radius). Epicalyx is present as an additional whorl of bracteole just below the calyx. Calyx has five sepals that may be free or joined at the base. Corolla has five petals usually free. Androecium consists of indefinite numbers of monadelphous stamens. The lower parts or filaments join together to formtion staminal tube. Gynoceium consists of 5 carpels, syncarpous, and ovary is superior, pentalocular, having axile placenta. Fruit is a capsule.

Cotton, Bhindi, and hollyhock are other examples of members of this family.

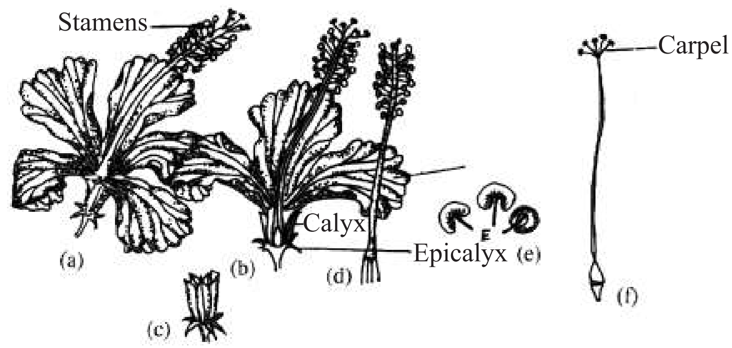


Fig. 3.6b A Chinarose flower

Liliaceae- A monocot family (Lily family)

The plants are mostly perennial herbs. The stem is a rhizome or bulb-like. Leaves may be fleshy, cauline (arising from the underground stem)

Flowers are bisexual, actinomorphic, mostly trimerous (all the whorls have either three units or multiples of three) and hypogynous. Perianth is large, petaloid (corolla-like) usually six, arranged in two whorls of three each, free or united.

Stamens usually six (3+3) in two whorls situated opposite to the perianth lobes. Carpels three, syncarpous, ovary superior, axile placentation. Fruit usually a capsule.

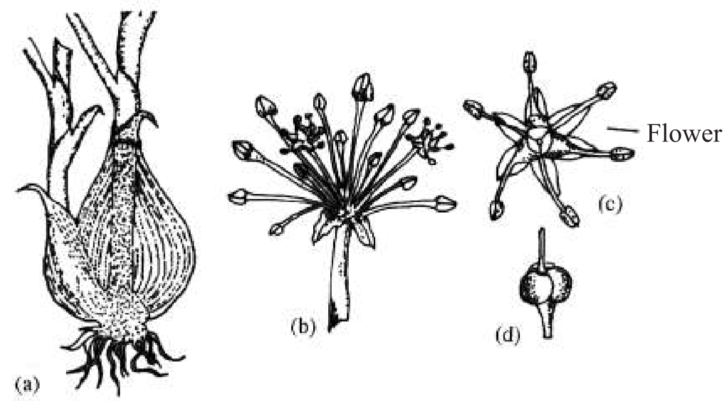


Fig. 3.6c An onion plant.

Some examples of useful plants of Liliaceace

Common names	Botanical names
Ghrit kumari	*Aloe barbadensis*
Shatawar or satmuli	*Asparagus racemosus*
Tulip	*Tulipa tulip*
Kalihari	*Gloriosa superba*
Lily	*Lilium candidum*
Onion	*Allium cepa*

Family Poaceae – A monocotyledonous family

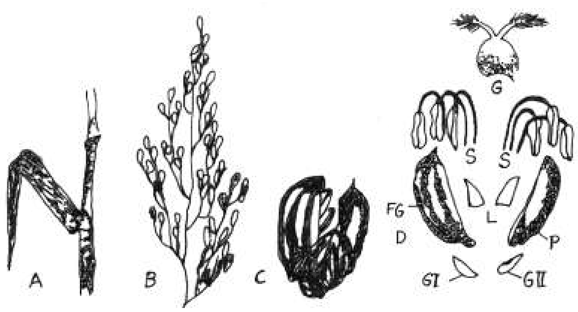
The plants are herbs, rarely woody as in sugarcane. inflorescence, spike of spikelets, For example, wheat. A small spikelet may contain not more than 5 flowers.

Flowers are very small, inconspicuous, with scale-like structures (Fig 3.6d).

Stamens are 3, sometimes 6 as in rice and bamboo, three carpels, syncarpous unilocular, ovary superior bearing a single basal ovule. Fruit is caryopsis (**seed coat and ovary wall inseparably fused**).

Some examples of useful plants of Poaceae

Common Names	Botanical Names
Rice	*Oryza sativa*
Wheat	*Triticum aestivum*
Maize	*Zea mays*
Sugarcane	*Saccharum officinarum*
Sarkanda	*S. spontaneum*
Barley	*Hordeum vulgare*



A. Portion of a branch with sheathing leaves and ligules;
B. A panicle of spikelets;
C. 1-flowered spikelet (note the glumes and stamens)
D. Spikelet dissected out
GI. First empty glume;
G II. Second empty glume;
FG. Flowering glume;
P. Palea;
L. Lodicules;
S. Stamens; and
G. Gynoecium.

Fig. 3.6d Rice plant (*Oryza sativa.*)

INTEXT QUESTIONS 3.4

1. Name one dicotyledonous and one monocotyledonous family.
2. Give the number of stamens in
   (a) Papilionaceae ....
   (b) Malvaceae ....
3. Give botanical names of
   (a) Rice ....
   (b) Arhar ....
   (c) Ghrit kumari ....
4. Where do seeds develop in angiosperms?
   ....

3.6 KINGDOM ANIMALIA

Includes the animals which animalia show a wide variety yet have some common features.

3.6.1 Few general features of kingdom animalia

- These are multicellular eukaryotes
- They have ingestive, heterotrophic nutrition.
- They have the power of locomotion.
- They show increased senstivity through nervous system.

Basis of classification of animals

Organization, symmetry, body cavity, number of embryonic cell layers and presence or absence of notochord are the features used for distinguishing broad categories of animals.

Organization : Bodies of animals are multicellular. although then cells may or may not be organised into tissues and organ systems. Animals such as sponges are aggregates of cells. These are at **cellular level** of organisation. Cnidarians have groups of cells performing specialised functions. They are at **tissue level** of organisation. All other animals have organs and systems for performing body functions. They are at **organ-system** grade.

Symmetry : means *dividing the body into two equal and identical parts*. Sponges are **asymmetrical**. Cnidaria and Echinoderm larvae are radially symmetrical. All other animals are **bilaterally symmetrical or dorsiventral**.

Body Cavity or Coelom : is a cavity between body wall and food canal. It is not present in Acoelomates (a = no, coelom = body cavity) and is present in Eucoelomates (eu = true). Pseudocoelom (pseudo = false) is not a true body cavity. It is found in roundworms.

Embryonic layers : Three layers of cells, ectoderm, mesoderm and endoderm in the embryo (germinal layers) give rise to various parts of the body of the animals. Sponges and Cnidaria do not have mesoderm in their embryos. They have two germinal layers ectoderm and endoderm (diploblastic). Others have three germinal layers (triploblastic).

Notochord : is a solid found in embryonic stage or adults of some animals which are grouped as **phylum Chordata**. All animal groups lacking notochord are termed, **non-chordates**.

Kingdom Animalia
(Multicellular Eukaryotic Heterotrophs)

Sub-Kingdom

	Parazoa	**Eumetazoa**
	(a) No symmetry	(a) Symmetrical
	(b) No tissues (cellular grade of organisation)	(b) Tissue and organ. grade of organisation
	Phylum Porifera	
Organisation and germinal layers	(a) Tissue grade of organisation	(a) Organ system grade of organisation.
	(b) Two embryonic germ layers. (diploblastic)	(b) Three embryonic germ layers (triploblastic)
	Phylum Cnidaria	All other Phyla

Symmetry	Asymmetrical ↓ **Phylum Porifera**	With Radial Symmetry ↓ **Phylum Cnidaria**	Bilateral Symmetry ↓ **All other phyla**
Body Cavity	Aoelomates (No coelom) ↓ **Phyla Porifera, Cnidaria Platyhelminthes**	Pseudocoelomates (False coelom) ↓ **Phylum Aschelminthes**	Eucoelomates (True coelom) ↓ **All other Phyla**
Notochord	Presence or absence of **Notochord**	no notochord **Non-chordata**	Notochord at some stage of life **Chordata**

3.6.2 Major phyla included in Kingdom Animalia

Phylum Porifera (Includes sponges)

Main characters:

- Body with many pores, canals or chambers through which water flows is called the **canal system**.
- large aperture called **osculum** at the upper end.
- Body encloses a large cavity **spongocoel**.
- No organs, movable parts or appendages. Different kinds of cells perform different functions.
- Usually with an internal skeleton of calcareous or siliceous **spicules**, or of **spongin** fibres, or both.
- Reproduction asexual by budding; also sexual.
- Almost all marine.

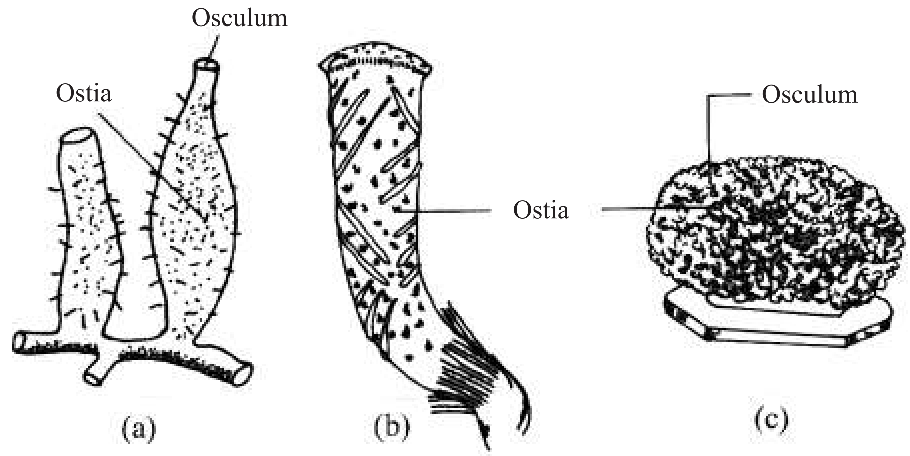


Fig. 3.7 : Phylum Porifera (a) *Sycon;* (b) *Euplectlella;* (c) *Euspongia*

2. Phylum Cnidaria (Includes hydroids, jelly fishes, sea anemone and corals)

Main Characters:

- Body with no head and no segmentation.
- Body wall two layered: external epidermis and inner gastrodermis, jelly-like, non-cellular mesogloea in between.
- Cnidoblasts (stinging cells) present, help to catch prey (carnivorous)
- Skeleton calcareous, horny or none.
- Asexual reproduction by budding in the sessile (polyp) stage, and sexual reproduction in free swimming (medusa) stage.
- Radial symmetry
- All marine, except Hydra (found in fresh water)
- Either fixed like hydra, sea-anemones and corals, or free floating like the jelly fish.

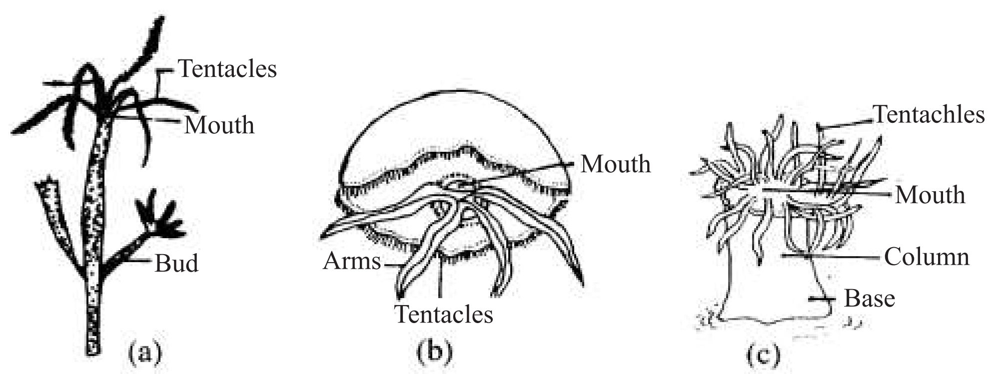


Fig. 3.8 Three common Cnidarians (a) Hydra (b) Jelly fish (c) Sea Anemone

3. Phylum Platyhelminthes (Flat worms)

Main Characters:

- Elongated, soft bodied, dorsoventrally flattened worms, without true segmentation.
- No body cavity

- Suckers or hooks or both for attachment to the body of the host
- Sexes usually united, mostly sexual reproduction, with asexual reproduction in some.
- Alimentary canal has only one opening–the mouth. In some forms (e.g. tapeworms) there is no alimentary canal at all.
- A few are free-living but mostly parasites.

Examples: *Planaria* (free living),
Fasciola (liver-fluke) is a parasite of sheep liver, *Taenia* (tapeworm) is a parasite of the human intestine.

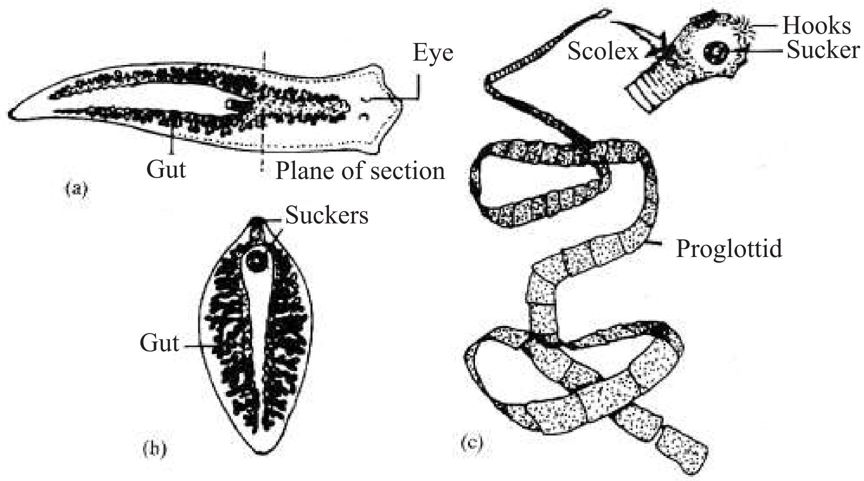


Fig. 3.9 Phylum Platyhelminthes (a) *Planaria* (b) *Fasciola* (c) *Taenia*

3. Phylum Aschehelminthes (Class Nematoda)

(Roundworms, thread worms)

Main characters:

- Elongated cylindrical round body
- Body cavity is a pseudocoelom (false body cavity)
- Alimentary canal opens at the two ends, mouth and anus.
- Sexes separate, males smaller than females (Fig 3.10).
- Mostly parasitic in animals but some live freely in the soil.
- *Ascaris* is a common roundworm, parasitic in the intestine of humans.
- Pinworm and *Wucheria* (Filariaworm) are some other examples.

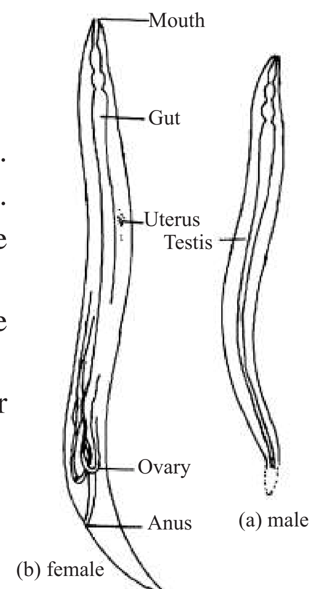


Fig. 3.10 *Ascaris* (a) Female (b) Male

4. Phylum Annelida (Includes earthworms)

Main characters:

- Elongated, segmented, coelomate (true body cavity) worm-like animals.
- Body provided with setae or parapodia for locomotion.

– Well developed digestive system with the alimentary canal open at both the ends.
– Excretory organs called **nephridia**.
– Sexes united (as in earthworm) or separate (as in *Nereis*).
– Regeneration quite frequent.
– Aquatic, some terrestrial animals, some living in tubes and some even parasitic.

Examples: *Nereis*, Earthworms like *Pheretima* (free-living in soil), *Hirudinaria* (leech, a parasitic on cattle, See figure 3.11.

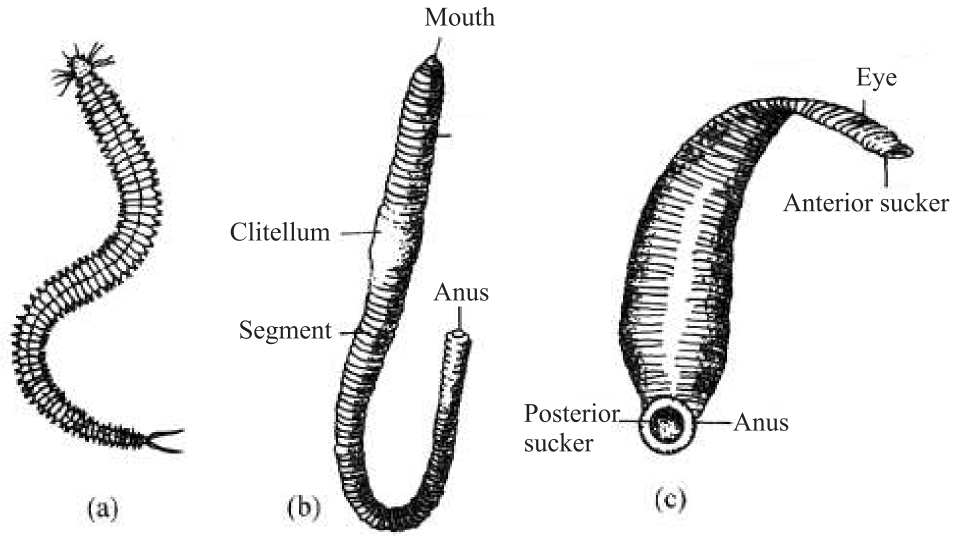


Fig. 3.11 Annelids (a) *Nereis* (b) *Pheretima* (c) *Hirudinaria*

6. Phylum Arthropoda (includes Crab, scorpion, insect, spiders etc.)

Main Characters:

– Segmented body, can be differentiated into head, thorax and abdomen
– Head and thorax often fused to form **cephalothorax**
– Jointed legs for locomotion, one pair each on some or all body segments
– Exoskeleton of chitinous cuticle, shed at intervals (moulting)
– Sexes usually separate.

Arthropods are further divided into classes.

(i) Crustacea (ii) Myriapoda (iii) Insecta (iv) Arachnida

Classification

Phylum Arthropoda

Class 1 Arachnida	Class 2 Crustacea	Class 3 Myriapoda	Class 4 Insecta
(a) Cephalothorax with 2- chelicerae, 3- pedipalpi, and 4 pairs of walking legs	(a) body covered with dorsal covering called carapace	(a) Body with numerous segments	(a) body divisible into head, thorax, and abdomen.

(b) abdomen usually without legs	(b) cephalothorax with 13 pairs of legs in appendages sexes usually separate	(b) each segment bearing 1-2 pairs of legs terrestrial and air-breathing arthropods	(b) thorax 3-segmented with 3 pairs of legs in each segment usually 2 pairs of wings on the last two thoracic segments.
(c) eyes simple	(c) eyes compound	(c) eyes compound	(c) eyes compound
(d) sexes separate	(d) sexes separate	(d) sexes separate	(d) sexes separate
(e) Example scorpion (Fig. 3.12a)	(e) Example Prawn (Fig. 3.12b)	(e) Example (Scolopendra) and Millipede (Fig. 3.12c)	(e) Example: Cockroach (Fig 3.12d)

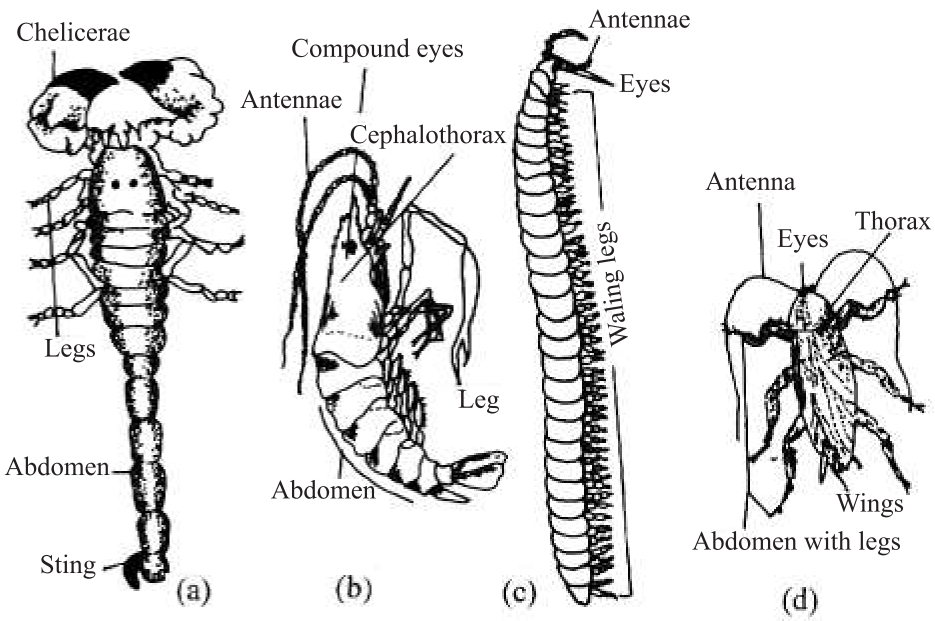


Fig. 3.12 Arthropods (a) Scorpion; (b) Prawn; (c) Millipede; (d) Cockroach

7. Phylum Mollusca (includes squids, snails and oysters)

Mollusca

These animals have a soft, unsegmented body, with a hard, calcareous shell to protect the soft body. They have a muscular foot to help in locomotion and also to act as a weapon in some cases. Examples: snails, slugs, oysters, mussels, clams, squids, and octopuses (Fig. 3.13).

Main Characters.

- Unsegmented soft-bodied animals terrestrial or aquatic,
- Exoskeleton in the form of a shell. When present shell is usually univalved or bivalved; internal shell present in some.
- Sexes separate or united.
- Have a muscular foot for locomotion.

Examples. Apply snail (*Pila*), Freshwater mussel (*Unio*), Cuttlefish (*Sepia*), Slugs, Octopus.

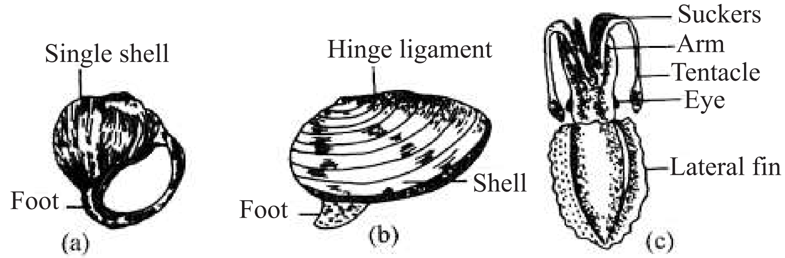


Fig. 3.13 Three molluscs (a) *Pila* (b) *Unio* (c) *Sepia*

8. Phylum Echinodermata (Includes starfishes, brittle stars, sea urchins, sea cucumbers)

Main Characters:

- Marine animals, with unsegmented body.
- Head absent, body surface marked with 5 radiating areas.
- Radial symmetry.
- Endoskeleton of dermal calcareous ossicles with spines.
- Movement by tube feet.
- Sexes usually separate.
- Regeneration of lost parts a peculiarity.
- Adults are radially symmetrical, but the larvae are bilaterally symmetrical.

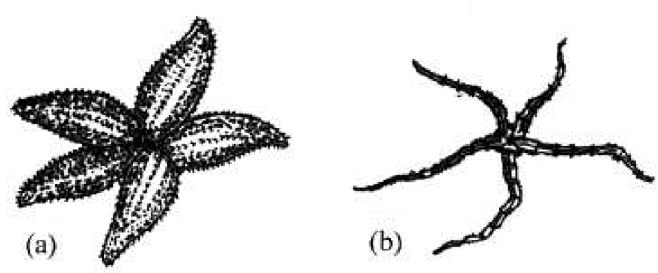


Fig. 3.14 Echinoderms (a) Asterias (b) Ophiara

INTEXT QUESTIONS 3.5

1. Member of which phylum possesses the cnidoblasts?

   ....

2. What do the earthworms possess which help them in locomotion?

   ....

3. Are all the Platyhelminthes parasites?

   ....

4. How many pairs of legs do the following have

   (i) Insects; ....

   (ii) Scorpions; ....

(iii) Spiders ....

5. Name the organs by which the starfish move?

....

6. Give two examples of the Phylum Arthropoda :

....

7. Name the phyla which have the following characteristics :
   (i) Tube feet. ....
   (ii) Cnidoblasts ....
   (iii) Chitinous exoskeleton ....
   (iv) Jointed legs ....
   (v) Nephridia ....
   (vi) Flattened body and a gut without anus. ....

3.9 PHYLUM CHORDATA

Main Characters:

– Notochord present at some stage of life, in most cases replaced by backbone.

– Dorsal tubular nerve cord.

– Gill slits present at some stage of life. (larva or adult)

– Body with a head and trunk and two pairs of appendages.

Classification

Phylum Chordata

1. Subphylum Urochordata	2. Subphylum-Cephalochordata	3. Subphylum Vertebrata
(a) Notochord present only in larval stage. (uro-tail)	(a) Notochord and nerve cord remain present throughout the life and extend through entire length of the body.	(a) Notochord replaced by vertebral column (back bone)
(b) Body bag-shaped, covered by a particular tunic or testa in adult stage.	(b) Body elongated and flattened from sides.	(b) Body with well developed head and paired fins or limbs. Cartilaginous or bony endoskeleton
(c) Limbs absent	(c) Limbs or paired fins absent.	(c) paired limbs present (tetrapoda)
(d) Dorsal tubular nerve cord present in the larval forms and reduced in adult.	(d) Dorsal tubular nerve cord present in adults.	(d) Dorsal tubular nerve cord present which is divided into brain and spinal cord.
(e) Example: *Herdmania* (Fig. 3.15a)	(e) Example: *Amphioxus* (Fig 3.15b)	(e) Examples.: All animals with backbone (Fig. 3.15c)

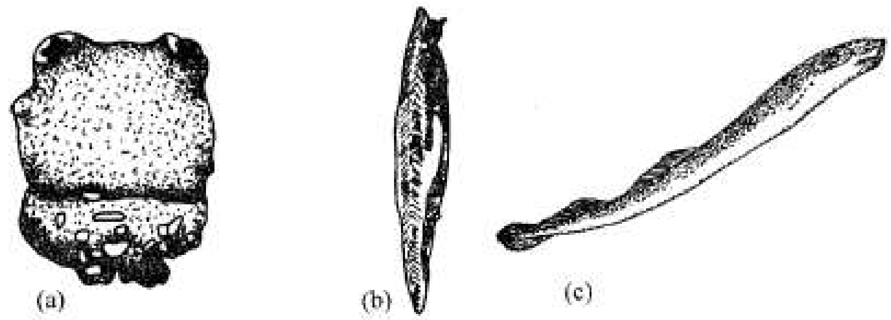


Fig. 3.15 Chordates (a) *Herdmania* (b) *Amphioxus* (c) *Petromyzon*

The subphylum vertebrata has 2 super classes Agnatha (jawless vertebrate) and Gnathostomata (jawed vertebrata)

Super-class Agnatha (A, no ; Gnathos : jaw)	Super-class Gnathostomata
(jawless vertebrates)	(jawed vertebrates)
Class : Cyclostomata	Class (1): Chondrichthyes
(Cyclo = circular, Stoma = mouth)	Class (2): Osteichthyes
– no jaws	Class (3): Amphibia
– 7 pairs of gill-slits	Class (4): Reptilia
– no paired fins	Class (5): Aves
– eg. Petromyzon (Lamprey) (Fig. 3.15)	Class (6): Mammalia

The two classes of fish include the cartilaginous and bony fish. Fishes are aquatic animals, gill breathing and move with the help of scales.

Class 1. Chondrichthyes

(Gk, Chondro = cartilage; ichtyes = fish)

– mouth ventral
– tail heterocercal
– Skeleton cartilaginous
– Five to seven pairs of gills
– Operculum (gill cover) absent

Example: *Scoliodon* (*dog-fish*) (Fig 3.16a)

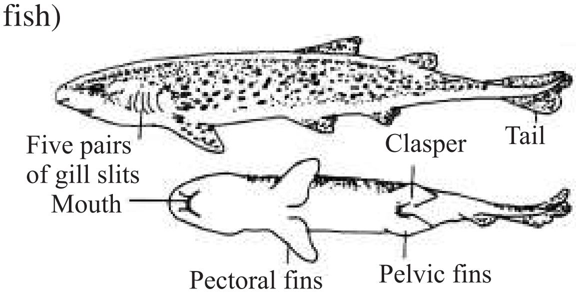


Fig. 3.16a Scoliodon

Class 2. Osteichthyes

(os = bone; ichthyes = fish)

– Mouth terminal
– Tail homocercal
– Skeleton bony
– Four pairs of gills
– Operculum present

Example : *Labeo* (Rohu) (Fig. 3.16b)

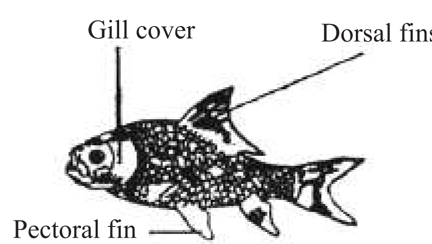


Fig. 3.16b Labeo

INTEXT QUESTIONS 3.6

1. Name the following
   (i) The category of animals possessing backbone.
   ....
   (ii) The group of backboned animals but having no jaws.
   ....
   (iii) Any one cartilaginousfish.
   ....
2. State one difference between cartilaginous and bony fishes.
   ....
3. Name one bony fish.
   ....
4. List the three main characters of the phylum Chordata.
   ....

Class 3 : Amphibia (amphi: double or both, “bios” : life referring to life on land as well as in water)

Main characters:

– The animal partly live in water and partly on land.

– Skin smooth or rough, rich in glands.

– Two pairs of limbs; pentadactyl (five-fingered), digits without claws.

– Body with distinct head and trunk, no neck.

– Two nostrils opening into the buccal cavity.

– Tympanum present on surface of body wall.

– Eggs are laid in water.

– In the early stage of life (larvae), they breathe by means of gills, but adults breathe by lungs.

– Heart three-chambered.

– Larval stage tailed and aquatic.

Some are tailed (salamander) and some are tailless (Frog, Toad)

Examples : *Salamandra*, *Proteus* (Fig. 3.17a), *Rana* (Frog, Bufo Toad (Fig. 3.17b) *Ichthyophis* (Fig. 3.17c)

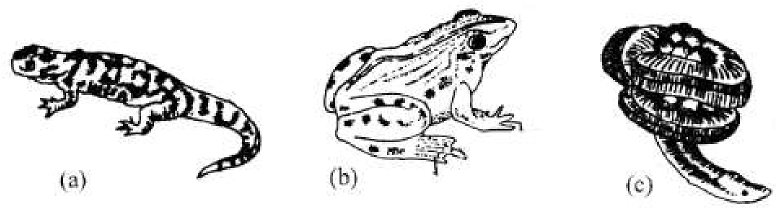


Fig. 3.17 *Amphibian* (a) *Salamandra* (b) Frog (c) *Ichthiophis*

INTEXT QUESTIONS 3.7

1. How many chambers are there in an amphibian heart?

   ....

2. Name one tailless amphibian.

   ....

3. What is the literal meaning of the term "amphibia".?

   ....

Class 4 : Class Reptilia (reptere: to crawl) : are four-legged or legless crawling animals whose body is covered by scales. they lay eggs on land

Characteristic features:

- Terrestrial (live on land), or some are aquatic (live in water).
- Body covered with horny scales.
- Skin is dry.
- Paired pentadactyl limbs (absent in snakes) with clawed digits.
- Tympanum small and depressed (absent in snakes).
- Respiration by lungs.
- Heart three-chambered but with a partially divided ventricle (4- chambered in crocodiles).
- Their eggs have leathery shell.

Examples : Tortoise, turtles, garden lizard (calotes) wall lizard (*Hemidactylus*), cobra (*Naja naja*) and crocodile (*Crocodilus*) and Gharial (*Gravialis*)

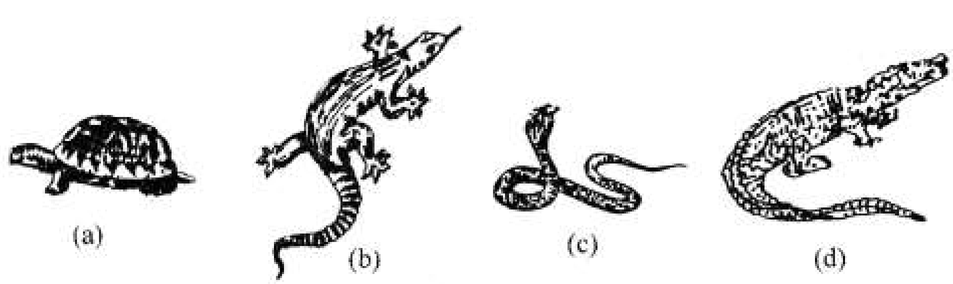


Fig. 3.18 Reptiles (a) Turtle (b) Wall lizard (c) Cobra (d) Crocodile

Class (5) Class : Aves (avis = Bird)

Characteristic features:

- Warm-blooded (homoiothermal, also called endothermal i.e. body temperature remains constant).
- Body covered with feathers, scales are present only on hind-limbs
- Body is divisible into three parts: head, neck and trunk.
- Jaws with horny beak, no teeth.
- Hind-limbs with four digits adapted for perching, walking or swimming
- Bones with air spaces to make the skeleton light (pneumatic bones).
- Forelimbs modified into wings for flight.
- Heart 4-chambered, lungs for respiration connected with air-sacs.
- Voice-box or **syrinx** (present at the junction of trachea and bronchi).
- Only left ovary and oviduct present in the females (economy in body weight.)
- All oviparous (lay eggs), egg with much yolk and calcareous shell.

Example : *Struthio* (Ostrich), *Abteryx* (Kiwi), *Pavo* (Peacock) *Columba*, (Pigeon), Corvus (Crow), etc. (Fig. 3.19).

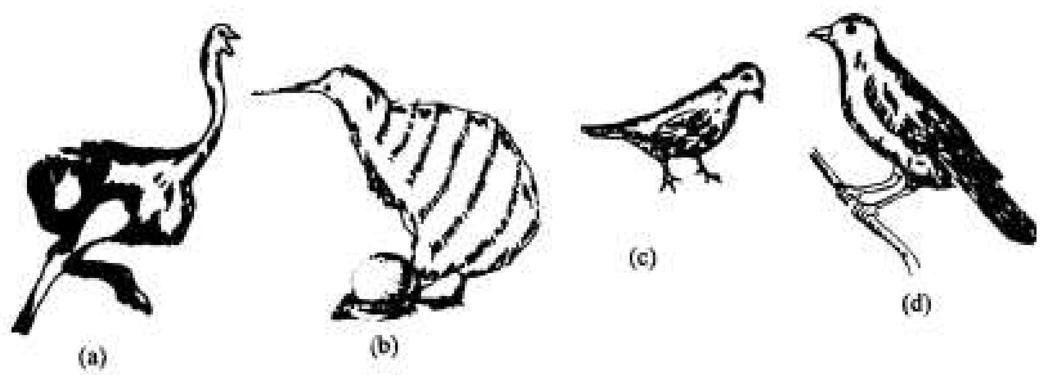


Fig. 3.19 Aves (a) Ostrich (b) Kiwi (c) Pigeon (d) Crow

INTEXT QUESTIONS 3.8

1. Name an aquatic reptile.

   ....

2. How many chambers are there in the heart of a:

   (i) lizard; ....

   (ii) crocodile ....

3. What is the voice box in birds called?

   ....

Class (VI) Mammalia (Mamma : breast)

Characteristic features:

– Body covered with hair.

– Presence of milk (Mammary) glands.

– Sweat and oil glands present in the skin.

– Body divisible into head, neck, trunk and tail; tail absent in some.

– Projecting external ears (pinna) present.

– Digits usually ending in claws, nails or hoofs.

– Dentition thecodont (teeth in sockets of jaw bones) and generally heterodont (four different types).

– Seven neck vertebrae

– Homoiothermal, warm blooded and heart four-chambered.

– Testes are extra-abdominal (not within abdominal cavity) contained in scrotal sacs

– Viviparous, give birth to the young, some primitive mammals are oviparous (lay eggs).

– Foetus is nourished by mother through placenta.

Classification of Class Mammalia

1. Sub-class Prototheria	2. Sub-class Metatheria	3. Sub-class Eutheria
(a) No external ear.	(a) External ear present.	(a) External ear well developed
(b) Teeth found only in young	(b) teeth found in both young and adults	(b) Teeth present in young as well as adults.
(c) Placenta absent	(c) No placenta for nouri-shment to the embryo	(c) Placenta is present
(d) Mammary glands are devoid of nipples	(d) Mammary glands present	(d) Mammary glands present
(e) Females are oviparous. Example: Duck-bill platypus (Ornithorh-ynchus) (Fig. 3.20a)	(e) Immature young ones are born. Marsupium (pouch) is present in females Example: Kangaroo (Macropus) (Fig. 3.20b)	(e) Mature young ones are born (For further classification and examples, see below).

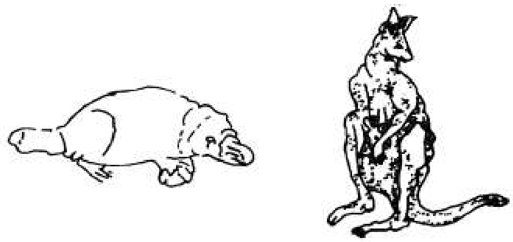


Fig. 3.20 (a) Duck-billed Platypus (b) Kangaroo

Birds and mammals have a constant body temperature. The are termed homoiothermal.

Sub-class Eutheria has been divided into a number of orders. Some important ones are as follows:

Order 1 : Rodentia

– Herbivorous and terrestrial.
– Incisors long, sharp and chisel-shaped.
– Forelimbs shorter than the hindlimbs.

Example: Rat, Squirrel (Fig. 3.21).

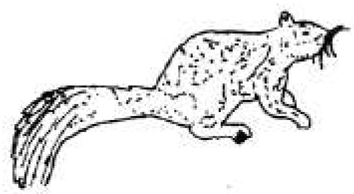


Fig. 3.21 Squirrel

Order 2 : Cheiroptera:

– These are flying mammals.
– Fore-limbs adapted for flight.
– Skin folded i.e. patagium works as wing.
– Hind-limbs thin and short.
– Nocturnal (active at night).
– Bats have poor eyesight. They avoid colliding against objects by **echolocation** in which the bat emits supersonic waves which are reflected back from the objects and the bat can perceive the reflected waves to determine the position of the object. The method is very similar to radar.

Example- Bat (Fig. 3.22)

Fig. 3.22 Bat

Order 3. Carnivora

– Flesh-eating mammals.
– Large pointed and sharp canines to tear the flesh.
– Fingers with sharp claws.

Example: Lion, Tiger, Cat, Dog (Fig. 3.23).

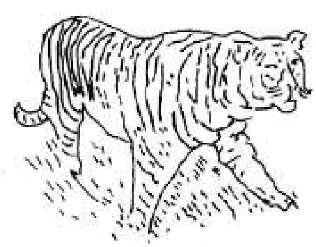


Fig. 3.23 Tiger

Order 4. Primates

– Highly developed brain.
– Eyes are set forward in the head to provide binocular (depth-perception) vision

– The neck is mobile.
– Limbs have five digits with flat nails.
– The thumb of the hand and the greater toe of the feet are opposable (for grasping)
– Two thoracic mammae (breasts) present.

Example: Monkey, Apes, Man (Fig. 3.24).

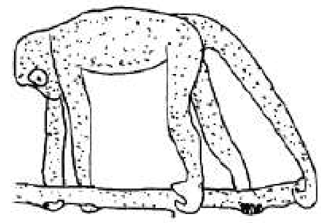


Fig. 3.24 Monkey

Order 5. Cetacea

– Aquatic.
– Fore-limbs are changed into paddles.
– No neck.
– Fish-like shape but respiration by lungs.

Example: whale (Fig. 3.25)

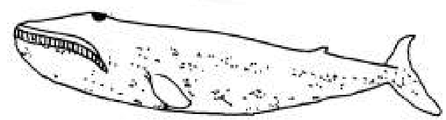


Fig. 3.25 Whale

Order 6. Proboscidea

– Large, herbivorous, terrestrial.
– Fusion of upper lip and nose to form a long mobile trunk.
– Only one pair of incisors in upper jaw which form huge tusks in males.

Example: Elephant (Fig. 3.26).

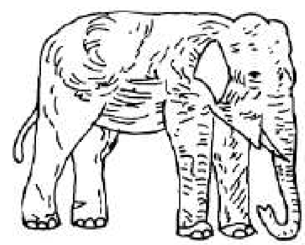


Fig. 3.26 Elephant

Order 7. Ungulata

– Hoofed mammals.
– Herbivorous.
– Usually domesticated by man.
– Mammae are abdominal with teats.

Example: Deer, Cows, Sheep (Fig. 3.27)

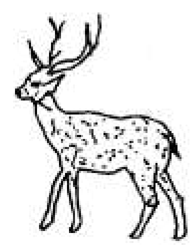


Fig. 3.27 Deer

INTEXT QUESTIONS 3.9

1. Match the items in Column I with those in Column II

	Column I		Column II
(i)	Humans	(a)	Carnivora
(ii)	Platypus	(b)	Ungulata
(iii)	Tiger	(c)	Primates
(iv)	Whale	(d)	Prototheria
(v)	Horse	(e)	Metatheria
(vi)	Kangaroo	(f)	Cetacea

2. Name the Group of Mammals which includes
   (i) Egg-laying mammals ....
   (ii) Pouched mammals ....
   (iii) Flesh-eating mammals ....
   (iv) Aquatic mammals ....
   (v) Flying mammals ....
3. For which characteristic feature are certain animals placed in class mammalia?
   ....
4. Name a mammal which has marsupium.
   ....
5. Which group of chordates possesses hair?
   ....

WHAT YOU HAVE LEARNT

- Animals are multicellular eukaryotes with heterotrophic nutrition, locomotion and sensitivity through nervous system.
- They may be at cellular grade of organisation (Phylum Porifera), tissue grade (Phylum Cnidaria) or organ grade of organisation (other animal phyla).
- Their body may be asymmetrical (Porifera), radially symmetrical (Cnidaria), or bilaterally symmetrical (other animal phyla).
- Kingdom Animalia is divided into two groups: Non-chordates and Chordates.
- Non-chordates are included in three sub phyla Urochordata, Cephalo-chordata and Vertebrata. Vertebrata has super classes-Agnatha (Jawless) and Gnathostomata (possessing jaws).
- Gnathostomata includes six classes – Chondrichthyes (cartilaginous fishes), Osteichthyes (bony fishes), Amphibia (frog), Reptilia (lizard) Aves (birds) and Mammalia (rat)
- Porifera are characterised by ostia, osculum, spongocoel and canal system.
- Cnidaria have cnidoblasts (stinging cells), coelenteron and the polyp and medusoid forms.
- Platyhelminthes (flat worms) include some free-living but mostly parasites like tapeworm and liver fluke.
- Class Nematoda of phylum Aschelminthes includes roundworms.
- Annelida (Earthworms) show metameric segmentation and have nephridia.
- Arthropods have jointed appendages and chitinous cuticle as their exoskeleton.
- Mollusca includes soft-bodied animals covered by a calcareous shell.

- Echinodermata includes spiny-skinned, marine animals which have tube feet for locomotion.
- Chordates have (i) a notochord (ii) a dorsal hollow nerve cord and (iii) gill slits at some stage of the life.
- Amphibians live on land as well as in water. Their limbs have no claws.
- Reptiles have horny scales covering the body. They are mostly terrestrial.
- Class Aves includes birds–the flying vertebrates with forelimbs modified into wings.
- Mammals possess hair and mammary glands which secrete milk to feed the young ones.
- Kingdom Plantae is classified into two divisions i.e. Bryophyta and Trachaeophyta.
- Bryophytes are amphibians of plant kingdom and are non-vascular.
- Main plant body of Bryophytes is a gametophyte; sporophyte remains attached to gametophyte.
- The main plant body of Pteridophytes is a sporophyte.
- All groups of Plantae show alternation of generations
- Gymnosperms and Angiosperms are seed-producing plants.
- In Gymnosperms seeds are naked, whereas in Angiosperms seeds are enclosed in ovary.
- Main difference between dicotyledonous and monocotyledonous plants is number of cotyledons in the embryo.
- Brassicaceae and Fabaceae are dicot families, whereas Poaceae and Liliacea, are monocot families.

TERMINAL EXERCISES

1. List the main groups of Kingdom Plantae.
2. Give the two main types of Bryophytes.
3. Differentiate between gametophyte and sporophyte.
4. Define alternation of generations.
5. Why are Pteridophytes grouped under Trachaeophyta?
6. Differentiate between Angiosperms and Gymnosperms.
7. Give three main differences between dicot and monocot plants.
8. Name three families of Angiosperms giving one character of each family.
9. Define an animal.
10. With examples name (i) the three kinds of symmetry and (ii) the three grades of organisation met within the Kingdom Animalia.

11. Explain the term triploblastic.
12. Name the major non-chordate phyla. Give one characteristic feature and one example of each.
13. Give one major difference between
    (i) Cyclostomes and other fishes
    (ii) Chondrichthyes and Osteichthyes, Cite examples.
14. Why are frogs included in the class Amphibia?
15. Give two characteristic features of reptiles. Cite examples of five reptiles
16. Give three features of birds which adapt them to aerial life and give two examples of flightless birds.
17. Give three features of mammals and one difference between Prototheria, Metatheria and Eutheria.
18. Name any five orders of Mammalia, Give one characteristic feature and one example of each.

ANSWERS TO INTEXT QUESTIONS

3.1 1. They complete their life cycle in water and land.

2. Alternation of gametophytic phase with sporophytic phase.

3. Antheridia and Archegonia

4. Cool and humid place.

3.2 1. Sporophytic 2. Sporophyte 3. They have vascular tissues

4. Antheridia and Archegonia 5. Prothallus

3.3 1. Naked seeds 2. *Cycas* and *Pinus* 3. Timber, resins

3.4 1. Fabaceae, Poaceae. 2. 10, infinite

3. (i) *Oryza sativa* (ii) *Cajanus cajan* (iii) *Aloe barbadumins*

4. In the Ovary after fertilization

3.5 1. Cnidaria 2. Cetae 3. No

4. (i) 3 (ii) 4 (iii) 3

5. Tube feet 6. Prawn, Millipede or any other

7. (i) Echinodermata (ii) Cnidaria

(iii) Arthropoda (iv) Arthropoda

(v) Annelida (vi) Platyhelminthes

3.6 1. (i) Vertebrata (ii) Agnatha (iii) Scoliodon

2. Endoskeleton bony in bony fishes and cartilaginous in cartilaginous fishes

or

5 to 7 pairs of gills in cartilaginous fishes and 4 pairs in bony fishes.

3. *Labeo, Catla*.

4. 1. notochrod at some stage of life

2. dorsal tubular nerve cord

3. gill slits at some stage of life.

3.7 1. Three 2. Ichthyophis

3. Can live both, in water and on land.

3.8 1. Turtle, seasnake 2. Three and four

3. Syrinx

3.9 1. (i) and c (ii) and d (iii) and a (iv) and f

(v) and b (vi) and e

2. (i) Prototheria (ii) Metatheria (iii) Carnivora

(iv) Cetacea (v) Cheiroptera

3. Mammary or milk glands 4. Kangaroo

5. Mammalia

4

CELL – STRUCTURE AND FUNCTION

INTRODUCTION

All organisms are composed of structural and functional units of life called 'cells'. The body of some organisms like bacteria, protozoans and some algae is made up of a single cell whereas the body of higher fungi, plants and animals are composed of many cells. Human body is built of about one trillion cells.

Cells vary in size and structure as they are specialized to perform different functions. But the basic components of the cell are common to all biological cells. This lesson deals with the structure common to all types of the cells. You will also learn about the kinds of cell division and the processes involved therein in this lesson.

OBJECTIVES

After completing this lesson, you will be able to :

- *justify that cell is the basic structural and functional unit of all organisms;*
- *list the components of the cell and state cell theory;*
- *differentiate between prokaryotic and eukaryotic cells;*
- *differentiate between plant and animal cells;*
- *illustrate the structure of plant and animal cells by drawing labelled diagrams;*
- *describe the structure and functions of plasma membrane, cell wall, endoplasmic reticulum (ER), cilia, flagella, nucleus, ribosomes, mitochondria, chloroplasts, golgi body, peroxisome, glyoxysome and lysosome;*
- *describe the general importance of the cell molecules-water, mineral ions, carbohydrates, lipids, amino acids, proteins, nucleotides, nucleic acids, enzymes, vitamins, hormones, steroids and alkaloids;*
- *justify the need for cell division;*
- *describe various phases of cell cycle;*
- *explain the term karyotype and mention the karyotype analysis and its significance.*

4.1 THE CELL AND CELL THEORY

4.1.1 Landmarks in the study of a cell

Soon after Anton Van Leeuwenhoek invented the microscope, Robert Hooke in 1665 observed a piece of cork under the microscope and found it to be made of small compartments which he called "cells" (Latin cell = small room). In 1672, Leeuwenhoek observed bacteria, sperms and red blood corpuscles, all of which were cells. Much later, in 1831, Robert Brown, an Englishman observed that all cells had a centrally positioned body which he termed the **nucleus**.

4.1.2 The cell theory

In 1838 M.J. Schleiden and Theodore Schwann formulated the "cell theory." Which maintains that:

- all organisms are composed of cells.
- cell is the structural and functional unit of life, and
- cells arise from pre-existing cells.

The cells vary considerably, in shapes and sizes (Fig.4.1). Nerve cells of animals have long extensions. They can be several centimeter in length. Muscle cells are elongated in shape. Egg of the ostrich is the largest cell (75 mm). Some plant cells have thick walls. There is also wide variation in the number of cells in different organisms.

4.1.3 The Cell

A cell may be defined as a unit of **protoplasm** bound by a plasma or cell membrane and possessing a nucleus. Protoplasm is the life giving substance and includes the cytoplasm and the nucleus. The cytoplasm has in it **organelles** such as ribosomes, mitochondria, golgi bodies, plastids, lysosomes and endoplasmic reticulum. Plant cells have in their cytoplasm, large vacuoles containing non-living inclusions like crystals, and pigments. The bacteria have neither defined cell organelles nor a well formed nucleus. But every cell has three major components:

- plasma membrane
- cytoplasm
- DNA (naked in bacteria) and enclosed by a nuclear membrane in all other organisms

Two basic types of cells

Cytologists recognize two basic types of cells (Fig. 4.1). Their differences have been tabulated below in Table 4.1. Organisms which do not possess a well formed nucleus are **prokaryotes** such as the bacteria. All others possess a well defined nucleus, covered by a nuclear membrane. They are **eukaryotes**.

Table 4.1 Differences between Eukaryotic and Prokaryotic cells

Eukaryotic cell (eu = true, karyon = nucleus)	**Prokaryotic cell** (Pro = early/primitive)
1. Nucleus distinct, with well formed nuclear membrane.	1. Nucleus not distinct, it is in the form of a nuclear zone 'nucleoid'. Nuclear membrane absent.
2. Double-membraned cell organelles (Chloroplasts, mitochondria, nucleus) and single membraned (Golgi apparatus, lysosomes, vacuole, endoplasm reticulum) are present	2. Single-membraned cell bodies like mesosomes present. Endoplasmic reticulum, plastids, nitochondria microbodies like lysosomes, and Golgi body absent.
3. Ribosomes - 80 S	3. Ribosomes - 70 S
4. Distinct compartments in the cell i.e. the cytoplasm and the nucleus	4. No compartments.
5. Depending upon the species number of chromosomes per nucleus varies from two to many.	5. There is only one chromosome per cell.
6. Each chromosome is linear with its two ends free.	6. The chromosome is circular and remains attached to cell membrane at one point.
7. Each chromosome has one linear double-stranded DNA complexed with histones	7. The chromosome has single double-stranded circular DNA molecule and is not associated with histones.
8. Each chromosome has one centromere that divides a chromosome into two arms. However, if the centromere is terminal, the chromosome would have only one arm	8. The chromosome lacks a centromere.

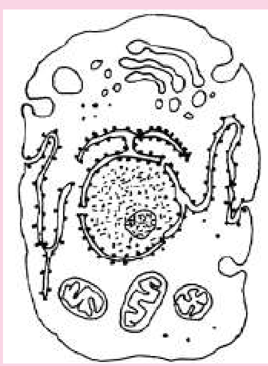


Fig. 4.1a Eukaryotic Cell

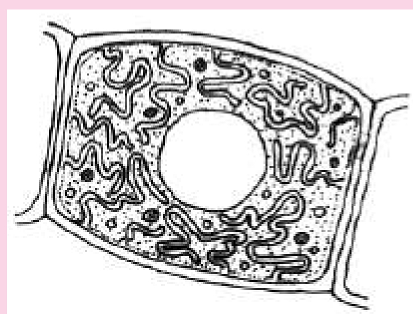


Fig. 4.1b Prokaryotic Cell

(As seen in an electron micrograph.)

Svedberg unit

When the cell is fractionated or broken down into its components by rotating in an ultracentrifuge at different speeds the ribosomes of eukaryotic and prokaryotic cells sediment (settle down) at different speeds. The coefficient of sedimentation is represented in Svedberg unit and is depicted as S.

The plant cell and the animal cell also differ in several respects as given in Table 4.2 and shown in Fig. 4.2.

Table: 4.2 Differences between plant cell and animal cell

Plant cell	Animal cell
1. Cellulose cell wall present external to cell membrane.	1. No cell wall, outermost structure is cell membrane or plasma membrane
2. Vacuoles are usually large.	2. Generally vacuoles are absent and if present, are usually small..
3. Plastids present.	3. Plastids absent.
4. Golgi body present in the form of units known as dictyosomes.	4. Golgi body well developed having 2 cisternae
5. Centriole absent.	5. Centriole present.

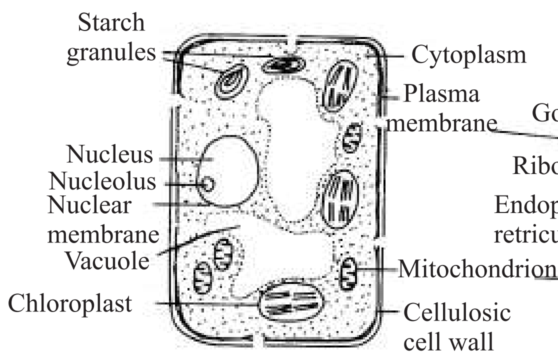


Fig. 4.2a Generalised plant cell

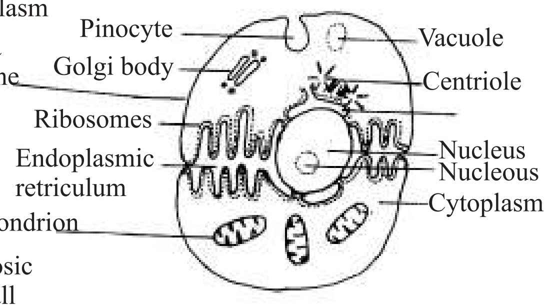


Fig. 4.2b Generalised animal cell

INTEXT QUESTIONS 4.1

1. From where do new cells arise?

   ....

2. Name the scientists who proposed the 'cell theory'.

   ....

3. Name an organelle which a plant cell has but an animal cell does not.

   ....

4. Give two points of difference between a prokaryotic cell and a eukaryotic cell

   ....

4.2 COMPONENTS OF THE CELL

The major components of the cell are (1) cell membrane, (2) cytoplasm, and (3) nucleus.

4.2.1 Cell membrane (Plasma membrane)

Each cell has a limiting boundary, the cell membrane, plasma membrane or plasmalemma. It is a living membrane, outermost in animal cells but internal to cell wall in plant cells.

It is flexible and can fold in (as in food vacuoles of *Amoeba*) or fold out (as in the formation of pseudopodia of *Amoeba*)

The plasma membrane is made of proteins and lipids and several models were proposed regarding the arrangement of proteins and lipids. The **fluid mosaic model** proposed by Singer and Nicholson (1972) is widely accepted. It is represented in Fig 4.3.

According to the fluid mosaic model,

(i) The plasma membrane is composed of a lipid bilayer of phospholipid molecules into which a variety of globular proteins are embedded.

(ii) Each phospholipid molecule has two ends, an outer head hydrophilic i.e. water attracting, and the inner tail pointing centrally hydrophobic, i.e. water repelling

(iii) The protein molecules are arranged in two different ways:

 (a) Peripheral proteins or extrinsic proteins: these proteins are present on the outer and inner surfaces of lipid bilayer.

 (b) Integral proteins or intrinsic proteins: These proteins penetrate the lipid bilayer partially or wholly.

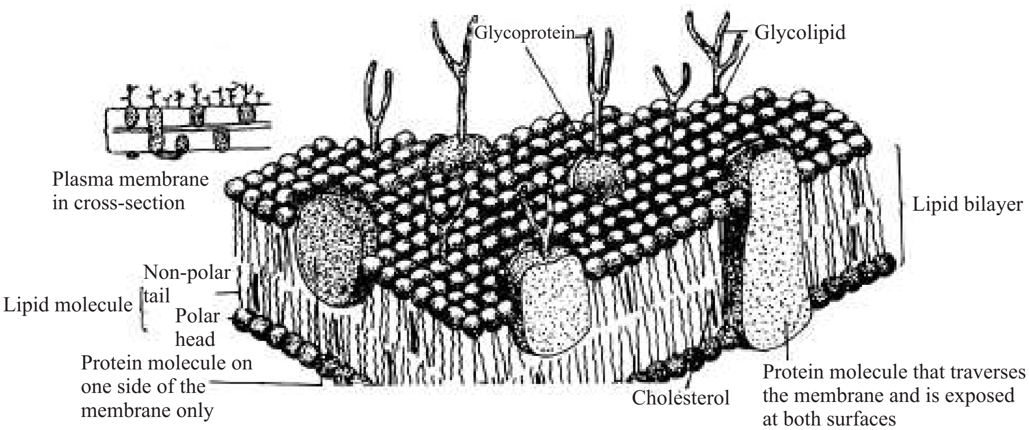


Fig. 4.3 The fluid mosaic model of cell membrane.

Functions

(i) The plasma membrane encloses the cell contents.

(ii) It provides cell shape (in animal cells) e.g. the characteristic shape of red blood cells, nerve cells, and bone cells.

(iii) It allows transport of certain substances into and out of the cell but not all substances so much it is termed '**selectively permeable**'.

Transport of small molecules (such as glucose, amino acids, water, mineral ions etc).

Small molecules can be transported across the plasma membrane by any one of the following three methods:

(i) **Diffusion** : molecules of substances move from their region of higher concentration to the regions of lower concentration. This does not require energy. Example : absorption of glucose in a cell.

(ii) **Osmosis:** movement of water molecules from the region of their higher concentration to the region of their lower concentration through a semipermeable membrane. There is no expenditure of energy in osmosis. This kind of movement is along concentration gradient.

(iii) **Active Transport:** When the direction of movement of a certain molecule is opposite to that of diffusion i.e. from region of their lower concentration towards the region of their higher concentration, it would require an "active effort" by the cell for which energy is needed. This energy is provided by ATP (adenosine triphosphate). The active transport may also be through a carrier molecule.

Transport of large molecules (bulk transport)

During bulk transport the membrane changes its form and shape. It occurs in two ways:

(i) endocytosis (taking the substance in)

(ii) exocytosis (passing the substance out)

Endocytosis is of two types :

Endocytosis

Phagocytosis	Pinocytosis
1. intake of solid particles 2. membrane folds out going round the particle, forming a cavity and thus engulfing the particle (Fig. 4.4a)	1. intake of fluid droplets 2. membrane folds in and forms a cup-like structure and sucks in the droplets (Fig. 4.4b)

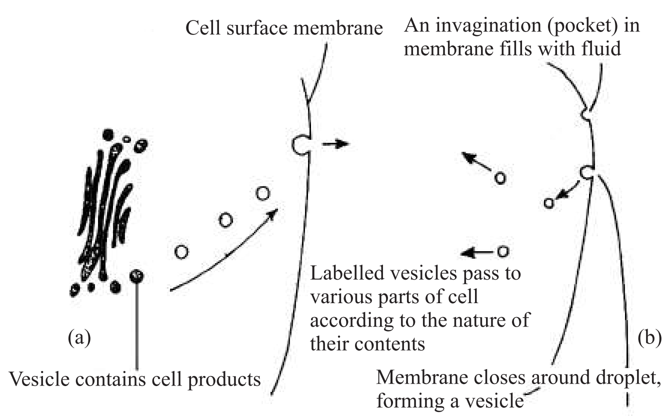


Fig. 4.4 Diagrammatic representation of (a) phagocytosis; (b) pinocytosis

Cell membrane regulates movement of substance into and out of the cell. If the cell membrane fails to function normally, the cell dies.

Cell wall

In bacteria and plant cells the outermost cell cover, present outside the plasma membrane is the **cell wall** about which we shall study now.

Bacterial cell wall is made up of peptidoglycan. Given below is the structure and function of the plant cell wall.

(a) Structure

– Outermost non-living layer present in all plant cells.
– Secreted by the cell itself.
– In most plants, it is chiefly made up of cellulose but may also contain other chemical substances such as pectin and lignin.
– The substance constituting the cell wall is not simply homogeneous but it consists of fine threads or fibres called microfibrils.
– It may be thin (1 micron) and transparent as in the cells of onion peel. In some cases it is very thick as in the cells of wood.

(b) Functions

– The cell wall protects the delicate inner parts of the cell.
– Being rigid, it gives shape to the cell.
– As it is rigid, it does not allow distension of the cell, thus leading to turgidity of the cell that is useful in many ways
– It freely allows the passage of water and other chemicals into and out of the cells
– There are breaks in the primary wall of the adjacent cells through which cytoplasm of one cell remains connected with the other. These cytoplasmic strands which connect one cell to the other one are known as **plasmodesmata**.
– Walls of two adjacent cells are firmly joined by a cementing material called **middle lamella** made of calcium pectinate.

INTEXT QUESTIONS 4.2

1. Define diffusion and osmosis.

   ....

2. What does active transport mean?

   ....

3. Give one point of difference between phagocytosis and pinocytosis.

   ....

4. Match the following :

(i) hydrophilic end	(a) cell wall
(ii) microfibrils	(b) inner ends of lipids
(iii) fluid-mosaic model	(c) fluid droplets
(iv) hydrophobic end	(d) outer ends of lipids
(v) pinocytosis	(e) Nicholson and Singer

5. Give two functions of the plant cell wall.
   (i) .... (ii) ....

4.3 THE CYTOPLASM AND THE CELL ORGANELLES

The cytoplasm contains many cell organelles of which we shall learn about :

1. those that trap and release energy e.g. mitochondria and chloroplasts;
2. those that are secretory or involved in synthesis and transport e.g. Golgi, ribosomes and endoplasmic reticulum
3. the organelles for motilily - cilia and flagella
4. the suicidal bags i.e. lysosomes
5. the nucleus which controls all activities of the cell, and carries the hereditary material

4.3.1 Mitochondria and chloroplast - the energy transformers

Mitochondria (found in plant and animal cells) are the energy releasers and the chloroplasts (found only in green plant cells) are the energy trappers.

Mitochondria (Singular = mitochondrion)

Appear as tiny thread like structures under light microscope. Approximately 0.5 - 1.00 µm (micrometer)

Number usually a few hundred to a few thousand per cell (smallest number is just one as in an alga, **Micromonas**.

Structure: The general plan of the internal structure of a mitochondrion observed by means of electron microscope is shown in Fig. 4.5. Note the following parts.

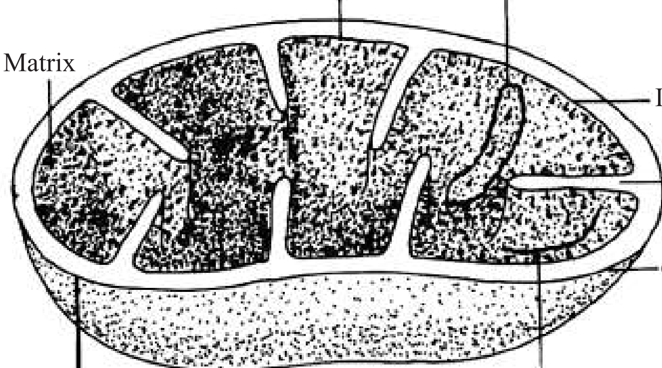


Fig. 4.5 Structure of a mitochondrion

- Wall made up of double membrane
- The inner membrane is folded inside to form projections called '*cristae*' which project into the inner compartment called the 'matrix'.

Function : Oxidises pyruvic acid (breakdown product of glucose) to release energy which gets stored in the from of ATP for ready use. This process is also called **cellular respiration**. That is why mitochondria are called the 'power house' of a cell.

A highly simplified flow-chart of the fate of glucose to release energy is shown below :

In cytoplasm. glucose enters cells (containing 6 atoms of carbon)	Broken into two Pyruvic acid molecules (containing 3 atoms of carbon)	In mitochondria Acetyl-Co-A is Oxidised into CO_2, H_2O and ATP

Plastids

Plastids are found only in a plant cell. These may be colourless or coloured. Based on this fact, there are three types of plastids.

(i) Leucoplast - white or colourless

(ii) Chromoplast – blue, red, yellow etc.

(iii) Chloroplast – green

4.3.2 Chloroplast

- Found in all green plant cells in the cytoplasm.
- Number 1 to 1008 (how so definite)
- Shape: Usually disc-shaped or laminate as in most plants around you. In some ribbon - shaped as in an alga *Spirogyra* or cup-shaped as in another alga *Chlamydomonas*.
- Structure: the general plan of the structure of a single chloroplast has been shown in Fig. 4.6.

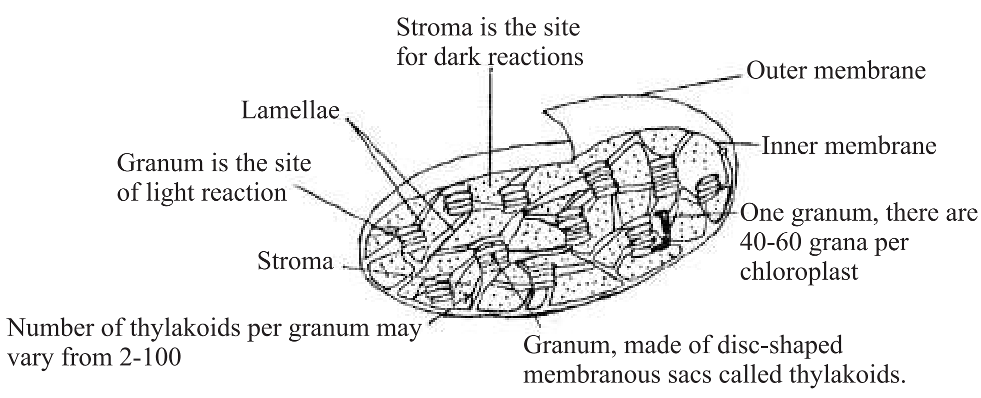


Fig. 4.6 Structure of a single chloroplast

Note the following parts :

- Wall made up of double membrane i.e. outer membrane and inner membrane numerous stack-like (piles) groups or *grana* (singular = granum) are interconnected by *lamellae*.
- Sac-like structures called thylakoids placed one above the other constitute a granum.

- Inside of the chloroplast is filled with a fluid medium called stroma.
- Function: chloroplasts are the site of photosynthesis (production of sugar, from carbon dioxide and water in the presence of sunlight).

Chloroplast versus mitochondria

Can you now visualize how these two organelles are opposite to each other, one traps the solar energy locking it in a complex molecule (by photosynthesis), the other releases the energy by breaking the complex molecule (by respiration).

Similarities between mitochondria and chloroplasts : both contain their own DNA (the genetic material) as well as their own RNA (for protein synthesis). Thus, they can self-duplicate to produce more of their own kind without the help of nucleus.

Thought the chloroplasts and mitochondria contain their own DNA the hereditary molecule and also their own ribosomes, they are termed as semi-autonomous only because they are incapable of independent existence outside the cytoplasm for a long time. Since most of their proteins are synthesised witht he help of the nuclear DNA.

INTEXT QUESTIONS 4.3

1. What is a cell organelle?

   ....

2. Name the chemical which provides energy trapped in its bonds to the cell.

   ....

3. Which part of the chloroplasts is the site of light reaction?

   ....

4. Name the sac like–structure which form the grana?

   ....

5. Why is mitochondrion called the "power house" of the cell?

   ....

6. Which organelle contains enzymes for cellular respiration?

   ....

7. State two similarities between mitochondria and chloroplasts.

   ....

8. Which plastid imparts colour to flower petals?

   ....

9. Which plastid is green in colour?

   ....

10. Why are mitochondria and chloroplast called semi-autonomous?

    ....

4.3.3 Endoplasmic reticulum (ER), golgi body and ribosomes

The Endoplasmic reticulum (ER) and Golgi body are single membrane bound structures. The membrane has the same structure (lipid-protein) as the plasma membrane but ribosomes do not have membranes. Ribosomes are involved in synthesis of proteins in the cell, Golgi bodies in secreting and the ER in transporting and storing the products. These three organelles operate together.

Fig. 4.7 and Fig. 4.8 show the diagram of ER and Golgi body as seen under an electron microscope. Note the ribosomes present in the ER.

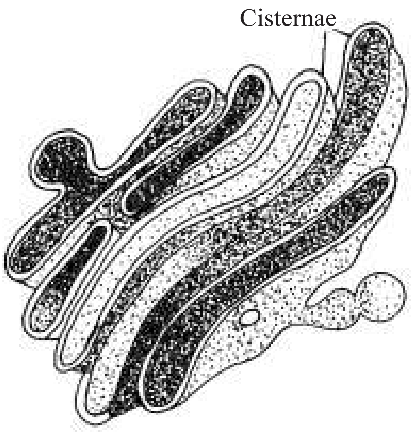


Fig. 4.7 Golgi body

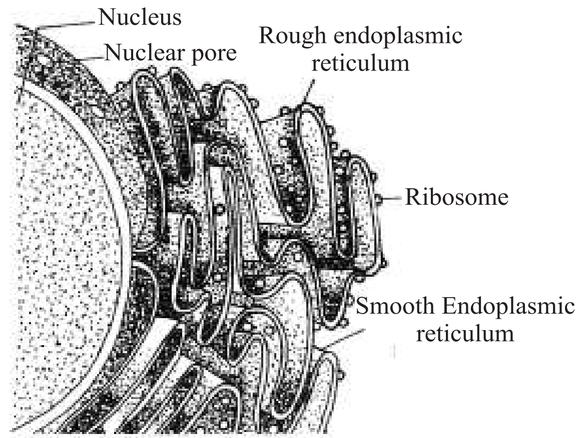


Fig. 4.8 Endoplasmic reticulum

Endoplasmic reticulum (ER)	Golgi body	Ribosomes
Structure		
A network of membranes with thickness between 50 - 60A°. It is of two types– rough endoplasmic reticulum (RER) i.e. when ribosomes are attached to it and Smooth endo-plasmic reticulum (SER) when no ribosomes are present.	Is a stack of membranous sacs of the same thickness as ER. Exhibit great diversity in size and shape.	Spherical about 150 - 250 Å in diameter, made up of large molecules of RNA and proteins (ribonucleo proteins)
Distributed hroughout the cytoplasm and is in contact with the cell membrane as well as the nuclear membrane.	In animal cells present around the nucleus, 3 to 7 in number. In plant cells, many in number of and present scattered throughout the cell called dictyosomes.	Present either as free particles in cytoplasm or attached to ER. Also found stored in nucleolus inside the nucleus. 80S types found in eukaryotes and 70S in prokaryotes (S-svedberg unit of measuring ribosomes).
Function		
Provides internal framework, compartment and reaction surfaces, transports enzymes and other materials through out the cell. RER is the site for protein synthesis and SER for steroid synthesis, stores carbohydrates.	Synthesis and secretion as enzymes, participates in transformation of membranes to give rise to other membrane structure such as lysosome, acrosome, and dictyosomes, synthesize wall element like pectin, mucilage.	Site for protein synthesis.

INTEXT QUESTIONS 4.4

1. Given below is a list of functions, relate them to their respective organelles:
   (a) synthesis of some enzymes ....
   (b) synthesis of steroids ....
   (c) storage of carbohydrates ....
   (d) Intracellular transport ....
   (e) Synthesis of proteins ....
2. Name the equivalent structure of Golgi body in plants. Mention two differences between their structures.
   (i) …………………………...…. (ii) …………..................………..
3. Mention any two advantages of the extensive network of endoplasmic reticulum.
   (i) …………………………….. (ii) ………………....………………
4. What are the three places where ribosomes occur in a cell?
   ....
5. Name the membrane system that connects the nuclear membrane with the cell membrane?
   ....

4.3.4 The microbodies (tiny but important)

These are small sac-like structures bounded by the single membranes. These are of different kinds of which we will take up three, viz. lysosomes, peroxisomes and glyoxysomes.

1. Lysosomes (lysis = breaking down; soma = body)

Lysosomes are present in almost all animal cells and some non-green plant cells (Fig 4.9). They perform intracellular digestion.

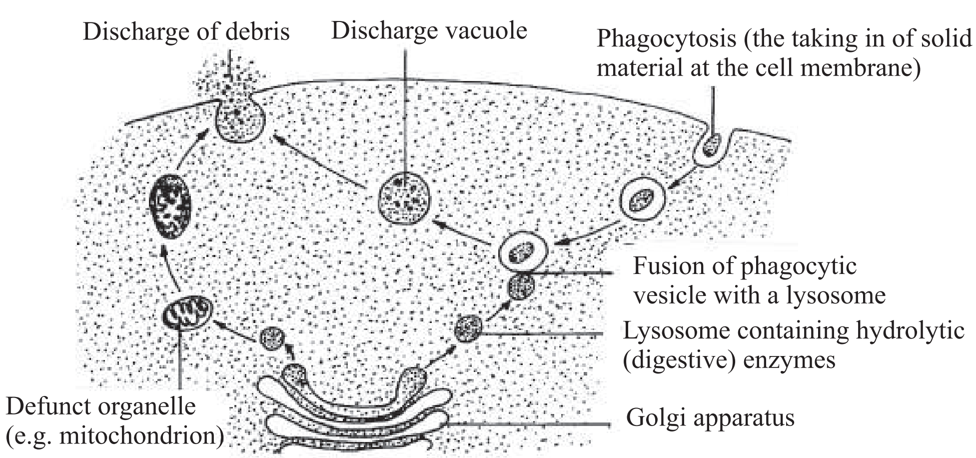


Fig. 4.9 Lysosomes

The main features of lysosomes are as follows :

(i) Membranous sacs budded off from Golgi body.

(ii) May be in hundreds in a single cell.

(iii) Contain several enzymes (about 40 in number)

(iv) Materials to be acted upon by enzymes enter the lysosomes.

(v) Lysosomes are called "suicidal bags" as enzymes contained in them can digest the cell's own material when damaged or dead.

Importance of intracellular digestion by the lysosomes

(i) help in nutrition of the cell by digesting food, as they are rich in various hydrolysing enzymes which enable them to digest almost all major chemical constituents of the living cell.

(ii) Help in defence by digesting germs, as in white blood cells.

(iii) Help in cleaning up the cell by digesting damaged material of the cell.

(iv) Provide energy during cell starvation by digestion of the own parts of the cells (autophagic, auto : self; phagos: eat up).

(v) Help sperm cells in entering the egg by breaking through (digesting) the egg membrane.

(vi) In plant cells, mature xylem cells lose all cellular contents by lysosome activity.

(vii) When cells are old, diseased or injured, lysosomes attack their cell organelles and digest them. In other words lysosomes are autophagic, i.e. self devouring.

2. Peroxisomes

Found both in plant and animal cells. Found in the green leaves of higher plants. They participate in oxidation of substrates resulting in the formation of hydrogen peroxide.

- They often contain a central core of crystalline material called nucleoid composed of urate oxidase crystals.
- These bodies are mostly spherical or ovoid and about the size of mitochondria and lysosomes.
- They are usually closely associated with ER.
- They are involved in photorespiration in plant cells.
- They bring about fat metabolism in cells.

3. Glyoxysomes

- The microbodies present in plant cells and morphologically similar to peroxisomes.
- Found in the cell of yeast and certain fungi and oil rich seeds in plants.
- Functionally they contain enzymes of fatty acid metabolism involved in the conversion of lipids to carbohydrates during germination.

INTEXT QUESTIONS 4.5

1. Why are lysosomes called suicidal bags?

   ....

2. List the usefulness of intracellular digestion by lysosomes

   ....

3. What is the function of peroxisomes in plant cells

   ....

4.3.5 Cilia and flagella (the organelles for motility)

(i) Some unicellular organisms like *Paramecium* and *Euglena* swim in water with the help of cilia and flagella respectively.

(ii) In multicellular organisms some living tissues (epithelial tissues) have cilia. They beat and create a current in the fluid in order to move in a given direction e.g. in the wind pipe (trachea) to push out the mucus and dust particles.

(iii) Cilia beat like tiny oars or pedals (as in a boat) and flagella bring about whiplash like movement.

(iv) Both are made up of contractile protein tubulin in the form of microtubules.

(v) The arrangement of the microtubules is termed as 9 + 2, that is, two central microtubules and nine duplet sets surrounding them.

Cilia	Flagella
shorter (5 to 10 µm)	longer (15 µm)
several 100 per cell structure : protoplasmic projection and membrane bound	usually 1 or 2 in most cells
consist of 9 sets of peripheral duplet microtubules and 1 set of two singlet tubules in the centre	same as in cilia

Centriole

It is present in all the animal cells (but not in *Amoeba*), located just outside the nucleus. It is cylindrical, 0.5 µm in length and without a membrane. It has 9 sets of peripheral triplet tubules but none in the centre (9 + 0). Each set has three tubules arranged at definite angles (Fig. 4.10). It has its own DNA and RNA and therefore it is self duplicating.

Function : Centrioles are involved in cell division. They give orientation to the 'mitotic spindle' which forms during cell division

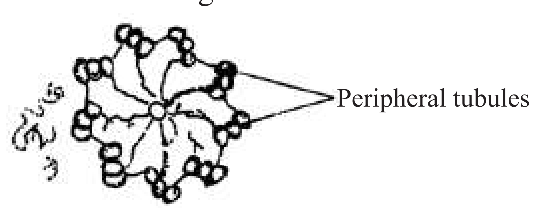


Fig. 4.10 Centriole (showing 9 + 0 structure)

Basal bodies

These are structures similar to centrioles. They have the same nine sets of triplet organization (9 + 0), as in the centrioles. The cilia and flagella appear to arise from the basal bodies.

4.4 NUCLEUS (THE HEREDITARY ORGANELLE)

General structure of the nucleus :

(i) It is the largest organelle seen clearly when the cell is not dividing.

(ii) It stains deeply, is mostly spherical, WBC have lobed nuclei.

(iii) It is mostly one in each cell (uninucleate, some cells have many nuclei; (multinucleate).

(v) Double layered nuclear membrane having fine nuclear pores encloses nucleoplasm which contains chromatin network and a nucleolus.

Functions

- Maintains the cell in a working order.
- Co-ordinates the activities of other cell organelles.
- Takes care of repair work.
- Participates directly in cell division to produce genetically identical daughter cells. This division is called mitotic cell division.
- Participates in production of meio-gametes and meiospores through another type of cell division called meiotic cell divisioin.

The parts of a nucleus are given here :

4.4.1 Nuclear membrane

- Double layered membrane is interrupted by large number of nuclear pores.
- Membrane is made up of lipids and proteins (like plasma membrane) and has ribosomes attached on the outer membrane which make the outer membrane rough.
- The pores allow the transport of large molecules in and out of nucleus, and the membranes keep the hereditary material in contact with the rest of the cell.

4.4.2 Chromatin

- Within the nuclear membrane there is jelly like substance (karyolymph or nucleoplasm) rich in proteins.
- In the karyolymph, fibrillar structures form a network called *chromatin fibrils*, which gets condensed to form distinct bodies called **chromosomes** during cell division. On staining the chromosomes, two regions can be identified in the chromatin material heterochromatin, dark and euchromaticn (light). Heterochromatin has highly coiled DNA and genetically less active than euchromatin which has highly uncoiled DNA and genetically more active.

- The number of chromosomes is fixed in an organism. During mitotic cell division chromosomes divide in a manner that the daughter cells receive identical amounts of hereditary matter.

4.4.3 Nucleolus

- Membraneless, spheroidal bodies present in all eukaryotic cells except in sperms and in some algae.
- Their number varies from one to few, they stain uniformly and deeply.
- It has DNA, RNA and proteins.
- Store house for RNA and proteins; it disappears during early phase of cell cycle and reappears after telophase in the newly formed daughter nuclei.
- Regulates the synthetic activity of the nucleus.
- Thus nucleus and cytoplasm are interdependent, and this process is equal to nucleo–cytopalsmic interaction.

INTEXT QUESTIONS 4.6

1. Why cannot the cell survive without the nucleus?

   ....

2. Explain the following terms:

   (a) chromatin network...... ....

   (b) chromosomes ....

3. What is the function of the nucleolus in the cell?

   ....

4.5 MOLECULES OF THE CELL

The cell and its organelles are made of organic chemicals such as proteins, carbohydrates, nucleic acid and fats. These are aptly termed biomolecules. Inorganic molecules such as water and minerals are also present in a cell.

A. Water

- Water with unique physical and chemical properties has made life possible on earth.
- It is a major constituent of protoplasm.
- It is a medium in which all the metabolic reactions occur.
- It is a universal solvent in which most substances remain dissolved sparingly or completely.
- It is responsible for turgidity of cells.

B. Elements necessary for life

Elements	Functions
Hydrogen, Carbon, Oxygen, Nitrogen, Calcium, Potassium, Sodium, Magnesium, Phosphorous, Sulphur, Chlorine, Iron, Boron, Silicon, Manganese, Copper, Zinc, Cobalt, Molybdenum, Iodine	1. Required for organic compounds of the cell and present as major constituents. (Ca in plant cell wall, C, H, O, N as organic compounds) 2. Act as major cations (Na, K) and anions (Cl) in most physiological processes. 3. As cofactor of enzymes participate in most of the biochemical reactions of a cell (Fe, Cu, Mo, Zn, B) 4. Involved in energy transfer reactions (P in ATP). 5. Green pigment chlorophyll in plants have magnesium in the centre of tetrapyrrole ring.

C. Biomolecules

(i) **Carbohydrate**

Structure	Functions
1. Composed of C, H and O	1. Most abundant organic substance present in nature which occurs in the form of cellulose in plant cell wall.
2. Simple six carbon sugar (glucose) is called a monosaccharide.	2. In both plants and animals it is used as a source of energy (sugar).
3. Two molecules or units join together to form disaccharide (sucrose).	3. An important storage form in plants is starch and in animals it is glycogen.
4. More than ten units of monosaccharides join in a chain to form a polysaccharide e.g. starch and cellulose.	4. Present in nucleic acids as five carbon sugar (Ribose in RNA, and deoxyribose in DNA).
(ii) **Amino acid**	
1. Basic amino acid structure shows that the central carbon atom is attached with an amino group ($-NH_2$), a carboxylic acid group ($-COOH$), one hydrogen and one side group (R).	1. Plants have the ability to utilize inorganic nitrogen and synthesize amino acid.
2. There are 20 different side groups which give 20 different amino acids.	2. In an animal, principal source of amino acids is provided by the plants or animals that it consumes in its diet (pulses are rich in protein).
(iii) **Proteins**	
1. Composed of C, H, O and N.	1. Structurally proteins form integral part of the membranes

2. Amino acids join together by “peptide” bonds to form protein molecules.	2. Functionally in the form of enzymes they play a vital role in metabolic reactions.
3. Twenty different amino acids make numerous simple and complex proteins.	3. Synthesis of DNA is regulated by proteins (enzymes).
4. Based on the complexity of structure the proteins can have primary, secondary, tertiary and quaternary structures.	4. Proteins are so important that nucleic acids directly regulate protein synthesis
5. When proteins exist with other molecules they are known as conjugated proteins e.g. glycoprotein, lipoprotein and chromoprotein.	
(iv) **Nucleic Acids**	
1. They are of two types : Deoxyribose nucleic acid (DNA) and Ribose nucleic acid (RNA)	1. DNA is the main genetic material for almost all organisms except certain viruses.
2. They are long chain polymers composed of units called **nucleotides**. as purines (Adenine and Guanine) and pyrimidines as (Thymine, Cytosine and Uracil)	2. RNA molecules are involved in information transfer and protein synthesis; and RNA acts as genetic material in some viruses e.g. TMV (Tobacco Mosaic Virus)
3. Each nucleotide has pentose sugar, nitrogen base and phosphate group.	
4. DNA has one oxygen less in its sugar molecule.	
(v) **Lipids**	
1. Composed of C, H, O. Amount of oxygen is very less.	1. Due to their low oxygen content, and higher number of C-H bonds they store higher amount of energy and release more energy during their oxidation
2. They are synthesized from fatty acids and glycerol. Simple lipids are called glycerides.	2. A molecule of fat can yield twice as much energy as from carbohydrate.
3. Fats can be saturated or unsaturated.	3. Phospholipids are important components of cell membranes.
4. Fats are solid at room temperature, those that remain liquid at room temperature are called oils.	
(vi) **Vitamins**	
1. Vitamins are organic compounds required in the diet of animals for their healthy growth.	1. Vitamins (from plant) are essential nutrients in animals diet as animals can not synthesise such compounds.
2. Vitamins are classified according to their solubility into two groups : Water soluble e.g. vitamin B and ascorbic acid and fat soluble vitamins (viz. A,D, E, K)	2. Their deficiency causes various diseases in animal, like deficiency of vitamin B causes “beri-beri” and that of vitamin C causes scurvy.

3. Plants have the ability to synthesize vitamins from CO_2, NH_3 and H_2S.	3. Vitamin A present in the carotene pigment of carrot. Vitamin D can be produced by man with the help of sunlight. Vitamin K is produced by bacteria in the human intestine.
(vii) **Hormones**	
1. Hormones are specific organic substances effective in low concentrations, synthesized by cells in one part of the organism and then transported to another part of the organism, where it produces characteristic physiological responses.	1. In animals hormones are produced in ductless glands called endocrine glands which control all the biochemical activities of the organism 2. In animals hormones may be proteins, peptides or steroids. 3. In plants hormones (growth regulators) are generally produced in metabolically active cells and control the vegetitive and reproductive growth of the entire plant. Proteinaceous hormones are not found in plants.
(viii) **Alkaloids**	
1. Alkaloids are complex organic compounds made of C, H, O and N.	1. The active principles of drugs from medicinal plants are generally alkaloids e.g. Quinine from the *Cinchona*. Ephedrine from and Morphine from *Papaver* species
2. Alkaloids in plants are produced from amino acids.	
(ix) **Steroids**	
1. These are fat soluble lipid compounds synthesized from cholesterol.	
2. They are produced by the reproductive organs like ovaries, testes and placenta and also by adrenal glands.	Most of the steroids act as life-saving drugs, and others act as hormones which are effective in performing specific functions in specific organs of animal body.
3. They include testosterone, estrogen, and cortisol	

INTEXT QUESTIONS 4.7

1. What is the importance of water in a living cell.

....

2. Which is the basic molecule in starch?

   ....

3. What is a peptide bond and where will you find it?

   ....

4. Which is the most energy rich biomolecule in living organisms?

   ....

5. What are nucleotides?

   ....

4.7 CELL DIVISION

A single cell divides many times and forms a multicelled organism. Unicellular bacteria and protozoa divide and increase in number. The injured tissues are replaced by new cells through cell division. Thus cell division is one of the most important activities in all organisms. In this lesson you will study about the two kinds of cell division and the processes involved in them.

Majority of cells in a multicellular organism grow and then can divide. However, the cells like the nerve and muscle cells of animals and guard cells of plants do not divide.

The process of cell division is almost same in all organisms. A cell passes through phases of growth after which are able to duplicate their chromosomes before they divide. These phases in the life of a cell constitute the **cell cycle.**

4.7.1 The cell cycle

You can use the term mother or parent cell for the cell that undergoes division and the daughter cells for the ones that are the result of this division. Before each daughter cell undergoes division, it must grow to the same size as its mother cell. We can distinguish two main phases in the life of a cell.

(i) Interphase - Non-dividing period (Growth phase)

(ii) Dividing phase - Also called M-phase (M for mitosis or meiosis)

(i) **Interphase - (Inter = in between)**

The interval between two successive cell divisions is termed interphase (phase at which the cell is not dividing). It is the longest period in the cell cycle (Fig.4.11). The interphase is subdivided into three main periods - G_1, S and G_2.

G_1 (Gap-1) Phase i.e. **First phase of growth** – This is the longest phase. Lot of protein and RNA are synthesised during this phase.

S or synthetic Phase - It comes next. Lot of DNA is (synthesised). A chromosome contains a single double helical strand of DNA molecule. After S-phase each chromosome becomes longitudinally double except at centromere, and thus, it has two molecules of DNA and two chromatids. Thus each chromatid contains one molecule of DNA. The two chromatids are joined by a centromere (which does not divide at this stage) to form a single chromosome.

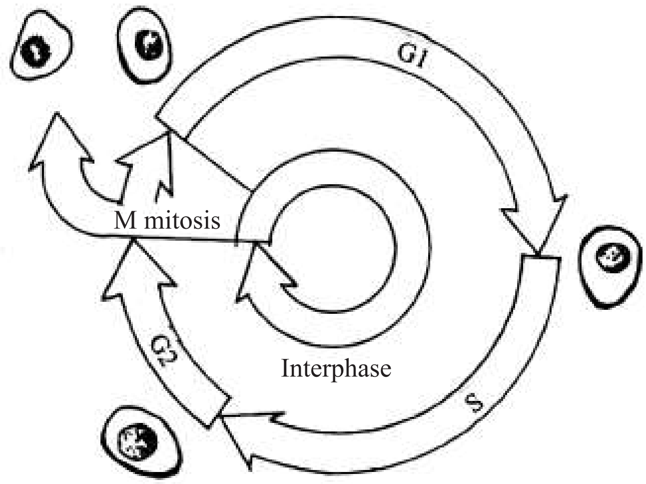


Fig. 4.11 The cell cycle consists of various stages (G_1, S, G_2 and M)

G_2 (GAP 2) phase - More protein including the histones are synthesised in this phase. Cytoplasmic organelles such as mitochondria and golgi bodies get duplicated. Centriole also divides into two centrioles contained in a single centrosome.

(ii) **M-phase or dividing phase** - Represented by the symbol M (Mitosis or meiosis) (Fig. 4.11). Mitosis occurs so that during this period the chromatids separate and form daughter chromosomes. The daughter chromosomes go to daughter nuclei and cytoplasm divides forming two identical daughter cells.

INTEXT QUESTIONS 4.8

1. Explain in one sentence
   (i) Interphase ....
   (ii) Synthetic-phase ....
   (iii) Dividing-phase ....
2. What is the full form of the following in the cell cycle?
   (i) G_1 ....
   (ii) S ....
   (iii) G_2 ....
   (iv) M-Phase ....

4.7.2 Kinds of cell division

There are two kinds of cell division- mitotic cell division and meiotic cell division.

1. Mitotic : Cell division is for growth and replacement of older cells by new cells wherein the two daugher cells are identical and similar to mother cell in all respects. Mitotic cell division occurs in haploid as well as diploid cells.
2. Meiotic cell division occurs in the gonads for sexual reproduction to produce gametes. The resultant cells, egg (in female) and sperms (in male), possess half the chromosome number of that present in the parent cell. Meiotic cell division takes place only in diploid cells responsible for production of haploid spores or gametes.

1. **Mitosis (mitos = thread)** Mitosis is divided into 4 phases or stages termed as

   (i) Prophase (ii) Metaphase

   (iii) Anaphase (iv) Telophase

   These phases refer to the changes taking place in the nucleus (Fig. 4.12).

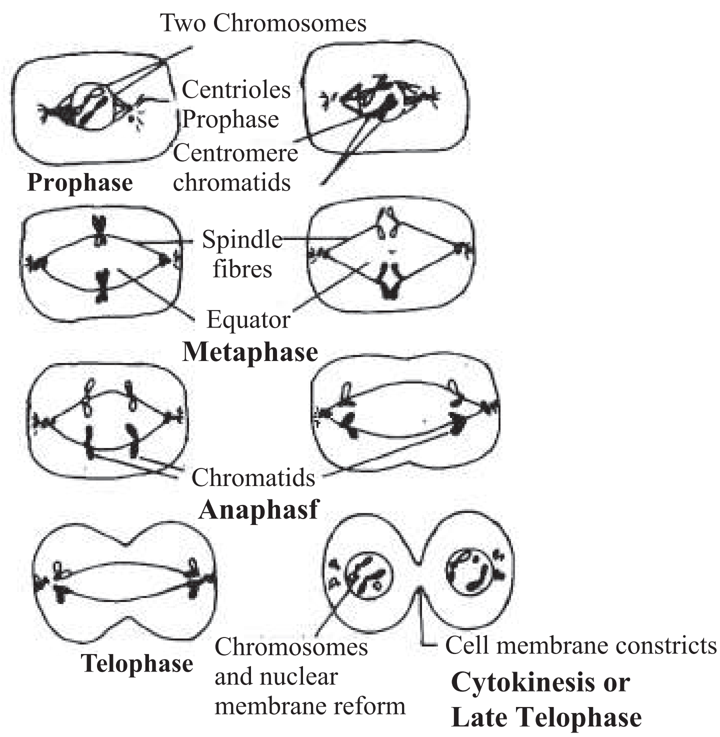
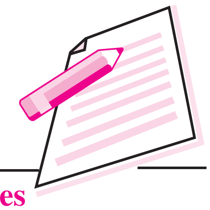


Fig. 4.12 Stages of Mitosis in an animal cell presuming there is just one pair of chromosome in the dividing cell

The nucleus divides first and then the whole cell divides. Division of one nucleus to produce two daughter nuclei a is called (**karyokinesis**). Division of cytoplasm to give two daughter cells is called **cytokinesis**.



Notes

Prophase : It shows three subphases :

(i) **Early prophase**

(a) Centriole divides and each of the two centrioles start moving towards opposite poles of the nucleus of the dividing cell.

(b) Chromosomes appear as long threads, and start coiling.

(c) Nucleus enlarges and becomes less distinct (Fig. 4.13a)

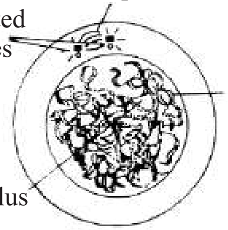


Fig. 4.13a Prophase

(ii) **Middle prophase**

(a) Chromosome condensation is complete and they become short and thick

(b) Each chromosome is made up of two chromatids held together at their centromeres.

(c) Each chromatid contains newly replicated daughter DNA molecule.

(iii) **Late Prophase**

(a) Centrioles reach the opposite poles of the dividing cell.

(b) Some spindle fibres extend from pole to the equator of the dividing cell.

(c) Nuclear membrane disappears

(d) Nucleolus is not visible.

Metaphase

(a) chromosomes are brought towards the equator of the cell, with the help of spindle fibres.

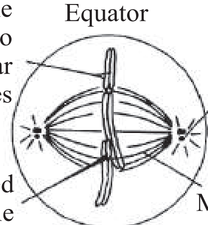


Fig. 4.13b Metaphase

(b) Each chromosome becomes attached to the two spindle fibres by centromere. Whereas each centromere is joined to the opposite poles.

(c) The sister chromatids are not yet separated. (Fig. 4.13b) because the centromere has not divided

Anaphase

(a) Centromeres of all the chromosomes divide and then each chromatid becomes a chromosome.

(b) Spindle fibres contract and pull the centromeres to the opposite poles.

(c) As the chromosomes are pulled by spindle fibres to opposite poles by their centromeres, they acquire various shapes such as V, J or I depending upon the position of centromere.

(d) Half the number of chromosomes move towards one pole and the other half to the opposite pole.

(e) Cytokinesis begins as the cleavage furrow starts from the periphery towards the centre in animal cells, and in plants, cell plate appears in the centre that grows centrifugally towards periphery.

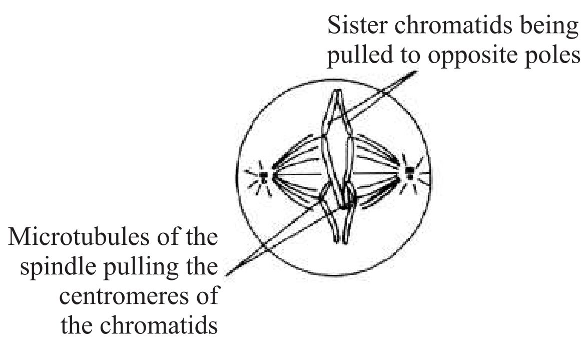


Fig. 4.13c Anaphase

Telophase

(a) Chromosomes uncoil to form a chromatin network as in the parent nucleus.

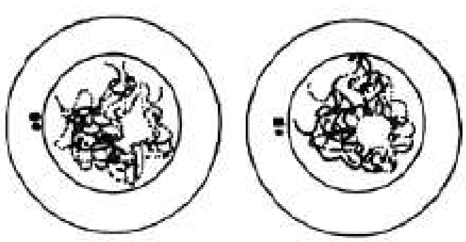


Fig. 4.13d Telophase

(b) New nuclear membrane is formed around each daughter nucleus

(c) Nucleolus reappears again in each newly formed daughter nucleus.

Cytokinesis

It is the process of the division of cytoplasm of a dividing cell into two. It is initiated in the beginning of telophase and is completed by the end of telophase. The mechanism of cytokinesis is different in plant and animal cells. In an animal cell, invagination of plasma membrane proceeds from the periphery of the cell towards the interior. In plant cell phragmoplast (cell plate) begins to form in the centre of cell and then expands towards the periphery (Fig. 4.13e).

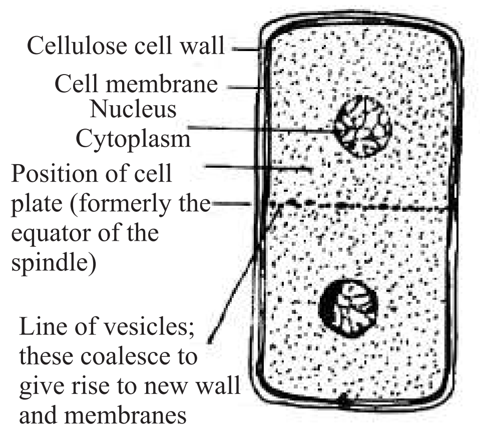


Fig. 4.13e Cytokinesis

Siginificance of Mitosis

It is an equational division, and the two newly formed daughter cells are identical in all respects. They receive the same number and kind of chromosomes as were in the mother cells.

- It is the only mode of reproduction in unicellular organisms.
- It is the process by which growth takes place in multicellular animals and plants by constantly adding more and more cells.
- It also plays a role in repair during growth, for example in wound healing, regeneration of damaged parts (as in the tail of lizard), and replacement of cells lost during normal wear and tear (as the surface cells of the skin or the red blood cells).

Mitotic Cell Division (Limited or unlimited)

Growth by mitosis occurs in a limited or controlled manner to the extent it is required in the body. But at times due to some special cases the number of cells may increase abnormally which may cause **Cancer**.

In plant tissue culture, a cell from a plant can be grown in a nutrient medium, where it divides repeatedly by mitosis to give an undifferentiated cell mass called **callus** capable of differentiating into a plant in the presence of nutrients and specific growth hormones. In animals, stem cell culture is also based on the ability of a cell to divide and give rise to cells of specific type.

INTEXT QUESTIONS 4.9

1. Name the stage of cell cycle during which chromatin material is duplicated.

   ....

2. Is the number of chromosomes reduced in the daughter cells during mitosis? yes/no?

   ....

3. Name the stage in nuclear division described by each of the following sentences:

   (i) disappearance of the nuclear membrane

   ....

   (ii) The nuclear membrane and nucleolus reappear

   ....

   (iii) The centromere divides and the chromatids move to opposite poles due to the shortening of spindle fibres

   ....

   (iv) The chromosomes arrange themselves at the equatorial plane of the spindle with the spindle fibres attached to the centromeres.

   ....

---

2. Meiotic Cell Division (GK meioun = make smaller, sis = action)

This division is also known as '**reduction division**'. But why this name? This is because, in this kind of cell division the normal **chromosome number of the mother cell is reduced to half in daughter cells.** The normal chromosome number in human being is 46 (23 pairs), but as a result of meiosis in ovary and testes this number is halved to 23 in daughter cells (called sperms or the egg).

Where does it occur? It occurs in reproductive cells, e.g. in the testes of male and in the ovaries of female animals; and in plants, in the pollen mother cell of the anthers (male organs) and in the megaspore mother cells of the ovary (female organ) of the flowers.

Why does it occur? In meiosis the chromosome number is reduced to half so that when doubled at fertilisation (zygote formation) during the reproduction it once again becomes ristored to the deploid state.

- The number of chromosomes remains constant in a species generation after generation.
- Cells divide mitotically in the organisms that reproduce vegetatively/asexually. Thus, there is no change in the number of chromosomes, but sexually reproducing organisms form gametes such as sperms in males and ova in females. The male and female gametes fuse to form the zygote which develops into a new individual. .
- If these gametes were, produced by mitosis, the offspring developing from zygote then would have double the number of chromosomes in the next generation.
- Every living organism has a definite number of chromosomes in its body cells. e.g. onion cell-16; potato-48; horse-64; man-46. Therefore to keep the chromosome number constant the reproductive cells of the parents (ovaries and testis in animals, and pollen mother cells in anthers and megaspore mother cells in the ovules inside the ovary in plants) divide through meiosis.

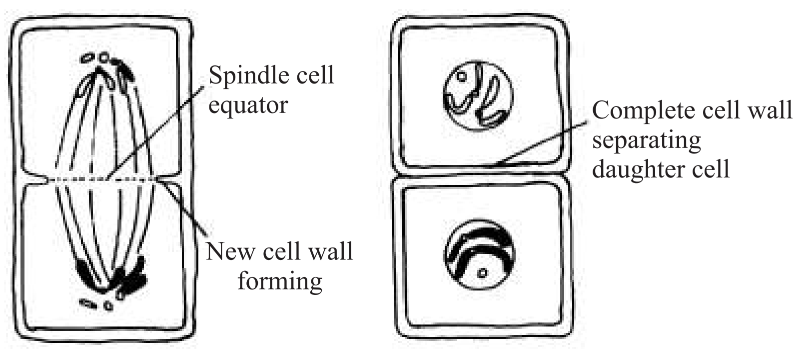


Fig. 4.14 : Cell wall formation after mitosis in a plant cell

How does meiosis occur?

Meiosis is characterized by two successive divisions of the nucleus (meiosis I and II) and cytoplasm, whereas the chromosomes divide only once. The phases of meiotic division are given in the flow-chart drawn here.

– **The interphase** which precedes the onset of meiosis is similar to the interphase which precedes mitosis. At S-phase, the DNA molecule of each chromosome duplicates to give rise to two DNA molecules and hence two chromatids are found in one chromosome attached to a single centromere.

- Meiosis
  - Meiosis I
    - Prophase I
      - Leptotene
      - Zygotene
      - Pachytene
      - Diplotene
      - Diakineses
    - Metaphase I
    - Anaphase I
    - Telophase I
  - Meiosis II
    - Prophase II
    - Metaphase II
    - Anaphase II
    - Telophase II

– Meiosis-I and meiosis-II are continuous and have been divided into sub-stages only only for convenience to study the process of nuclear division.

Meiosis-I

Like mitosis, meiosis-I also consists of four stages; prophase-I, metaphase-I, anaphase-I and telophase-I.

Prophase-I

The prophase-I of meiosis-I is much longer as compared to the prophase of mitosis.

- It is further sub-divided into the following five sub-stages :

(i) **Leptotene** (GK 'leptos' - thin; 'tene - thread) (Fig. 4.15a)

- The chromosomes become distinct and appear as long and thin threads bearing fine beads due to condensation (coiling of DNA) at specific points called chromomeres.
- Each chromosome consists of two chromatids held together by a centromere but these are not easily visible.
- Nuclear membrane and nucleolus are distinct.

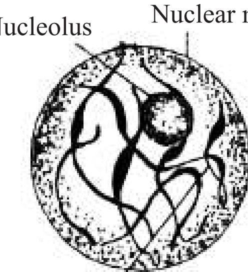


Fig. 4.15a Leptotene

(ii) **Zygotene** (GK. 'Zygos'-pairing) (Fig. 4.15b)

- Chromosomes continue coiling and become shorter and thicker
- Similar or homologous chromosomes start pairing from one end. This pairing is known as **synapsis.**
- Each pair of homologous chromosomes is called a **bivalent**.
- Nuclear membrane and nucleolus are distinct.

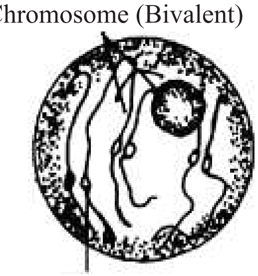
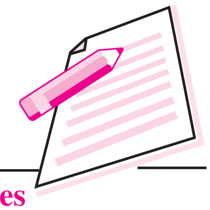


Fig. 4.15b Zygotene



(iii) **Pachytene** (GK. 'pachus' - thick) : (Fig. 4.15c)

- The chromosomes become shorter and thicker due to further coiling.
- Each paired unit called a 'bivalent' shows four chromatids hence bivalents are also known as **tetravalents**.

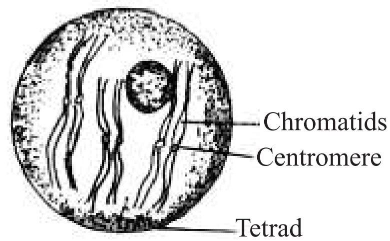


Fig. 4.15c Pachytene

- Crossing-over occurs at the end of pachytene i.e. break and exchange of parts (genes) occurs between non-sister chromatids (chromatids of a homologous pair)

  The point of interchange and rejoining appears X-shaped and is known as chiasma (plural-chiasmata) or the point of **crossing over**.

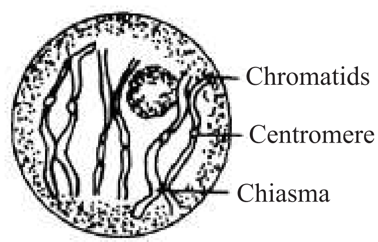


Fig. 4.15d Diplotene

(iv) **Diplotene** ('Diplous'-double) (Fig. 4.15d)

- Chromosomes continue coiling further and become shorter.
- The centromeres of homologous chromosomes start repelling each other
- The two non-sister chromatids of a homologous pair of chromosomes remain, attached at one or two points, the **chiasmata**.
- Nucleolus and nuclear membrane become indistinct.
- It is at the chiasmata that exchange of segments of nonsister chromatids (genes) between homologous chromosomes has taken place. The process of gene exchange is known as **genetic recombination**.

(v) **Diakinesis** (GK dia = through, in different directions, kinesis = motion; Fig. 4.15e)

- The bivalents become the shortest and thickest due to maximum coiling.
- The centromeres and non-homologous parts of homologous chromosomes of a bivalent move apart due to repulsion from each other.

- Consequently, the bivalents acquire various configurations such as O, X or 8, depending upon the number of chiasmata per bivalent.
- Nuclear membrane and nucleolus disappear.
- Spindle formation is completed.

Fig. 4.15e Diakinesis

(vi) **Metaphase-I** (Fig. 4.15f)

- The bivalents arrange themselves at the equatororial plate.
- The homologous chromosomes arrange in such a way that all maternal or all paternal chromosomes do not get attached to same pole. In other words, some maternal and some paternal chromosomes are joined to each pole.
- The spindle fibres are attached at the centromere of the chromosomes.

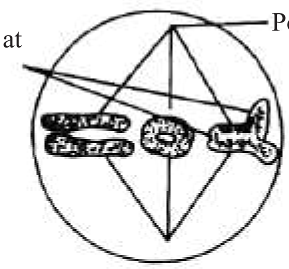


Fig. 4.15f Metaphase

- One centromere of a bivalent is joined to one pole and second centromere is joined to the opposite pole by the separate spindle fibres.

(vii) **Anaphase-I** (Fig. 4.15g)

- The spindle fibres shorten.
- The centromeres of homologous chromosomes are pulled along by the spindle fibres towards the opposite poles (no division of centromere)
- Thus, half of the number chromosomes (each with two chromatids) of the parent cell go to one pole and the remaining half to the opposite pole.

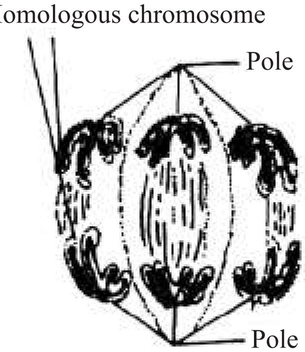


Fig. 4.15g Anaphase

- Each set of chromosomes that moves to one pole consists of a mixture of paternal and maternal chromosome parts (new gene combination). This is the basic reason for mixing of maternal and paternal genes in the products of meiosis.

(viii) **Telophase-I** (Fig. 4.15h)

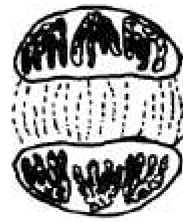


Fig. 4.15h Telophase

- The separated chromosomes uncoil in the newly formed daughter nuclei.
- The daughter nuclei have half the number of centromeres as compared to that in the parent nucleus. But, since each centromere has two chromatids, amount of DNA at the two poles at telophase-I is same i.e. 2n (diploid as in the parent nucleus wherein the chromosomes had duplicated at S-phase, thus amount of DNA in the dividing cell upto anaphase I was 4n)
- The daughter cells now have half the amount of DNA as compared to that at Anaphase-I, that is 2n.
- The nucleous reappears and nuclear membrane forms
- The daughter nuclei enter into the second meiotic division.,

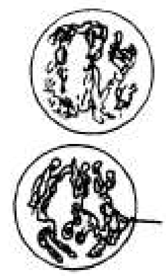


Fig. 4.15i Prophase II

Second Meiotic Division has the same four stages;

(i) Prophase II (ii) Metaphase II

(iii) Anaphase II (iv) Telophase II

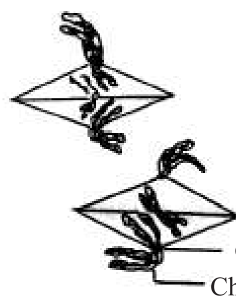


Fig. 4.15j Metaphase II

(i) **Prophase II** (Fig. 4.15i)

- The chromosomes shorten and chromatids become distinct. The two chromatids of each chromosome are attached to the single centromere.
- Formation of spindle starts.
- Nucleolus and nuclear membrane begin to disappear.

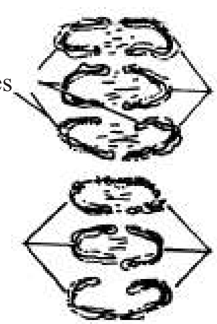


Fig. 4.15k Anaphase II

(ii) **Metaphase II** (Fig. 4.15j)

- The chromosomes arrange themselves along the equator.
- Formation of spindle apparatus is completed.
- The centromere of each chromosome is attached by two spindle fibres to the opposite poles.

(iii) **Anaphase II** (Fig. 4.15k)

- The centromere in each chromosome divides so that each chromatid has its own centromere and each chromatid is now a complete chromosome.

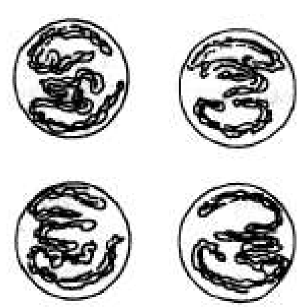


Fig. 4.15l Telophase II

- The chromatids get their respective centromere and become daughter chromosomes and begin to move towards the opposite poles due to contraction of spindle fibres.

(iv) **Telophase II** (Fig. 4.15l)

- On reaching the poles, the chromosomes organize themselves into haploid daughter nuclei.
- The nucleolus and the nuclear membrane reappear.
- Each of the four daughter nuclei has half the number of chromosomes (n) as well as half the amount of DNA as compared to the parent nucleus (2n).

Cytokinesis

- This may occur in two successive stages, once after meiosis I and then after meiosis II, or in some instances it occurs only after meiosis II.
- Thus after meiotic cell division four haploid cells are formed.

Significance of Meiosis

(i) It helps to maintain constant number of chromosomes in different generations of a species undergoing sexual reproduction.

(ii) Meiosis occurs during gamete formation (gametogenesis) and reduces the number of chromosomes from diploid (2n) to haploid (n) in the gametes. These haploid gametes fuse to form diploid zygote during fertilization. The diploid zygote develops into a normal diploid individual.

(iii) Meiosis establishes new combination of characters due to (i) mixing of paternal and maternal chromosomes and (ii) crossing over during prophase I. As a result the progeny inherits the traits of both the mother and the father in new gene combinations.

Comparison of Mitosis and Meiosis

Mitosis	Meiosis
1. Cell divides only once	There are two cell divisions. First meiotic division and the second meiotic division.
2. Takes place in somatic cells as well as in reproductive cells which may be haploid or diploid or polyploid	Takes place only in diploid germ cells.
4. Duration of prophase is short (few hours)	Prophase-I, is compartively longer. (takes many days).
5. Prophase simple.	Prophase I is complicated having five sub-stages namely leptotene, zygotene, pachytene, diplotene and diakinesis.
7. Synapsis does not occur.	Synapsis of homologous chromosomes takes place during prophase-I.
8. No exchange of segments during prophase between two nonsister chromatids of chromosomes.	Exchange of segments during crossing over between non sister chromatids of two homologous chromosomes takes place.
9. Each chromosome consists of two chromatids united by a centromere.	Each bivalent has four chromatids and two centromeres.

10. Chromosomes are duplicated at the beginning of prophase.	In prophase I, chromosomes appear single although DNA replication has taken place in interphase I.
11. In metaphase all the centromeres line up in the same plane.	In metaphase I, the centromeres are lined up in two planes which are parallel to one another.
12. The metaphasic plate is made up of duplicated chromosome.	The metaphasic plate is made up of paired chromosomes.
13. Centromere division takes place during anaphase.	No centromere divisions during Anaphase I, centromeres divide only during Anaphase II.
14. Spindle fibres disappear completely in telophase.	Spindle fibres do not disappear completely during telophase I.
15. Reappearance of nucleoli at telophase.	Nucleoli do not appear in telophase I.
16. The chromosome number does not change at the end of mitosis.	There is reduction in the chromosome number from diploid to haploid.
17. The genetic constitution of chromosomes daughter cells is absolutely identical to that of parent cells.	The genetic constitution of chromosomes in daughter cells is different as compared to the parent cells. The daughter cell chromosomes contain a mixture of maternal and paternal genes.
18. Mitosis is of shorter duration.	Meiosis is of longer duration.
19. It is the basis of growth and repair and reproduction in vegetatively or asexually reproducing organisms.	It is basis of maintaining same chromosome number in different generations of a species reproducting sexually as well as for providing genetic variation in the progeny.

What is a karyotype

Chromosomes can be seen distinctly only at metaphase. They are then photographed, cut and arranged in pairs according to size. Such an arrangement of homologous chromosomes of an individual in descending order according to size, is termed as a karyotype (see human karyotype in lesson 21).

INTEXT QUESTIONS 4.10

1. Name the sub-stage of meiosis-I in which the :

   (i) Homologous chromosomes pair

   ....

   (ii) Tetrads are formed.

   ....

   (iii) Homologous chromosomes begin to move away from each other.

   ....

2. Sites of meiosis in flowering plants, are :

   ....

3. Rearrange the following stages of meiosis I in their proper sequence :

   zygotene, pachytene, leptotene, metaphase-I diakinesis, anaphase-I, telophase-I.

   ....

4. Mention two major points in which meiosis I differs from meiosis II

   ....

WHAT YOU HAVE LEARNT

- A living cell is a self-sufficient unit of the body of a living plant or animal.
- Important cell organelles are mitochondria, Golgi complex, ER, ribosomes, peroxisomes, chloroplast, glyoxisomes, nucleus.
- With the exception of centrioles, ribosomes and nucleolus, all other organelles are membrane-bound.
- Although a cell fails to live, grow and reproduce in the absence of a nucleus, nucleus all by itself without cytoplasm is also ineffective.
- Some organelles like mitochondria and chloroplast have the capacity to duplicate themselves to some extent without the help of the nucleus i.e. they are termed semi-autonomous.
- The living cells divide by mitotic cell division to produce new cells.
- Growth in body occurs due to increase in the number of cells.
- The continuity of the chromosomal set is maintained by cell division.
- The life cycle of a cell includes interphase (G_1, S & G_2) and M-phase (mitosis or meiosis)
- Mitotic cell division occurs in somatic cells or reproductive cells that results in the formation of identical cells, both qualitatively and quantitively.
- Meiosis occurs in germ cells only i.e. testis and ovary. This is a reduction division where the chromosome number becomes half.
- The significance of mitosis is growth, and reproduction where the product of reproduction is identical.
- The Significance of meiosis is in sexual reproduction where ova and sperm both have half the number of chromosomes i.e. 23 each in human gametes (but normal number of chromosome of human is 46 or 23 pair) and on fertilization the chromosome number becomes normal.
- Meiosis also helps in mixing the paternal and maternal characters.

TERMINAL EXERCISES

1. Justify the statement that cell wall although a dead material, influences living processes inside the cell.
2. Differentiate between cell wall and cell membrane.
3. Draw Singer and Nicholson's model of cell membrane.
4. Why is cell membrane vital for the cell?
5. Draw structure of mitochondria and chloroplast as seen by electron microscope.
6. List functions of mitochondria and chloroplast.
7. Name the self–duplicating cell organelles? Why are they called so?
8. Differentiate between functions of ER, ribosomes and Golgi bodies.
9. Most organelles are membrane – bound. What is the advantage of such arrangement.
10. Differentiate between the structure and function of centriole and cilia/flagella.
11. Why are lysosomes known as "suicidal bags"?
12. What are the functions of nucleus?
13. List the cell organelles. Write in one line each, about their functions and explain the division of labour.
14. Give the points of difference between
    (i) prokaryotic and eukaryotic cell.
    (ii) plant and animal cell.
15. Why is the cell termed the structural and functional unit of living organisms?
16. Name the following :
    (i) The condition in which a cell has the normal paired chromosomes.
    (ii) The condition in which a cell contains only one member of each pair of chromosomes.
    (iii) The pairing of maternal and paternal chromosomes during meiosis.
    (v) The exchange of parts in homologous (maternal and paternal) chromosomes during prophase-I of meiosis.
    (vi) The point by which a chromosome is attached to the spindle fibre.
    (vii) The type of cell division that results in growth.
17. What are the sites of meiosis in a flowering plant and in a sexually reproducing animal?

18. List the sub-stages of prophase-I.
19. What is the significance of meiosis?
20. Draw a schematic diagram of various stages of the life-cycle of a cell.
21. Draw labelled diagrams of various stages of mitosis.
22. Tabulate the main differences between mitosis and meiosis.
23. Why is prophase of meiosis so prolonged and elaborate?
24. What is the difference between cytokinesis in animal cell and cytokinesis in plant cell?

ANSWERS TO INTEXT QUESTIONS

4.1 1. Pre-existing cells

2. Schleiden and Schwann
3. Chloroplast/plastid
4. Prokaryote - naked nucleus, no membrane bound cell organelles

   Eukaryote - distinct nucleus with a cell membrane, membrane bound cell organelles present

4.2 1. Diffusion : Movement of molecules from region of their higher concentration to region of their lower concentration.

   Osmosis : Movement of water molecules across a semipermeable membrane from region of their higher concentration to the region of their lower concentration.

2. Movement of molecules against concentration gradient that is region of lower to higher concentration by expending energy.
3. Intake of solid particles (phagocytosis)

   Intake of fluid droplets (pinocytosis)
4. (i) – d (ii) – a (iii) – e

   (iv) – b (v) – c
5. (i) Protection/shape

   (ii) Provide communication between cells through plasmodesmata

4.3 1. Membrane bound bodies in the cytoplasm

2. ATP
3. Grana
4. Thylakoids
5. Because energy as ATP is generated and stored in mitochondria
6. Mitochondria

7. (i) both are semiautonomous
   (ii) both contain DNA or both contain ribosomes
8. Chromoplasts
9. Chloroplast
10. They have their own DNA for production of more copies of themselves by self duplication but cannot lead independent life, outside the cell/ cytoplasm.

4.4 1. (a) Golgi body (b) ER, (c) amyloplasts (d) ER, (e) ribosomes
2. refer text
3. (i) internal framework, (ii) transport of cellular substances
4. cytoplasm, ER, Nucleolus; chloroplasts, mitochondria
5. ER

4.5 1. Because the lysosome can devour organelles of the same cell
2. They help in cleaning up the cell by digesting useless matter
3. Fat metabolism

4.6 1. Nucleus controls all the functions of the cell as it has the hereditary information
2. (a) Chromosomes are present as a network when not dividing, that is, at early interphase or Go-stage (Differentiation stage during development)
   (b) Bearers of hereditary information as genes on them
3. Site of RNA synthesis

4.7 1. (i) It is a universal solvent and most chemical reactions of the cell occur in aqueous medium
   (ii) It is a constituent of protoplasm
2. glucose
3. –NHCO–, between amino acids in a polypeptide, found in proteins
4. ATP
5. building blocks of nucleic acids, each containing a pentose sugar, nitrogenous base and phosphate

4.8 1. (i) Interphase - stage between two successive cell divisions;
   (ii) Synthetic phase - DNA is synthesised;
   (iii) Dividing phase - Mitosis in somatic cells or meiosis in the germ cells takes place.

2. (i) First growth phase; (ii) Synthetic phase;
   (iii) Second growth phase; (iv) Mitosis/meiotic phase.

4.9 1. S-shape of Interphase;

2. No;

3. (i) Late Prophase; (ii) Late Telophase; (iii) Anaphase; (iv) Metaphase

4.10 1. (i) zygotene (prophase I); (ii) Pachytene; (iii) Diplotene

2. Microspore/pollen mother cell in anthers and megaspore mother cell in the ovule.

3. Leptotene, zygotene, pachytene, diplotene, diakinesis, metaphase I, telophase I.

4. Reduction in chromosome number to half in Meiosis-II; exchange of genetic material in meiosis I.

5

TISSUES AND OTHER LEVELS OF ORGANIZATION

You have just learnt that cell is the fundamental structural and functional unit of organisms and that bodies of organisms are made up of cells of various shapes and sizes. Groups of similar cells aggregate to collectively perform a particular function. Such groups of cells are termed “tissues”. This lesson deals with the various kinds of tissues of plants and animals.

OBJECTIVES

After completing this lesson, you will be able to :

- *define tissues;*
- *classify plant tissues;*
- *name the various kinds of plant tissues;*
- *enunciate the tunica corpus theory and histogen theory;*
- *classify animal tissues;*
- *describe the structure and function of various kinds of epithelial tissues;*
- *describe the structure and function of various kinds of connective tissues;*
- *describe the structure and function of muscular tissue;*
- *describe the structure and function of nervous tissue.*

5.1 WHAT IS A TISSUE

Organs such as stem, and roots in plants, and stomach, heart and lungs in animals are made up of different kinds of tissues. **A tissue is a group of cells with a common origin, structure and function.** Their common origin means they are derived from the same layer (details in lesson No. 20) of cells in the embryo. Being of a common origin, there are similar in structure and hence perform the same function. Several types of tissues organise to form an **organ**.

Example : Blood, bone, and cartilage are some examples of animal tissues whereas parenchyma, collenchyma, xylem and phloem are different tissues present in the plants. The study of tissues is called **histology**.

A group of cells with similar origin, structure and function is called **tissue**. e.g. bone, and muscle in animals and meristem in tips of root and shoot in plants

5.2 THE PLANT TISSUES

The plant tissues are mainly of two catagories:

1. Meristematic (Gk. meristos : dividing)
2. Permanent (non-dividing)

1. **Meristematic tissues**
   - Composed of immature or undifferentiated cells without intercellular spaces.
   - The cells may be rounded, oval or polygonal; always living and thin-walled.
   - Each cell has abundant cytoplasm and a prominent nucleus in it.
   - Vacuoles may be small or absent.

Table 5.1 Types of meristematic tissue

Types	Location	Function
Apical Meristem	Root tip and shoot tip.	Growth in length of plants and their branches.
Intercalary Meristem	At the bases of leaves or at the bases of internodes.	Internodal growth, in monocots growth of leaf lamina in grasses.
Lateral Meristem	Cambium between xylem and phloem and cork. cambium in the cortex of dicot plants.	Growth in thickness of the plant body (secondary growth).

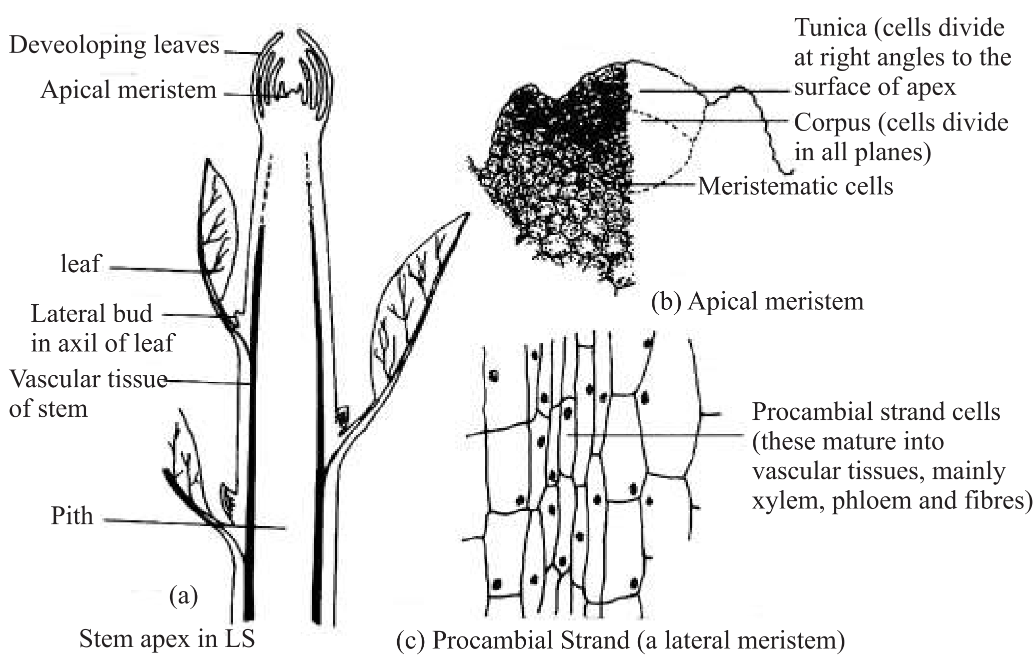


Fig. 5.1 Location of the meristematic tissues in an angiospermous plant

2. **Permanent tissues**
   - Permanent tissues are those in which growth has stopped either completely or for the time being.
   - Cells of these tissues may be living or dead; and thin-walled or thick-walled.
   - Thin-walled permanent tissues are generally living whereas the thick-walled tissues may be living or dead.

Types of permanent tissues

(i) **Simple tissues :** A simple tissue is made up of only one type of cells. Common simple tissues are parenchyma, collenchyma and sclerenchyma (Fig. 5.2, 5.3 and 5.4).

(ii) **Complex tissues :** A complex tissue is made up of more than one type of cells working together as a unit. Common examples are xylem and phloem (Fig. 5.5 and 5.6).

The structure, function and distribution of simple plant tissues is given in Table 5.2.

INTEXT QUESTIONS 5.1

1. Define a tissue.

   ....

2. Give one word equivalent for the following :

   (i) A plant tissue that consists of cells which continue to divide to produce more cells.

   ....

   (ii) The meristematic tissue responsible for the increase in thickness of the stem of a tree.

   ....

   (iii) The kind of plant tissues which consists of all similar cells.

   ....

   (iv) The category of plant tissues in which the cells do not divide.

   ....

3. What do you mean by "cells of a tissue have similar origin"?

   ....

4. Name that branch of Biology in which tissues are studied?

   ....

5. What is a complex tissue?

   ....

6. Mention any **two** special features of the meristematic cells.

   ....

5.2.1 Simple Plant Tissues

There are three types of simple plant tissues (Fig. 5.2, 5.3 and 5.4)

1. Parenchyma (Chlorenchyma and Aerenchyma)
2. Collenchyma
3. Sclerenchyma

Table 5.2 Structure, Function and Distribution of simple tissues

Tissue	Living or Dead	Structure	Function	Distribution
1. Parenchyma	Living	(i) Oval or round, thin-walled with sufficient cytoplasm. (ii) Has prominent nucleus and intercellular spaces (iii) Wall made up of cellulose	(a) They make large parts of various organs in most plants. (b) Act as storage cells. (c) Chlorenchyma carries out photosynthesis. (d) Turgid, parenchyma gives rigidity to the plant body.	1. Pith and cortex of stem and root. 2. Mesophyll of leaves. 3. Endosperm of seed. 4. Xylem and phloem parenchyma in vascular tissue. 5. Occur in leaves and stems of aquatic plants
(a) Chloren-chyma	Living	Parenchyma containing chloroplasts.		
(b) Aeren-chyma	Living	Parenchyma with large air spaces or intercellular spaces.		
2. Collenchyma (Gk. collen : glue)	Living	(i) Elongated cells with thick primary walls. Thickenings more in the corners of the cells. (ii) Wall material is cellulose and pectin (iii) Intercellular sapces present.	Gives mechanical support to the plant body. Specially in many dicot leaves and green stems	Occurs in the peripheral regions of stems and leaves.
3. Sclerenchyma (Gk. scleros = hard)	Dead	Sclerenchyma consists of thick walled cells, walls uniformly thick with lignin.	Sclerenchyma is mainly a supporting tissue, which can withstand strains and protect the inner thin-walled cells from damage.	• Fibres occur in patches or continuous bands in various parts of stem in many plants.
(a) Fibres	Dead	Elongated cells with pointed ends. Walls are thick with lignin.		• Sclereids occur commonly in fruits and seeds.
(b) Sclereids	Dead	Irregular in shape. Cell wall very thick making the cell cavity very small.		Present in some leaves in large numbers.

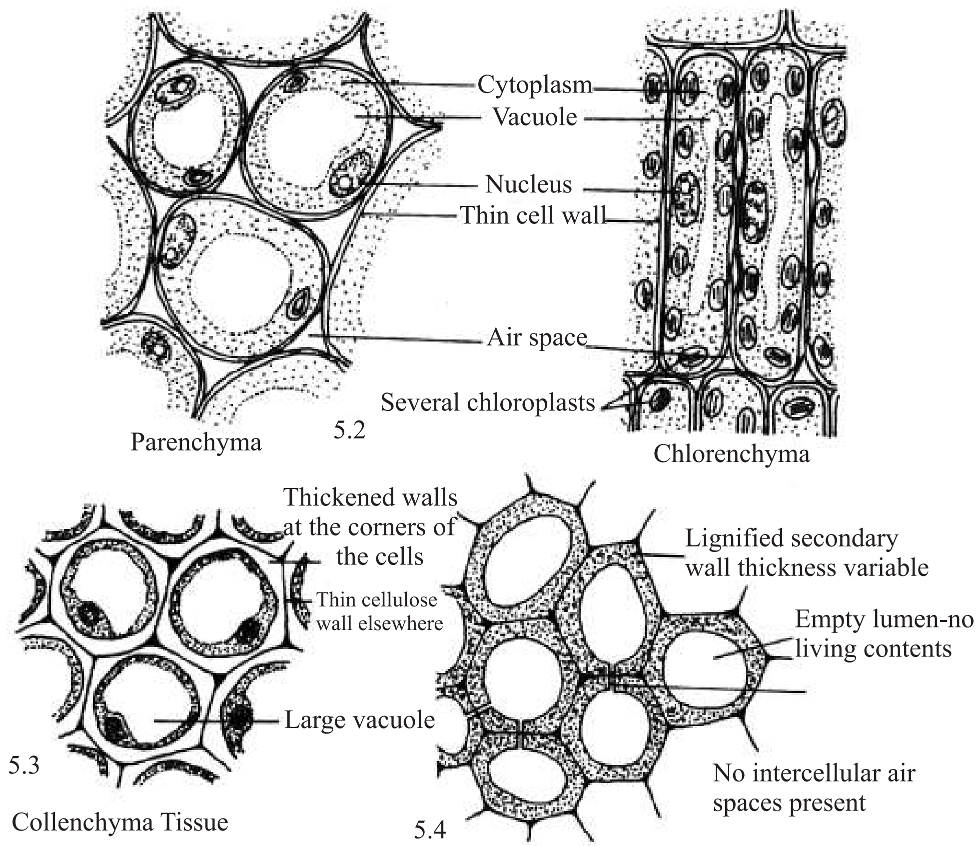


Fig. 5.2, 5.3, 5.4 Various types of simple tissues

5.2.2. Complex tissues

Complex tissues are mainly of two types :

(i) Xylem

(ii) Phloem

– Xylem and phloem form a continuous system inside the plants, that is from the roots through the stem and leaves.

– They are known as vascular tissues and form vasular bundles in roots and stems.

Xylem (Greek xylo = wood)

– Xylem is a conducting tissue which conducts water and salts upward from roots to leaves.

– Xylem is composed of (a) Tracheids, (b) Vessels (c) Fibres and (d) Xylem Parenchyma (Fig. 5.5)

Phloem

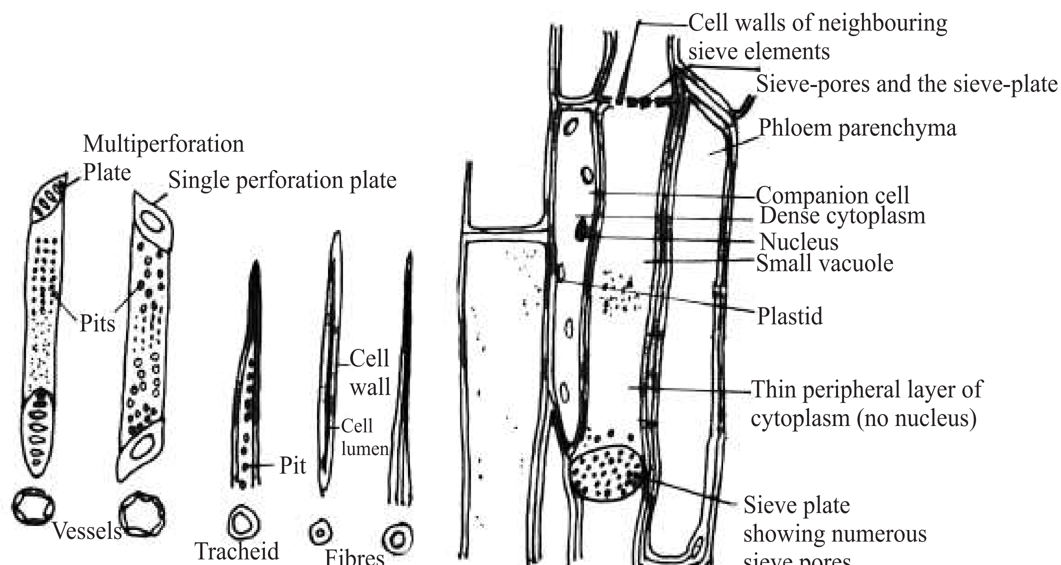
– Phloem too is a conducting tissue which conducts the metabolites (food) food synthesised in the leaves to different parts of the plant.

– Phloem is composed of (a) Sieve tube element (b) Companion cells (c) Phloem fibre and (d) Phloem Parenchyma (Fig. 5.6)

The structure, and function of the complex plant tissues is given in Table 5.3.

Table 5.3 Structure and function of the components of xylem and phloem

Tissues	Living or Dead	Structure	Function
Xylem			
1. Tracheids	Dead	Long cells with pointed ends. Walls thick with lignin. Have pores on the walls	All of them function as a unit to conduct water and minerals upward from root to leaves.
2. Vessels	Dead	Cells shorter and broader than tracheids. Walls thick with lignin and have pores. End walls open and the cells join to form a long tube.	
3. Xylem Fibres	Dead	Long cells with very thick lignin deposition on the walls, no pores on the walls.	
4. Xylem Parenchyma	Living	Small thin walled cells with cellulose walls.	
Phloem			
1. Sieve tube	Living	Elongated sieve elements join to form sieve tubes; cell wall of cellulose. End walls of the cells have perforations on them, which give them the name (sieve).	All of them function as a unit to translocate food assimilated in the leaves by photosynthesis to different parts of the plant.
2. Companion cell	Living	Long, rectangular cells associated with seive cells. Cell wall made of cellulose.	
3. Phloem fibre	Dead	Very long cells with thick lignified walls	
4. Phloem parenchyma	Living	Elongated cells. Cell walls thin and made of cellulose.	



5.5 Xylem Vessels, trachieds and fibres
5.6 Phloem parenchyma, Sieve tubes and Sieve Plate

Fig. 5.5, 5.6 Various types of complex tissues

5.2.3 Theories explaining growth of the plant at its shoot apex and root tip

There are two important theories that explain the growth of a plant at the extremities of shoot and root. These are (i) the Tunica corpus theory and (2) the Histogen theory.

Tunica Corpus Theory :

- Tunica corpus theory was developed for vegetative shoot apex.
- According to this theory, there are **two** zones of tissues in the apical meristems **the tunica** (Tunic = cover) consisting of one or more layers of peripheral layers of cells, and the **corpus** (corpus = body) a mass of cells enclosed by the tunica.
- According to the theory, different planes and rates of cell division and methods of growth in the apex set apart two regions.
- The layers of tunica show anticlinal (perpendicular to periphery) divisions and bring about surface growth.
- In the corpus, cell division is irregular and at various planes resulting in grwoth in volume of the mass.
- Tunica gives rise to the epidermis and cortex. Corpus gives rise to endodermis, pericycle, pith and vascular tissue.

Histogen Theory

- According to this theory, the apical meristem of stem and root are composed of small mass of cells which are all alike and divide fast (meristematic)
- These meristematic cells form promeristem, which differentiates into three zones **dermatogen, periblem** and **plerome**.
- Each every zone consists of a group of initials called a **histogen** (tissue builder).
  - (i) The dermatogen gives rise to epidermis of stems and epiblema of roots.
  - (ii) Periblem (middle layer) gives rise to cortex of stems and roots.
  - (iii) Plerome gives rise to the central meristematic region – pericycle, pith and vascular tissue.

Classification of plant tissues-at a glance

- Plant Tissue
  - Meristematic
    - Apical
    - Intercalary
    - Lateral
  - Permanent
    - Simple
      - Parenchyma
      - Collenchyma
      - Sclerenchyma
    - Complex
      - Xylem
      - Phloem

INTEXT QUESTIONS 5.2

1. Give Two characteristics and one example of the location of the given tissues in plants in the following table:

S.No.	Tissue	Characteristics	Example of location
(i)	Parenchyma	....	....
(ii)	Collenchyma	....	....
(iii)	Sclerenchyma	....	....

2. Name the plant tissues which
   (i) conduct water ....
   (ii) conduct food metabolites. ....

5.3 ANIMAL TISSUES

As in plants, tissues in animals are also of various types which perform different functions. See the flow-chart given below

Animal Tissues

- **Epithelial tissue** (Protection by covering, secretion, and absoption)
- **Connective Tissue** (Binding, support, transport)
- **Muscular tissue** (Movement and Locomotion)
- **Nervous Tissue** (Control and co-ordination)

5.3.1 Epithelial Tissue

Structural Characteristics : The cells forming epithelial tissue –

(i) are closely packed with no intercellular spaces in between.

(ii) arise from a non-cellular basement membrane.

(iii) are not supplied with blood vessels.

Function : Epithelian tissues line the surfaces, help in absorption, secretion, and also bear protoplasmic projections such as the cilia. (See Table 5.4 and Fig. 5.7)

Table 5.4 : Types of epithelial tissue

Type	Structure	Location	Function
1. Squamous Epithelium	Flattened cells with a centrally placed nucleus. Have irregular margins.	Lining of air sacs in the lungs.	For exchange of O_2 and CO_2.
		Lining of Kidney tubules.	For absorption.
		Lining of blood capillaries.	For exchange of materials.

2. Cubodial Epithelium	Cube like cells with a centrally placed nucleus, Cells appear polygonal.	Lining of salivary and pancreatic ducts. In sweat and salivary glands.	For absorption. For secretion
3. Ciliated Epithelium	Have cilia at free ends.	Lining of kidney tubules.	For flow of nephric filtrate.
4. Columnar epithelium	Long column-like cells, each with nucleus at the basal end	Lining of stomach, instestine	Secretion and absorption
5. Ciliated Columnar Epithelium	Cilia at free ends	Lining of trachea	Flow of fluids in a particular direction
6. Brush bordered Columnar Epithelium	Numerous folds at free ends—folds looking like bristles of a brush.	Lining of intestine	Increasing the surface area for absorption

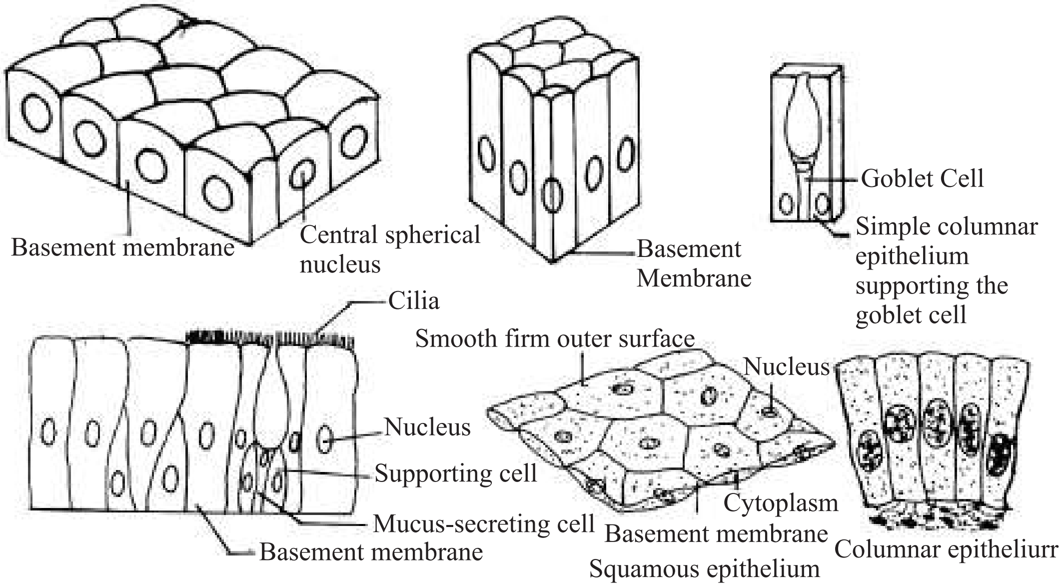


Fig. 5.7 The structure of different kinds of epithelial tissues

If the epithelial cells are in a single layer, they form simple eptihelium. If the epithelial cells are arranged in many layers, they form compound epithelium or stratified epithelium (many layers). Stratified eptihelium is present in the body, where there is lot of wear and tear. For example the skin and inner lining of cheeks.

INTEXT QUESTIONS 5.3

1. List the different types of animal tissues

   ....

2. Match the items in Column I with those in Column II by writing the corresponding serial number within brackets.

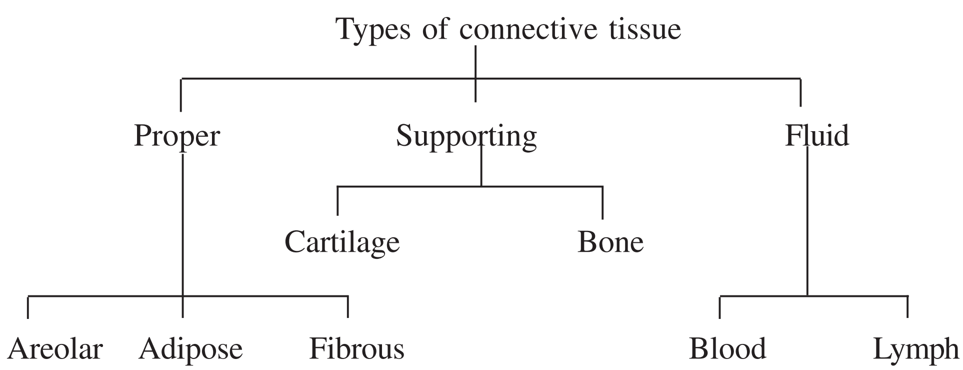
	Column I		Column II
(a)	Compound Epithelium	( )	(i) Epithelial tissue
(b)	Basement membrane	( )	(ii) For increasing the surface area
(c)	Brush-bordered epithelium	( )	(iii) Lining of trachea
(d)	Salivary gland	( )	(iv) Skin
(e)	Ciliated Epithelium	( )	(v) Cuboidal epithelium

5.3.2 Connecitve tissue

The connective tissue has two components :

(a) matrix, the ground substance and (b) cells

The matrix and cells are different in different connective tissues (Fig. 5.8).



A. Proper Connective Tissue

1. Areolar : Most widely spread connective tissue.

The cells forming the tissue are :

(i) **Fibroblasts**-which form the yellow (elastin) and white (collagen) fibres in the matrix.

(ii) **Macrophages**-which help in engulfing bacteria and micro-pathogens.

(iii) **Mast cell**-which secretes heparin, that helps in clotting of blood.

2. Adipose tissue : It has specialized cells which store fat and provide help in forming paddings.

3. Fibrous : It is mainly made up of fibroblasts. It forms tendons and ligaments.

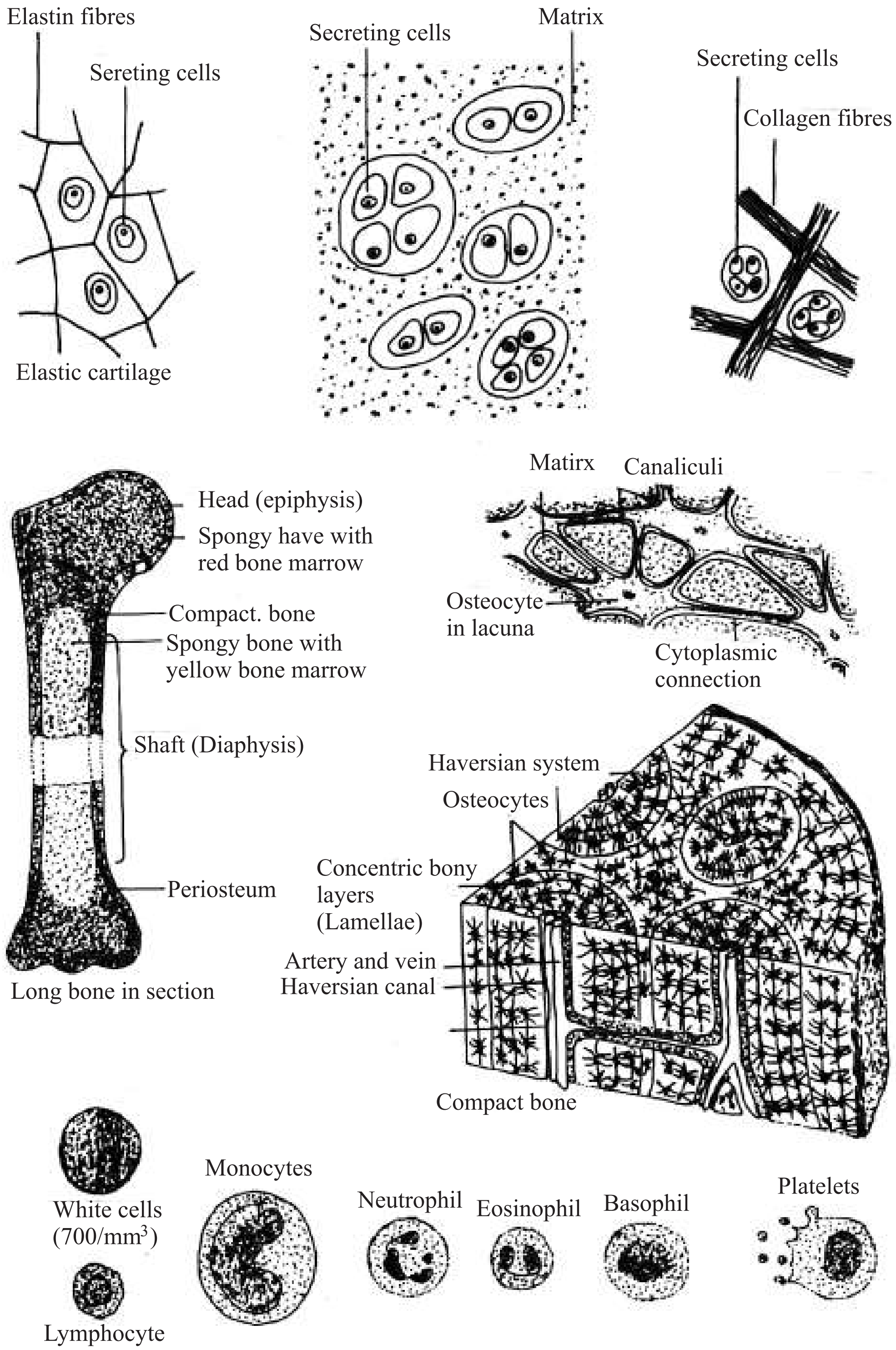


Fig. 5.8 Some representative types of connective tissues.

B. Supporting Connective Tissue

Supporting Connective Tissue

Cartilage	Bone
1. Matrix is composed of **chondrin.** The cells lie in the matrix singly or in groups of two or four surrounded by fluid-filled spaces. The cartilage may be elastic whose matrix has yellow fibres as in the pinna of the ear.	1. Matrix is composed of **ossein.** Matrix also contains salts of calcium, phosphorus and magnesium. Matrix in mammalian long bones (such as the thigh bone) is arranged in concentric rings. The **osteocyte**s (bone cells) lie on the lamellae (concentric rings in the matrix.) Osteocytes give out branched processes which join with those of the adjoining cells. Some bones have a central cavity which contains a tissue that produces blood cells. The substance contained in the bone cavity is called **bone marrow.**
2. The cartilage is a flexible and strong type of connective tissue in most of the vertebrates usually occurring as part of their endoskeleton.	2. Bones are of two types : **Spongy** and **Compact**. In a spongy bone, the bone cells are irregularly arranged. Such bones are found at the ends of the of long bones.
3. The cartilage can be calcified where calcium salts are deposited in the as in head of long bones.	3. In the compact bones, cells are arranged in circles or lamellae around a central canal- the Haversian canal.

C. Fluid connective tissue

Blood and Lymph are the two forms of fluid connective tissue.

Blood : It is a complex of blood cells and plasma. Plasma forms the matrix.

The blood cells are :

1. Red Blood Cells (Erythrocytes)-Transport O_2 and CO_2

2. White blood cells (Leucocytes)-Function in defence against bacteria, viruses and other invaders.

3. Platelets (Thrombocytes)-help in the clotting of blood.

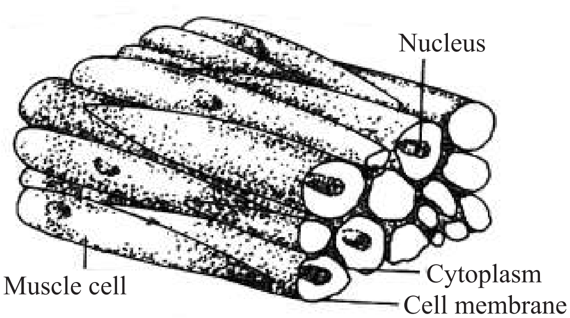
Plasma is the extracellular fluid matrix in the ground substance. It contains a large number of proteins such as Fibrinogen, Albumin, and Globulin to be transported to various parts of the animal body for various purposes.

5.3.3 Muscle tissue

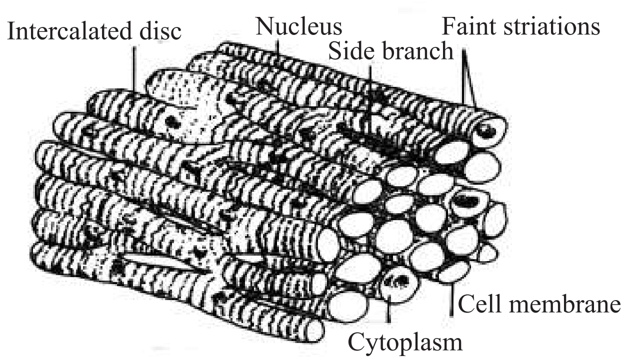
This is composed of long excitable cells containing parallel microfilaments of contractile proteins, as in actin, myosin, troponin and tropomysin. Because of its elongated shape, muscle cell is called a muscle fibre. The muscle fibres of vertebrates are of three different types (i) Striated (ii) Unstriated and (iii) Cardiac (Fig. 5.9) according to the shape and functions as mentioned in Table 5.5 and Fig. 5.9.

Table 5.5 Types of Muscle Fibres

Striated/Voluntary/Skeletal	Unstriated/ Involuntary	Cardiac
Location		
1. Attached to the skeleton like head, limbs, face etc.	In the walls of body organs like stomach, intestines.	Walls of heart.
Shape		
Elongated, cylindrical, unbranched fibres	Spindle shaped, tapering.	Elongated, cylindrical, branched.
Myofibrils so arranged in the cytoplasm, that there are striations seen.	No such striations seen as myofibrils are not uniformly arranged .	Striations (stripes) seen.
Sarcolemma		
Thin and tough membrane sarcolemma of the fibre (cell).	Thin cell membrane, no sarcolemma.	Thin
Nucleus		
Multi nucleated, Peripheral nuclei.	Uninucleated, centrally placed.	One nucleus in each unit, centrally placed.
Blood Supply		
Rich	Poor	Rich
Intercalate Discs		
Absent	Absent	Present
Voluntary (Contracts at will)	Involuntary	Involuntary



Smooth muscle fibres



Cardiac muscle fibres

Fig. 5.9 Types of Vertebrate Muscle Tissue

The muscle fibres have the following characteristics:

(i) Excitability, (respond to stimulus)
(ii) Extensibility, (stretch)
(iii) Contractility, (contract)
(iv) Elasticity, (move back to the original position)

INTEXT QUESTIONS 5.4

1. Name the different types of cells found in the different types of connective tissue.

   ....

2. Match the item in Column I with those in Column II, by writing the corresponding serial number within brackets:

	Column I			Column II
a.	Unstripped muscles	( )	(i)	multinucleate
b.	Myofibrils	( )	(ii)	run parallel to each other in a striped muscle
c.	Sarcolemma	( )	(iii)	cardiac muscles
d.	Striped muscle	( )	(iv)	outer tough membrane of a striped muscle fibre
e.	Branched myofibrils	( )	(v)	involuntary

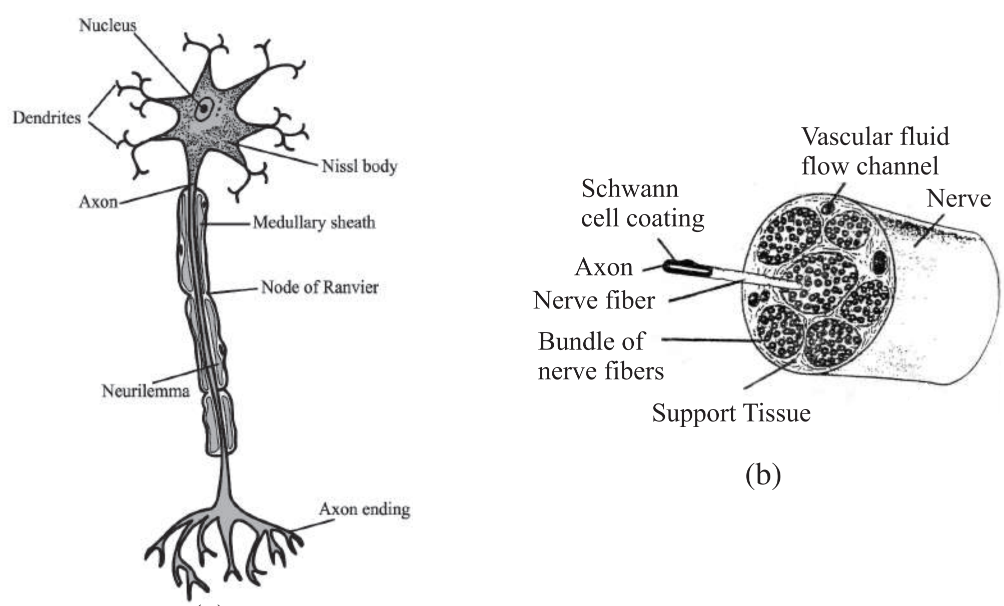
5.3.4 Nervous Tissues

Nervous tissues has two kinds of cells i.e. **neurons and neuroglia cells**

Neurons

Neuron is the functional unit of nervous tissue. Neurons are also called nerve cells. Nervous tissues constitute the brain, spinal cord, nerves and the sensory cells and sense organs.

A single neuron has a generalised appearance as shown in the Fig. 5.10.



(a)

Fig. 5.10 Nerve cell and nerve fibre.

Like any other cell of the body, the nerve cell or neuron has the main cell body called **cyton** from which project out a varying number of processes –one of which is usually very long. This long fibre is called the **axon**.

The smaller branching processes of the cyton are called the **dendrites** (GK dendros = tree). The cells bounded by plasma membrane, possess a nucleus and other organelles like mitochondria.

The cyton also contains dark granules called **Nissi** bodies. These are made of RNA and Protein.

Transmission of nerve impulse – The branching dendrites receive the stimulus and transmit it through the cyton to the axon, which finally transmits it through its variously branched ends into either a muscle (to order it to contract) or to a gland (to order it to secrete). The axon constitutes the nerve fibre. The nerve fibre may or may not be covered by an extra sheath called **medullary sheath** secreted by sheath cells. It is made of **myelin** a lipid like substance. Accordingly, the nerve fibre is termed **medullated** and **non-medullated.** The medullary sheath is not continuous and is broken at **nodes of Ranvier** (Fig. 5.10).

INTEXT QUESTIONS 5.5

1. What is the function of the nervous tissue?

   ....

2. What is the direction of the "flow of impulse" within a nerve cell from its dendrites to its axon end or from its axon end toward its dendrites?

   ....

3. What are the following parts in a nerve cell?
   (i) Cyton ....
   (ii) Dendrite ....
   (iii) Axon ....
   (iv) Medullary sheath ....
   (v) Node of Ranvier ....

5.4 LEVELS OF ORGANISATION – CELL TO ORGANISM

We started the lesson by talking about the smallest unit of life in any living organism i.e. the cell. The cell has a very complex system of its organelles, each organelle concerned with a particular task or activity, and each activity contributing to the total performance of the cell. Thus there is a division of labour at the cellular level. As evolution progressed and larger and larger organisms appeared with enormous number of cells in the body, it became necessary that the bodily functions are distributed among different groups of cells or tissues even among groups of tissues. Such higher and higher stages or groupings are known as the levels of organization. These levels are as follows:

(i) **Cellular Levels of Organization–** The organization of the activities by different organelles in a single cell. Example, white blood cells or a green cells of a leaf.

(ii) **Tissue Level–** The aggregates of cells of same origin and having same function, example, the surface epithelium of our skin or the dividing cells at the root cap of a plant.

(iii) **Tissue System–** Generally seen in plants where two or more different cell types combine to perform a particular activity. Example – Vascular tissue e.g. veins of a leaf, consisting of xylem and phloem, for transport of water and food materials.

(iv) **Organ Level–** A distinct recognizable part of the body, composed of a variety of tissues and performing one or more special functions which contribute to the well being of the organism. Example : Liver in animals and leaf in plants.

(v) **Organ System-** Combination of a set of organs all of which are usually devoted to one general function. Example : respiratory system (consisting of lungs, trachea, and diaphragm) in man or the shoot system (consisting of leaves, stem and branches) in a plant.

(vi) **Organism–** The complete individual made of different organ systems. Examples: man, monkey, or a mustard plant.

INTEXT QUESTIONS 5.6

1. Rearrange the following levels of organizations in their correct sequences:- tissue, cell, organ, organism, organ system.

   ....

2. Complete the following Table by giving one example of each of the following in an animal and plant.

Level of	**Examples**	
Organisation	**Animal**	**Plant**
Cell	....	....
Tissue	....	....
Organ	....	....
Organ system	....	....
Organism	....	....

WHAT YOU HAVE LEARNT

- A tissue is a group of cells which are essentially of the same kind and of the same origin and performing similar function.

- In plants there are, first of all two major categories of tissues- meristematic (dividing and undifferentiated) and permanent (specialized) tissues.
- Meristematic tissue is located at all growth points.
- Permanent tissue consists of the simple tissue (parenchyma, collenchyma and sclerenchyma) and complex tissue (xylem and phloem).
- The animal tissues consist of epithelium (closely packed cells usually on surfaces,) connective tissue which primarily support, connect or bind the body parts together (bones blood etc.), the contractile muscular tissue (different muscles,) and nervous tissue consisting of nerve cells adapted for conducting the message (brain cells,)
- The various tissues in both plants and animals are grouped together to form an organ. The different organs together form the organ system and the various organs systems together constitute the organism or the individual. Thus there are different levels of organization with increasing complexity and specialization from cell to organism.

TERMINAL EXERCISES

1. What is a tissue?
2. State one main structural characteristic and the special activity of the following tissue:

   meristem, sclerenchyma, xylem, phloem, epithelium, muscle, nervous tissue.
3. In what way do the following tissues differ from the one stated:-
   (i) Connective tissue from epithelial tissue
   (ii) Bone from blood
   (iii) Phloem from xylem
   (iv) Squamous epithelium from columnar epithelium
   (v) Tracheids from wood fibres
4. Name the different levels of organizations in animals (such as humans) giving one example of each.

ANSWERS TO INTEXT QUESTIONS

5.1 1. a group of cells with similar origin, structure and function

2. (i) Merisematic;
   (ii) Lateral meristem
   (iii) Simple
   (iv) Permanent

3. arising from same embryonic layer of cells

4. histology
5. composed of more than one type of cells all cooperating in performing common function

5.2 1.

S.No.	Tissue	Characteristics	Example of location
1.	Parenchyma	1. Round cells 2. Living	1. Root, stem and leaves
2.	Collenchyma	1. Polygonal cells with thickening at corners 2. Living	1. Petiole and Mid-rib of leaves
3.	Sclerenchyma	1. Elongated or irregular in shape 2. Dead and thick walled	1. Woody Stems

2. xylem, phloem

5.3 1. Epithelial, connective, muscular, nervous

2. a-iv, b-i, c-ii, e-iii

5.4 1.

Firbroblasts	-	areolar
Macrophages	-	areolar
Mast cells	-	areolar
Cartilage cells/chondrocyte	-	chondrocyte-cartilage
Bone cells/osteocyte	-	bone
Blood cells/WBC RBC	-	blood

2. a (v); (b) (ii); c (iv); d (i); e. (iii)

5.5 1. sensory

2. Dendrite to the axon

3. (i) cell-body (ii) thin processes of cyton (iii) sensory fibre (iv) medullary layer (v) interruptions in medullary sheath

5.6 1. Cell, tissue, organ, organ system, organism

2. refer to text subsection 5.4

MODULE - II

FORMS AND FUNCTIONS OF PLANTS AND ANIMALS

6

ROOT SYSTEM

The root system is the **descending** (growing downwards) portion of the plant axis. When a seed germinates, **radicle** is the first organ to come out of it. It elongates to form **primary** or the **tap root**. It gives off lateral branches (**secondary** and **tertiary** roots) and thus forms the root system. Its branches penetrate through large and deep areas in the soil and anchor the plant very firmly. It also plays another vital role of absorbing water and mineral salts from the soil and transporting them upwards. How is the root suited in structure to carry out such functions? You shall learn in this lesson.

OBJECTIVES

After studying this lesson, you will be able to :

- *define and identify root;*
- *distinguish between different types of root systems;*
- *describe and illustrate different regions of a root apex;*
- *describe various modifications and functions of roots;*
- *describe and distinguish between primary structure of dicot and monocot root;*
- *illustrate and explain the mode of secondary growth in a dicot root;*
- *describe the deep-seated (endogenous) origin of lateral roots.*

6.1. CHARACTERISTICS OF ROOTS

The main features of roots by which you can recognize them are :

- Non-green due to absence of chlorophyll;
- Not divided into nodes and internodes;
- Absence of leaves and buds;
- Positively geotropic **(grow towards gravity**);
- Positively hydrotropic (**grow towards water**);
- Negatively phototropic **(grow away from light**).

6.2. TYPES OF ROOT SYSTEMS

Root systems are mainly of two types:

(i) **Tap root system —** It is the root system that develops from the radicle and continues as the primary root (tap root) which gives off lateral roots. These provide very strong anchorage as they are able to reach very deep into the soil. It is the main root system of dicots e.g. gram, chinarose, neem (Fig. 6.1a).

(ii) **Fibrous root system** — In this root system, the primary root is short-lived. A cluster of slender, fiber-like roots arises from the base of the radicle and plumule which constitute the fibrous root system. They do not branch profusely, are shallow and spread horizontally, hence cannot provide strong anchorage. Fibrous root system is the main root system of monocots, e.g. maize, grasses, wheat (Fig. 6.1b).

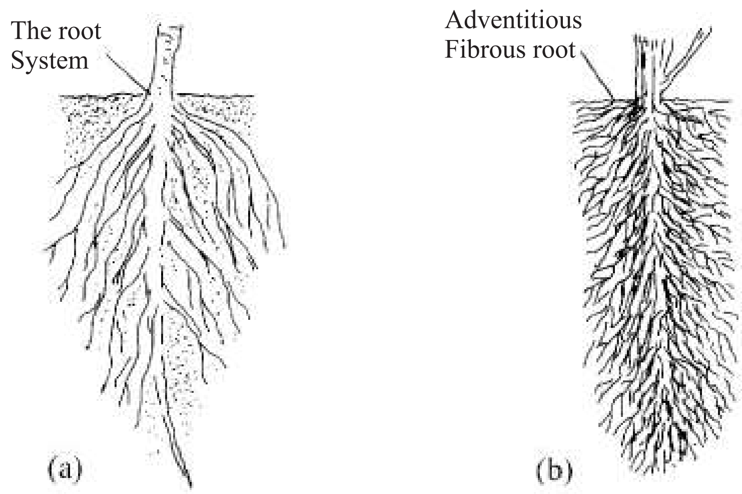


Fig. 6.1 Types of root systems (a) Tap root system (b) Fibrous root system

6.3 TYPES OF ROOTS

(i) **Tap root** – It is the **primary** and the main root that develops from the radicle, bears numerous branches and remains underground. It is usually found in dicots e.g. sunflower, mustard, carrot, mango (Fig. 6.1a).

(ii) **Adventitious root** – These are roots that develop from any part of the plant except the radicle. They may be aerial or underground (Fig. 6.1b). They may grow from node (money plant, bamboo), stem cutting (rose), tree branch (banyan) or stem base (fibrous roots in monocots).

INTEXT QUESTIONS 6.1

1. Name the plant organ which grows towards gravity and water but away from light?

   ....

2. From which part of the germinating seed does the root develop?

   ....

3. Which root system gives better anchorage and why?

   ....

4. Give two examples each of plants having fibrous and tap root system?

   ....

5. Mention three characters by which you can say that carrot which you eat is a root.

   ....

6.4 REGIONS OF ROOT

The apical region of roots of any root system shows the same zones or regions as can be seen in Fig.6.2a. A longitudinal section of root apex (Fig.6.2b) shows the following structures:

1. **Root cap region** — It is a thimble-like structure produced by meristematic (rapidly dividing) zone and protects the tender apex (apical meristem) from harsh soil particles. As the root grows further down in soil, root cap wears out but it is constantly renewed . In aquatic plants (*Pistia* and water hyacinth) root cap is like a loose thimble, called **root *pocket***.

2. **Region of meristematic cells** — is a small region of actively dividing cells called the apical meristem. It consists of :

   (i) Dermatogen (outermost layer whose cells mature into epiblema and root cap);

   (ii) Periblem (inner to dermatogen whose cells mature into cortex) and

   (iii) Plerome (central region whose cells mature into stele). In monocots, cap is formed by independent group of cells known as *Calyptrogen.*

3. **Region of elongation** — This is situated next to the meristematic region, wherein, the cells elongate and enlarge to make the root grow in length.

4. **Region of maturation** — This is next to the region of elongation, wherein the cells mature and differentiate into various tissues constituting (i) **Root hair** or **piliferous region** having unicellular hairs which absorb water and mineral salts from the soil and (ii) **Permanent region** which lies behind the root hair zone and is without hairs. It produces lateral roots, anchors the plant in soil and conducts water and minerals upwards.

In the maize root tip, Clowes (1958) discovered a central cup-like reservoir of inactive cells, lying between the root cap and the active meristematic region, called the **Quiescent Centre**. These cells become active whenever the previously active meristematic cells are damaged.

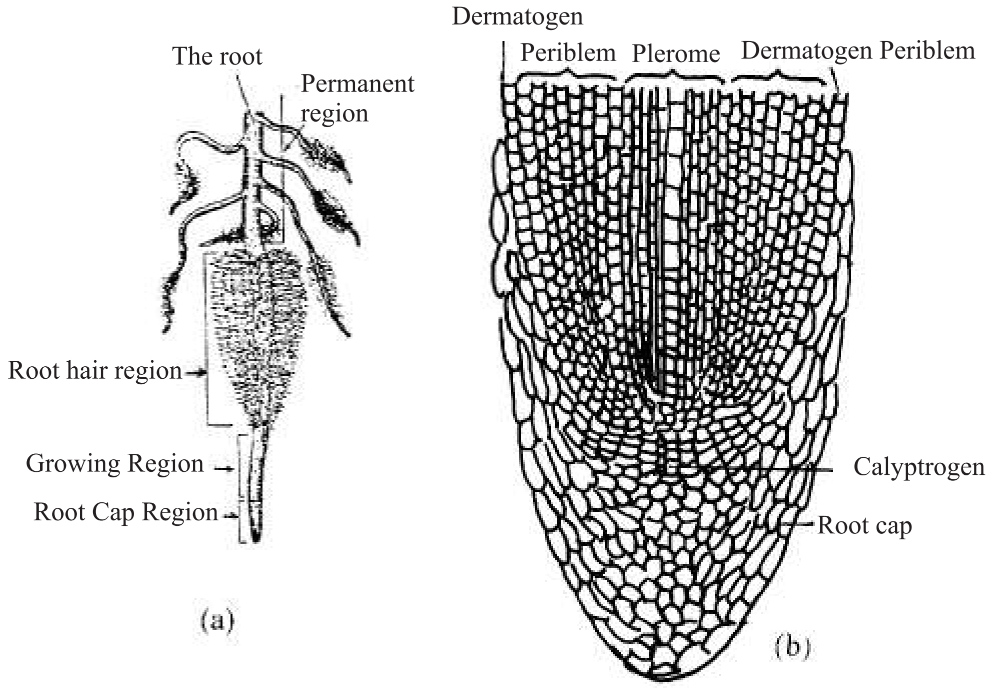


Fig. 6.2 (a) Apical part of a root showing four different regions; (b) LS through root apex

INTEXT QUESTIONS 6.2

1. Name the structure which protects the root apical meristem.

   ....

2. Give in a sequence, the various regions of root from its tip towards its base.

   ....

3. Into which tissues do dermatogen and plerome differentiate?

   ....

4. Which region of root absorbs water and mineral salts?

   ....

6.5 MODIFICATIONS OF ROOTS

Tap roots and adventitious roots can get modified into a variety of forms to perform various functions as can be seen from the following chart and Tables 6.1 and 6.2.

Modifications of roots

Tap root modification

(i) Conical root
(ii) Fusiform root
(iii) Napiform root
(iv) Tuberous root

Adventitious root modification

(i) Tuberous root
(ii) Fasciculated root
(iii) Nodulose roots
(iv) Moniliform roots
(v) Annulated roots
(vi) Assimilatory roots
(vii) Epiphytic roots
(viii) Pneumatophores/Respiratory roots
(ix) Sucking roots or haustoria
(x) Prop roots
(xi) Stilt roots
(xii) Climbing roots
(xiii) Clinging roots
(xiv) Floating roots

A. Tap root modifications

Tap roots become fleshy for storage of food (Table 6.1)

Table 6.1 – Tap root modifications for food storage

Type	Characters	Example
1. Conical (Fig. 6.3a)	Base is broad and tapers gradually towards apex	Carrot
2. Fusiform (Fig. 6.3b)	Swollen in middle, tapering towards both ends	Radish
3. Napiform (Fig. 6.3c)	Spherical at base tapering sharply towards the tip	Turnip
4. Tuberous (Fig. 6.3d)	Thick and fleshy with no definite shape	4 O'clock plant

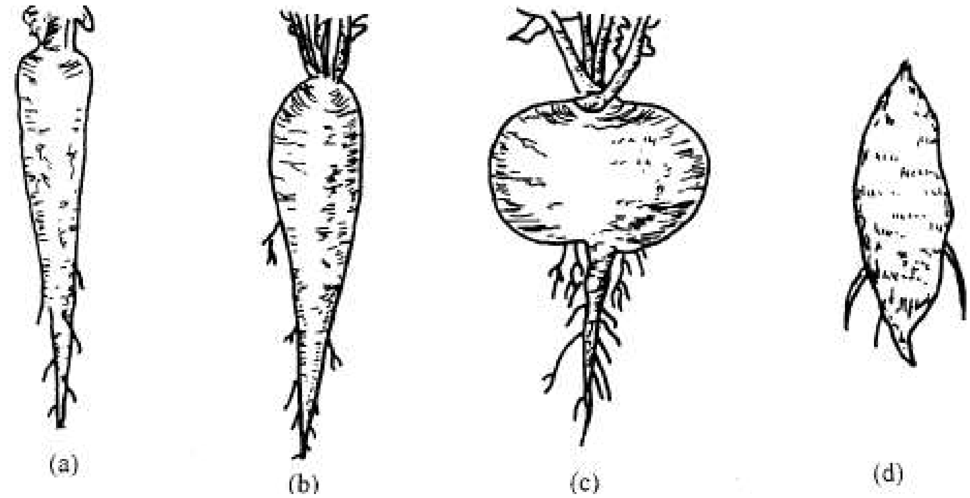


Fig.6.3 Modifications of tap root (a) Conical (carrot); (b) Fusiform (radish); (c) Napiform (turnip); (d) Tuberous (4 o'clock plant)

B. Adventitious root modifications

Adventitious roots get modified for various functions (Table 6.2)

Table 6.2 – Adventitious root modifications

Type	Characters	Example
(i) Modifications for food storage		
1. Tuberous (Fig 6.4a)	Swollen roots developing from nodes of prostrate stem	Sweet Potato
2. Fasciculated (Fig. 6.4b)	Swollen roots developing in a cluster from the stem	*Dahlia*
3. Nodulose (Fig. 6.4c)	Only apices of roots become swollen like single beads	Mango-ginger
4. Moniliform (Fig.6.4d)	Roots alternately swollen and constricted presenting a beaded or moniliform appearance	Grasses, Sedges
5. Annulated (Fig.6.4e)	Looks as if formed by a number of discs placed one above the other	Ipecac
(ii) Modification for photosynthesis		
Assimilatory roots (Fig6.4f)	Roots which when exposed to sun develop chlorophyll, turn green and manufacture food	*Tinospora* (aerial root), orchid

(iii) Modification for absorbing atmospheric moisture

Epiphytic roots (Fig.6.4f)	Aerial roots of epiphytes are greenish and covered with spongy tissue (Velamen) with which they absorb atmospheric moisture	orchids (*Vanda*)

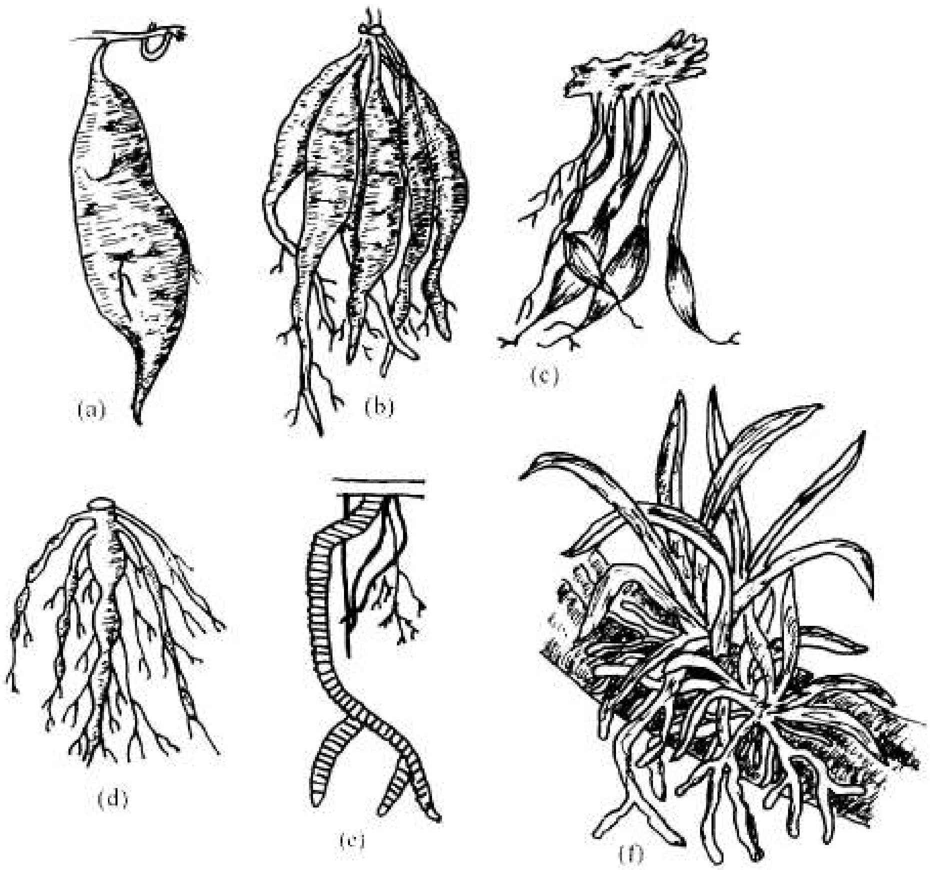


Fig. 6.4 Adventitious root modifications (a) Tuberous root (sweet potato); (b) Fasciculated roots (*Dahlia*); (c) Nodulose roots (mango ginger); (d) Moniliform roots (grass); (e) Annulated roots (*Ipecac*); (f) Assimilatory and epiphytic roots (orchid)

(iv) Modification for better gaseous exchange

Pneumatophores or respiratory roots (Fig.6.5a)	Some roots grow vertically up (negatively geotropic) into air. Exposed root tips possess minute pores through which roots respire, appear like conical spikes coming out of water	Mangroves (marshy plants) *Rhizophora*

(v) Modification for sucking nutrition from host

Sucking roots or haustoria (Fig.6.5 bi,bii)	Parasitic plants give out sucking roots or haustoria which penetrate living host plant and suck food from phloem.	*Cuscuta*

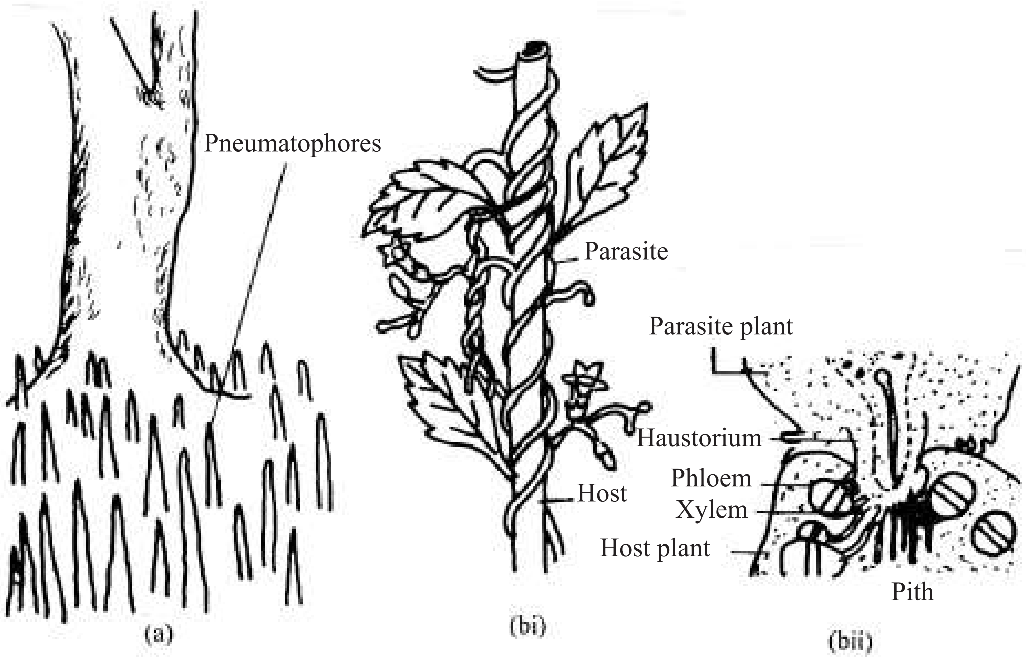


Fig. 6.5 Adventitious root modifications (a) Pneumatophores of a mangrove plant; (bi) *Cuscuta* (parasite) on host; (bii) Section showing sucking root or haustorium penetrating the host plant

(vi) Modification for strong support

1. **Prop roots** (Fig.6.6a)	Roots develop from tree branches, hang downwards and ultimately penetrate the ground, thus provide support to heavy branches	Banyan
2. **Stilt roots** (Fig.6.6b)	Extra roots developing from nodes near the base of stem, grow obliquely downwards and penetrate the soil giving strong anchorage	Sugarcane, Screwpine
3. **Climbing roots** (Fig.6.6c)	Weak climbers twine around and clasp the support with the help of climbing roots arising from their nodes	money plant betel
4. **Clinging roots** (Fig.6.4f)	Special clinging roots arise, enter the crevices of support and fix the epiphyte	epiphytes orchids

(vii) Modification for buoyancy and respiration

Floating roots (Fig.6.6d)	Spongy, floating roots filled with air, arise from nodes of some aquatic plants, and help in floating and respiration	*Jussiaea*

The great Banyan tree in Sibpur, Kolkata is more than 200 years old, forming a crown of over 404 meters in circumference and has about 1600 prop roots.

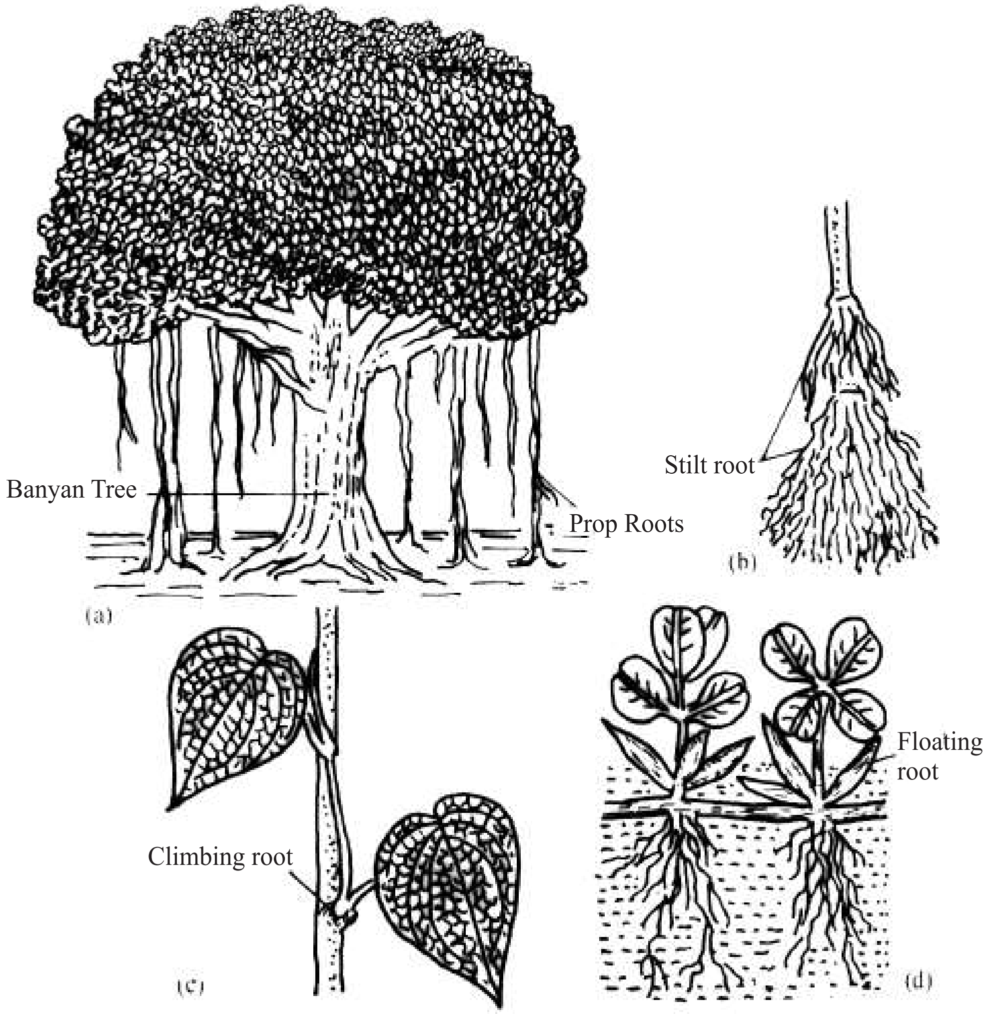


Fig.6.6 Adventitious root modifications – (a) Prop roots in banyan; (b) Stilt roots of sugarcane; (c) Climbing roots of betel; (d) Floating roots of *Jussiaea.*

6.6 FUNCTIONS OF ROOTS

(i) **Anchorage –** Roots anchor the plant firmly to the soil (mechanical function).

(ii) **Absorption –** Roots absorb water and mineral salts and conduct them upwards (physiological function).

(iii) **Special functions –** By undergoing modifications in their structure, roots perform special physiological functions like food storage, assimilation, absorption of atmospheric moisture, sucking food from host, better gaseous exchange and mechanical functions like floating (buoyancy), stronger anchorage and climbing.

INTEXT QUESTIONS 6.3

1. Are carrot, radish and turnip roots? Justify. Why have they become fleshy?

    ....

2. Name the type of root modification found in plants growing in marshy areas. What is their function?

    ....

3. What is the tissue in aerial roots of epiphytes known as which helps in absorption of moisture from the atmosphere?

    ....

4. What are the two main functions of roots?

    ....

5. Match the items of column A with those in column B

	A		B
(a)	Prop roots	(i)	Storage
(b)	Haustorium	(ii)	*Jussiaea*
(c)	Sweet potato	(iii)	Banyan
(d)	Floating roots	(iv)	*Cuscuta*

You would enjoy doing the following activity.

ACTIVITY 6.1

AIM : To study the characteristics of roots, type of root and modification of root in given plants.

Material required: Carrot, radish, turnip, sweet potato, sugarcane, money plant, uprooted grass, mustard/coriander plant.

Method: Observe the roots carefully and tabulate your answers to the following questions–

1. Is the root green?
2. Does it have nodes and internodes?
3. Are leaves present on the roots?
4. Are any buds present on the roots?
5. Is it a tap or adventitious root?
6. Name the type of modification, if present.

6.7 PRIMARY STRUCTURE OF ROOTS

A. DICOT ROOT (e.g. gram)

A thin transverse section of dicot root (Fig. 6.7) shows the following structures —

(i) **Epiblema :** Single, outermost layer of thin-walled cells. Some cells are prolonged to form unicellular root hairs. It protects and absorbs water.

(ii) **Cortex :** Large zone, many layered, cells thin-walled parenchymatous with intercellular spaces, stores food and water.

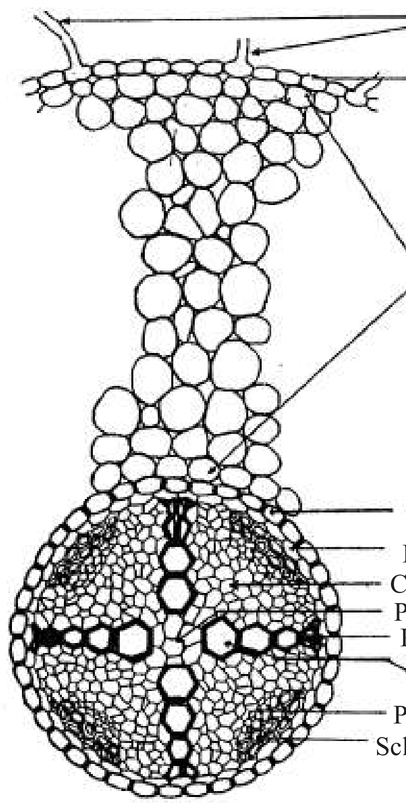


Fig. 6.7 A portion of dicot root in transverse section

(iii) **Endodermis :** Innermost layer of cortex, cells barrel-shaped, closely packed, that show band like thickenings on their radial walls called *casparian strips.* Some cells (opposite the protoxylem) which lack these strips are called *passage cells.* They help in the movement of water and dissolved salts from cortex directly into xylem.

Stele : All tissues inner to endodermis comprise stele.

(iv) **Pericycle :** Inner to endodermis lies a single layer of pericycle. It is the seat of origin of lateral roots and vascular cambium and cork cambium during secondary growth.

(v) **Vascular bundle :** It consists of xylem and phloem patches lying on alternate radii i.e., it is *radial*. Xylem is *exarch* where *protoxylem* (first formed , having narrow vessels and tracheids) lies towards the periphery and metaxylem (differentiates later, has wider vessels and tracheids) lies towards the center. Depending upon the number of xylem patches a root may be *diarch* (di-2 patches) to hexarch (hexa- 6 patches).

(vi) **Pith :** Sometimes the metaxylem of all xylem patches meet in the centre, and in that case pith is absent or is small and parenchymatous.

(vii) **Conjunctive parenchyma**: Parenchyma which separates xylem and phloem lying on different radii.

B. MONOCOT ROOT (e.g. maize root)

A thin transverse section of monocot root (Fig. 6.8) shows the following structures

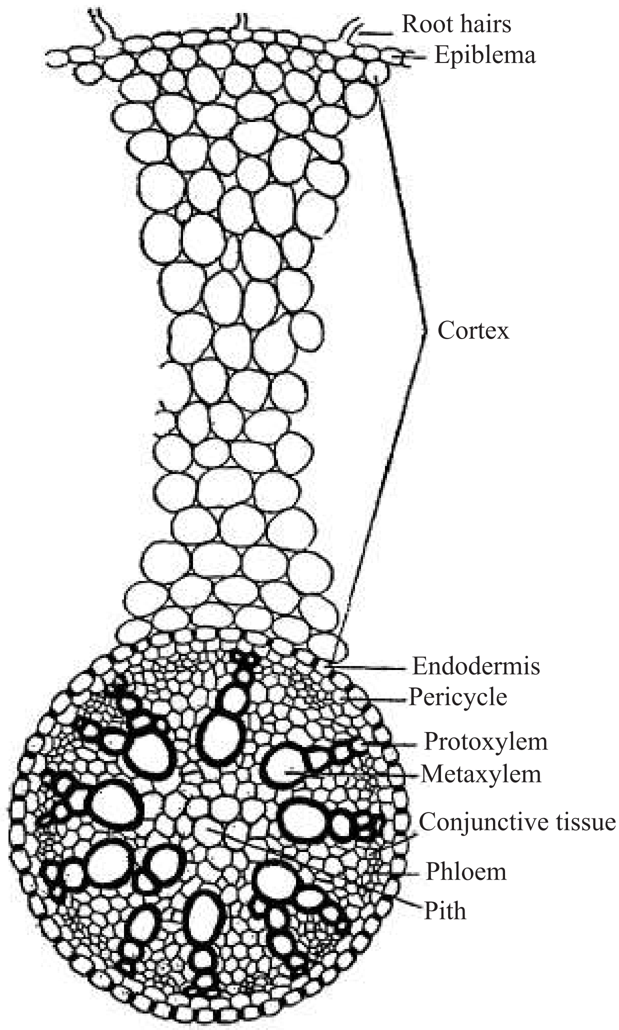


Fig. 6.8 A portion of monocot root in transverse section.

(i) **Epiblema :** Outermost, single layer of thin-walled, closely packed cells. Some cells are prolonged into unicellular root hairs.

(ii) **Cortex :** Large zone, multilayered, composed of parenchymatous cells with intercellular spaces, stores water and food material.

(iii) Endodermis : Innermost layer of cortex with characteristic *casparian strips* and *passage cells.*

Stele : All the tissues inner to endodermis constitute stele

(iv) Pericycle : Single layered, having polygonal thin walled cells. The lateral roots originate from this layer.

(v) Vascular bundle : It consists of many patches of xylem and phloem arranged radially. The xylem is exarch and polyarch (poly-many).

(vi) Pith : Is situated in the center, large, well developed, parenchymatous or sclerenchyamatous , stores food.

(vii) Conjunctive Parenchyma : Is located in between the strands of xylem and phloem.

The anatomical differences between Dicot and Monocot roots can be studied from Table 6.3

Table 6.3 Differences between a Dicot and Monocot root

Characters	Dicot root	Monocot root
1.Number of vascular bundles	2-6 (*di-hexarch*)	Many (*polyarch*)
2. Pericycle	Seat of origin of lateral roots, vascular and cork cambium	Seat of origin of lateral roots only
3. Cambium	Present	Absent
4. Secondary growth	Present	Absent
5. Pith	Very small or absent	Large

6.8 ORIGIN OF LATERAL ROOTS

- The origin of lateral roots is endogenous i.e. from a deeper layers.
- The seat of its origin is pericycle where cells opposite the protoxylem divide and form a hump in the endodermis (Fig. 6.9 a-b).
- The hump penetrates into the cortex (Fig. 6.9 c-d), and emerges as a lateral branch.

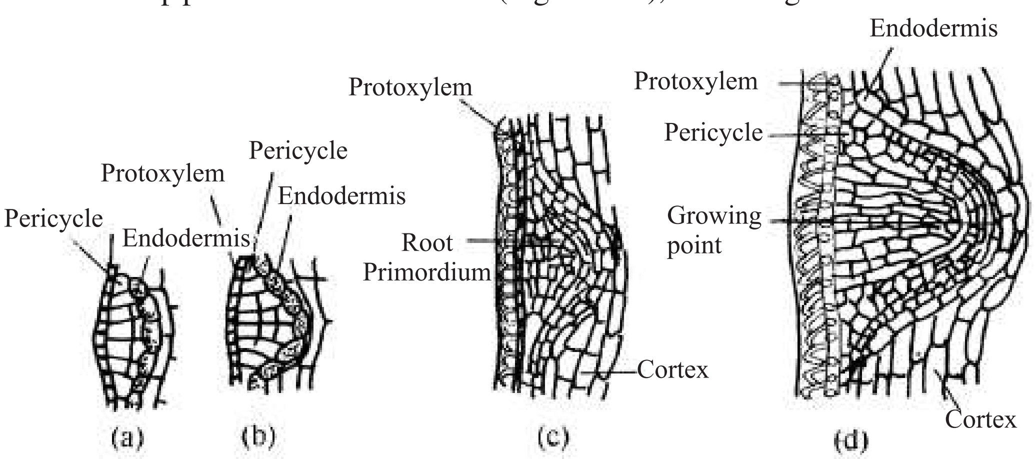


Fig. 6.9 a-d Formation of lateral root (Endogenous origin)- Stages as seen in longitudinal sections of root.

- Later, the hump differentiates into 3 regions of the root apex i.e. *dermatogen, periblem* and *plerome*.
- Finally the lateral root comes out.
- The number of lateral roots corresponds to the number of xylem bundles.

INTEXT QUESTIONS 6.4

1. Name the condition where protoxylem lies towards the periphery and metaxylem towards centre.

   ....

2. Why is it difficult to pluck lateral roots from carrot?

   ....

3. What is the seat of origin of lateral roots and cambium?

   ....

4. Name the endodermal cells which do not possess casparian strips and help in the movement of water?

   ....

5. Give two major differences between a dicot and monocot root.

   ....

6. If the number of xylem bundles is 4 (tetrarch), how many lateral roots will be formed in that area?

   ....

6.9 SECONDARY GROWTH IN DICOT ROOTS

The roots grow in length with the help of apical meristem. It is called **primary growth**. Apart from primary growth, roots grow in width i.e., they increase in girth. This increase is called **secondary growth**. It is found only in dicot roots.

The tissues involved in secondary growth are *lateral meristems* i.e., *vascular cambium* and *cork cambium*.

It is important to remember that the vascular cambium and cork cambium are secondary in origin and arise from the pericycle.

Secondary growth is as follows-

- Pericycle cells outside the protoxylem divide to form a strip of cambium (Fig 6.10b).
- Another strip of vascular cambium appears in the conjunctive tissue on the inner side of phloem bundle (Fig. 6.10 a, b).

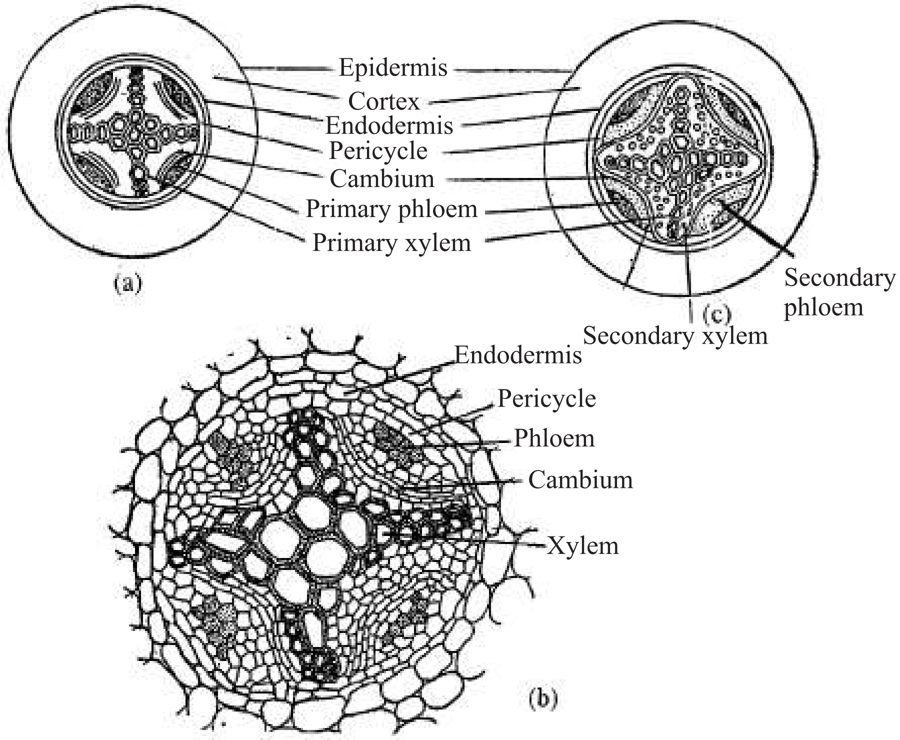


Fig. 6.10 T. S. Dicot Root – (a) and (c) (diagrammatic) – Early stages in secondary growth (b) Stele enlarged (cellular)

- These two vascular cambium strips join laterally to form a ring which may initially be wavy (Fig. 6.10c) but later becomes circular due to over production of secondary xylem tissue inner to primary phloem (Fig. 6.11a).
- Cambium cells consist of brick shaped cells which divide and add cells on its either side i.e. towards periphery and towards center. Those added towards the periphery differentiate into *secondary phloem* and the ones formed towards the center differentiate into *secondary xylem*.

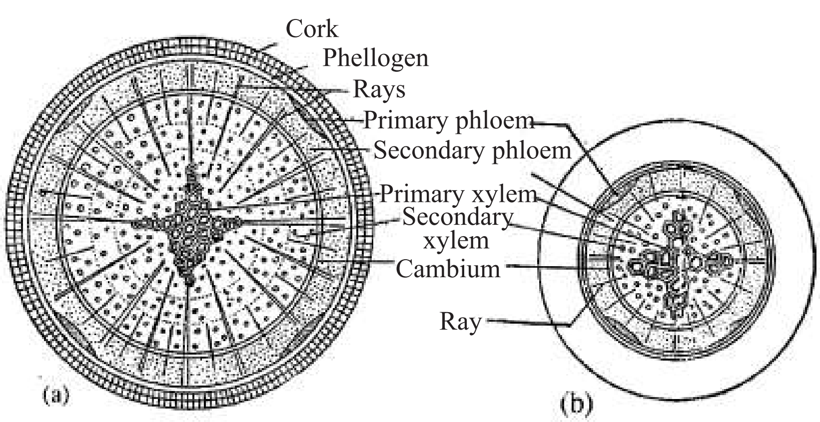


Fig. 6.11 T. S. Dicot root (Diagrammatic) a,b. Later stages in secondary growth.

- Secondary tissue formed outer to the protoxylem bundle differentiates into prominent *primary medullary ray* thus, protoxylem does not get crushed (Fig. 6.11a).

- Later, cork cambium (**Phellogen**) also differentiates in the pericycle (Fig. 6.11b).
- The cork cambium divides and gives rise to cork (**Phellem**) towards outside and secondary cortex (**Phelloderm**) towards inside.
- All the three layers i.e. *Phellogen*, *Phellem* and *Phelloderm* together form the **Periderm** of the root and have protective function.
- Finally all the primary tissues outside the developing cork (i.e. endodermis, cortex and epiblema) are sloughed off.

INTEXT QUESTIONS 6.5

1. Name the lateral meristems found in old dicot roots? What is their function?

   ....

2. From which layer does the vascular cambium originate?

   ....

3. What is the conjunctive tissue?

   ....

4. Define periderm. What role does it play in a root?

   ....

5. Do primary roots of dicot plant possess cambium?

   ....

WHAT YOU HAVE LEARNT

- The radicle elongates to form the primary or tap root.
- Roots are non-green due to the absence of chlorophyll, lack nodes and internodes, leaves and buds.
- These grow towards gravity (positively geotropic) and water (positively hydrotropic) but grow away from light (negatively phototropic).
- Root systems are of two types – Tap root system (in dicots) and Fibrous root system (in monocots).
- Tap root develops from the radicle while adventitious roots develop from any part of the plant except the radicle.
- Apical region of root has 4 regions namely root cap region, region of meristematic cells, region of elongation and region of maturation.
- Main functions of root are anchorage and absorption of water and ninerals.
- In some plants, roots undergo modifications in their structure to perform special physiological functions (food storage, assimilation, respiration, absorption of

atmospheric moisture and sucking nutrients from host plants) and mechanical functions (stronger anchorage, climbing, buoyancy).

- Internal structure of root shows unicellular hairs, single-layered epiblema, large multilayered cortex, prominent one-layered endodermis with casparian strips and some passage cells. The stele consists of single layered pericycle, radial vascular bundles, exarch xylem and pith.
- Dicot root differs from monocot root in having lesser number of vascular bundles (2-6), very small pith and presence of cambium (secondarily formed).
- Origin of lateral roots is endogenous.
- Number of lateral roots corresponds to the number of xylem bundles.
- Lateral roots , vascular cambium and cork cambium originate from pericycle in dicot roots.
- Due to the presence of cambium dicot roots undergo secondary growth.
- Because of apical meristem roots undergo primary growth and increase in length.
- The dicot roots grow in girth by undergoing secondary growth due to the involvement of lateral meristems (vascular cambium and cork cambium).
- Vascular cambium originates as a strip in pericycle cells lying outside the protoxylem and in conjunctive tissue inner to each phloem bundle.
- Initially the cambium is wavy but later becomes circular.
- The vascular cambium gives rise to secondary phloem towards periphery and secondary xylem towards centre.
- Primary medullary rays differentiate outer to protoxylem.
- Cork cambium (phellogen) also differentiates in the pericycle and gives rise to cork (phellem) towards periphery and secondary cortex (phelloderm) towards inside.
- Phellem, Phellogen and Phelloderm together form the periderm which is protective in function.

TERMINAL EXERCISES

1. Describe any four adventitious root modifications.
2. Give one point of difference between:
   (i) Tap root and adventitious root
   (ii) Prop and stilt roots
   (iii) Protoxylem and metaxylem
   (iv) Phelloderm and periderm
   (v) Vascular cambium and cork cambium

3. Describe the various types of edible roots which you have studied.
4. What are pneumatophores? Where are they found and what is their function?
5. Describe secondary growth in dicot roots.
6. Why is it difficult to break the lateral roots from the main root?
7. What is periderm ? How is it formed?
8. Give four characteristics by which you can identify a root.
9. What is the function of region of maturation?
10. Give one example each of plants having pneumatophores, climbing roots, floating roots and haustoria.
11. A cross section of plant organ when seen under the microscope shows—radial vascular bundles, exarch xylem, single layered pericycle and unicellular hair. What organ is it?
12. Name the meristematic tissues which help the dicot roots to grow in length and girth.
13. Name the modification of root which supports tree branches.
14. If a transverse section of root shows polyarch condition of vascular bundles, large pith and no cambium, which type of root will it be?
15. Differentiate between stele of dicot and monocot root.

ANSWERS TO INTEXT QUESTIONS

6.1
1. Root
2. Radicle
3. Tap root system gives better anchorage because it is very deep seated, and branches profusely which ramify through large areas in soil.
4. Fibrous root system in maize, sugarcane and tap root system in sunflower, mango.
5. Absence of nodes and internodes, buds and leaves.

6.2
1. Root cap
2. Root cap region, region of meristematic cells, region of elongation, region of maturation.
3. Dermatogen differentiates into epiblema and cap, whereas plerome differentiates into stele.
4. Root hair or piliferous region /Region of maturation.

6.3
1. Yes, they are roots since they do not have nodes and internodes, buds or leaves; they become fleshy for storage of food.

2. Pneumatophore, respiration
3. Velamen
4. Anchorage and absorption of water and mineral salts
5. (a) – (iii); (b) – (iv); (c) – (i); (d) – (ii)

6.4

1. Exarch
2. Because these arise from the inner layer i.e.pericycle/ endogenous origin
3. Pericycle
4. Passage cells
5. In dicot root 2-6 vascular bundles and cambium is present but in monocot root many vascular bundles are present while cambium is absent.
6. Four

6.5

1. Vascular cambium and cork cambium; Vascular cambium forms secondary vascular tissue while cork cambium forms cork and secondary cortex.
2. Pericycle and conjunctive tissue.
3. Conjunctive tissue is the parenchyma tissue lying between xylem and phloem patches that are arranged radially in roots.
4. Periderm is a tissue which is formed during secondary growth and consists of phellem, phellogen and phelloderm; protection.
5. No, cambium is absent in the primary dicot root.

7

SHOOT SYSTEM

Shoot system is an aerial and erect part of plant body which grows upwards. It is usually above the soil and develops from **plumule** of the embryo. It consists of stem, branches, leaves, flowers, fruits and seeds. In this lesson you will study about the structure, types, modifications and functions of stem, leaf, flower and fruit.

OBJECTIVES

After studying this lesson, you will be able to -

- *list the general characteristics of stems and distinguish them from those of root;*
- *describe the shoot apex and explain the origin of lateral branches;*
- *explain the types, modifications and functions of stem;*
- *describe the primary structure of dicot and monocot stems with the help of diagrams and distinguish between them;*
- *describe secondary growth in a dicot stem;*
- *define wood and its types;*
- *describe the general morphology of leaf and explain phyllotaxy;*
- *describe and illustrate various modifications of leaf highlighting their functions;*
- *describe and compare the internal structure of a typical dicot and monocot leaf;*
- *define inflorescence and describe it's major types;*
- *define a flower and describe it's structure and functions;*
- *define placentation and describe different kinds of placentation;*
- *define and explain the structure of fruit and enlist it's major categories with examples.*

7.1 STEM

7.1.1 Characteristics of Stem

(i) Arises as a prolongation of plumule (one end of an embryo).

(ii) Grows and bends towards light **(positively phototropic)** and away from gravity **(negatively geotropic).**

(iii) Divided into **nodes** (point of attachment of leaf) and **internodes** (regions between two nodes).

(iv) Bears leaves, branches and flowers on nodes.

(v) Bears **vegetative buds** which could be terminal (apical bud) for plant to grow upwards or axillary (bud in the axil of leaf) which give rise to lateral branches.

(vi) Bears **floral buds** (terminal or axillary) that grow into flowers.

7.1.2 Differences between stem and root

Table 7.1 gives the difference in morphology between stem and root.

Table 7.1 Morphological differences between stem and root

Stem	Root
1. Develops from plumule.	Develops from radicle.
2. Young stem is green because of chlorophyll.	Non green because chlorophyll is absent.
3. Divided into nodes and internodes.	Not divided into nodes and internodes.
4. Bears leaves, vegetative and floral buds.	Absent.
5. No cap present at the apex.	Root cap is present at the apex.
6. Positively phototropic and negatively geotropic.	Negatively phototropic but positively geotropic.
7. Origin of lateral branches is exogenous (originating from outer layers i.e. endodermis).	Origin of lateral roots is endogenous (originating from inner layers i.e. pericycle).

INTEXT QUESTIONS 7.1

1. Name the part of plant which bears nodes, leaves and flowers.

   ....

2. Lateral branch develops from which bud?

   ....

3. Why is it difficult to break lateral roots and not lateral branches on stem?

   ....

4. Roots are negatively phototropic and positively geotropic, what pattern of growth does the stem show?

   ....

7.1.3 The Shoot Apex

Shoot apex is the terminal, dome shaped part of shoot, formed of meristem called **apical shoot meristem** responsible for the development and differentiation of primary permanent tissue and mainly causes growth in length. It is divided into two regions - **Tunica** and **Corpus** (Fig. 7.1)

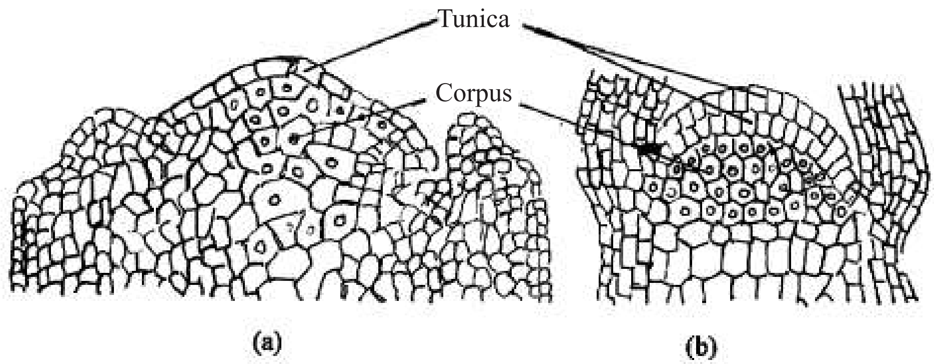


Fig.7.1 a-b L.S. of shoot apex to show tunica and corpus

(i) **Tunica** (covering)- An outer zone of shoot apex, 1-3 layers in thickness. It gives rise to epidermis and is responsible for surface growth, and its cells divide only anticlinally.

(ii) **Corpus** (body)- Inner multi-layered zone of cells which divide in all directions. They finally give rise to *procambium* (forms vascular tissue) and *ground meristem* (forms ground tissue). These cells also form leaf primordia (a newly developing leaf).

7.1.4 Origin of Lateral branches

Branches arise from axillary buds present in the axil of leaves (Fig 7.1). Each axillary bud is a small, compact, underdeveloped shoot covered with a large number of overlapping leaf primordia. Internodes of this bud enlarge and develop into a branch. Therefore the development of branches is **exogenous** (exo = outside).

INTEXT QUESTIONS 7.2

1. Name the meristematic zone in which cells divide in all planes.

   ....

2. From which meristematic layer does the vascular tissue develops?

   ....

3. Which structure gives rise to a lateral branch? Name the type of its origin.

   ....

4. What is the structure known as which covers the apical meristem of root but is absent in stem?

   ....

7.1.5 Types of stem

The stem may be (i) **aerial** (erect, rigid, strong and upright as in herbs, shrubs and trees) (ii) **sub aerial** (weak, unable to stay upright and trail on ground as **creepers** or climb up as **climbers)** or (iii) **underground** (buried in soil and produces aerial branches under favourable conditions only).

7.1.6 Modifications of Stem

Stems are variously modified into underground, sub aerial and aerial stems for performing functions like manufacturing and storing food, perennation (overcoming unfavourable climatic conditions), providing mechanical support and protection and for propagating vegetatively

Types of stem and modifications

Underground	Subaerial	Aerial
Rhizome	Runner	Tendrils
Corm	Stolon	Thorns
Bulb	Offset	Phylloclade
Tuber	Sucker	Cladode

Underground modified stems – Since underground, they may seem like roots but you can recognise them as stem due to the presence of :

(i) Nodes and internodes, (ii) scaly non green leaves, (iii) buds.

They serve two functions -

- Act as perennating structures by remaining leafless and dormant in winter but giving off aerial shoots under favourable conditions (next season)
- Store food and become thick and fleshy.

The various types of underground modified stems are given in Table 7.2.

Table 7.2 Underground Modified Stems

Type	Characters	Examples
1. **Rhizome** (Fig.7.2a)	Thick, fleshy, flattened horizontally growing stem near the soil surface. Bears scale leaves on nodes, terminal and axillary buds, adventitious roots.	Ginger (Adrak) Turmeric ('haldi')
2. **Corm** (Fig.7.2b)	Fleshy, spherical stem with flattened base, grows vertically; bears many scale leaves, distinct nodes and internodes, buds and adventitious roots.	Saffron ('kesar') Yam ('zimikand') Gladiolus

3. **Bulb** (Fig.7.2ci,ii)	Reduced, flattened discoid stem with crowded nodes bearing overlapping fleshy (inner) and dry (outer) scale leaves. Terminal bud (in centre) forms foliage (green) leaves. Adventitious roots grow from discoid base.	Onion
4. **Tuber** (Fig.7.2d)	Swollen tips of underground lateral branches of stem, store food as starch, bear "eyes". Each eye is a node which bears bud and scar of scale leaves.	Potato

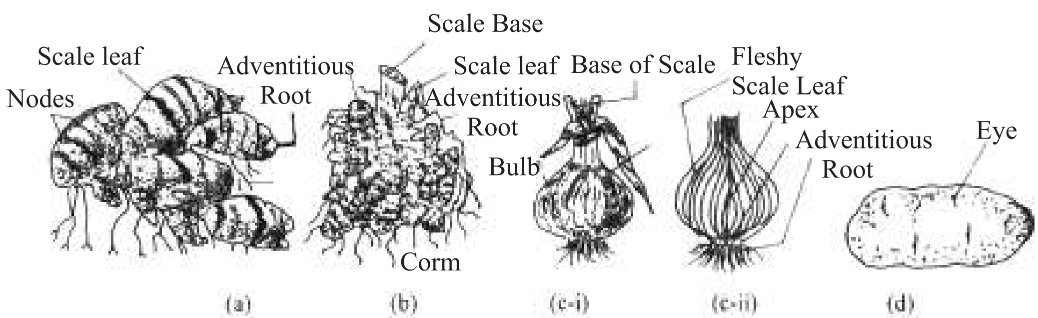


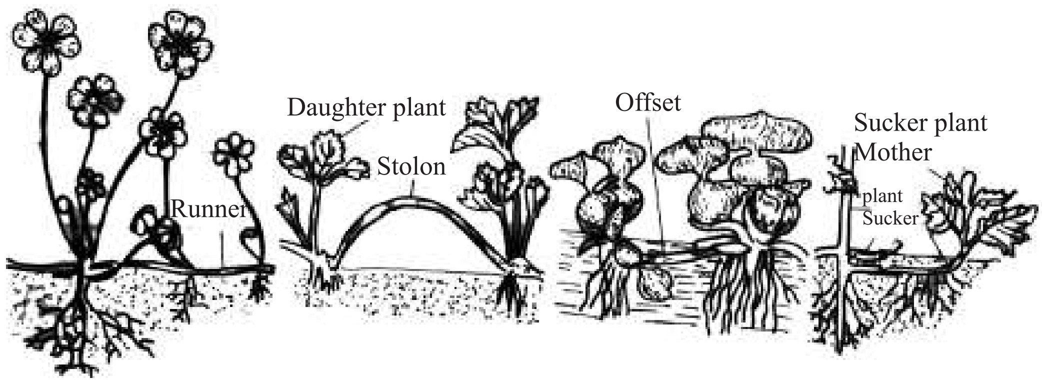
Fig.7.2 Underground modifications of stem – **(a)** Rhizome of Ginger, **(b)** Corm of Yam, **(ci)** Bulb of Onion **(cii)** V.S. bulb, **(d)** Tuber of potato.

Sub aerial modifications Of stem- Stems are weak, therefore lie prostrate on the ground or may get partially buried in the top soil. The plants bearing such stems are called creepers. Their stems serve the function of vegetative propagation.

Table 7.3 Modifications of Sub aerial stems

Type	Characters	Examples
1. **Runner** (Fig.7.3a)	Long, weak, slender branch with long internodes. Runs horizontally on soil surface giving off adventitious roots at nodes	Grass, *Oxalis*
2. **Stolon** (Fig. 7.3b)	Weak lateral branch which grows upwards then arches down to meet the soil, strike roots and produce daughter plants.	Mint ('Pudina'), Jasmine
3. **Offset** (Fig.7.3c)	Like runner but thicker and shorter, grow for a short distance then produce cluster (rosette) of leaves above and adventitious roots below; generally in aquatic plants	Water hyacinth, water lettuce
4. **Sucker** (Fig.7.3d)	Underground runner which grows horizontally for a distance under soil then emerges obliquely upwards, strikes roots and forms daughter plants	Chrysanthemum

Notes



(a) (b) (c) (d)

Fig.7.3 Sub-aerial modification of stem : (a) Runner; (b) Stolon; (c) Offset; (d) Sucker.

Aerial stem modifications - Whole stem or its part (axillary or terminal bud) gets modified to perform definite functions. You can recognise them as stems by following features :

(i) Arise in the axil of leaf (ii) Bear nodes and internodes (iii) may bear leaves, buds, flowers.

Table 7.4 Types of aerial stem modifications

Type	Characters	Examples
1. Stem tendrils (Fig.7.4a)	Thread like, spirally coiled, leafless structures (tendrils) which twine around neighbouring objects and help weak plants to climb	Grape vine
2. **Thorns** (Fig.7.4b)	Straight, pointed, hard structures; modifications of axillary *(Citrus)* or terminal *(Carissa)* bud; act as defence organs or as climbing organs	*Citrus*, Duranta *Carissa* *('Karonda')*
3. Phylloclade (Fig.7.4c)	Green, flattened or cylindrical fleshy stem, with nodes and internodes; bears spines (modified leaves to check evaporation); carries out photosynthesis, stores water. Found in plants growing in dry regions	*Opuntia* (prickly pear)
4. Cladode (Fig.7.4 di,dii)	It is a phylloclade with limited growth i.e. with only one or two internodes; help in photosynthesis	*Asparagus*

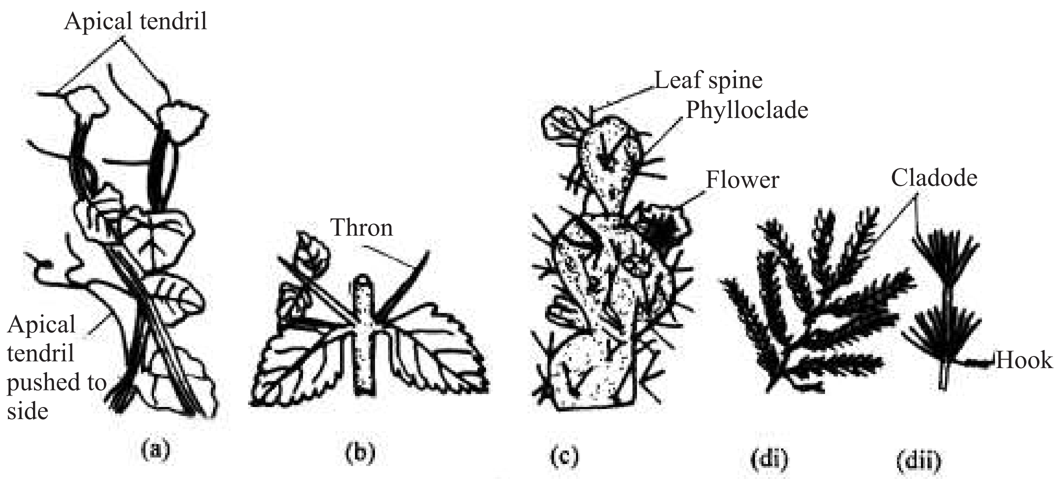


Fig. 7.4 Aerial stem modifications— (a) Stem Tendril; (b) Thorns; (c) Phylloclade of *Opunlia;* di, dii-Cladode *of Asparagus* and part enlarged

INTEXT QUESTIONS 7.3

1. What are plants with weak stem trailing on the ground known as?

   ....

2. Name the modification to which Runner, Stolon, Offset and Sucker belong.

   ....

3. What is a phylloclade with one or two internodes called?

   ....

4. 'Haldi' and onion belong to which category of stem modification respectively?

   ....

5. Match the items of column A with those of column B

A		B	
(a)	Tendril	(i)	Protection
(b)	Sucker	(ii)	Perennation
(c)	Thorns	(iii)	Reproduction
(d)	Bulb	(iv)	Photosynthesis
(e)	Phylloclade	(v)	Climbing

7.1.7 Functions of stem

A. Primary functions

1. **Support and orient the leaves** in a manner that they are exposed to maximum sunlight and for efficient gaseous exchange during photosynthesis and respiration.

2. **Conduct water and minerals** from roots to leaves and manufactured **food** from leaves to different parts of the plant.
3. **Bear flowers and fruits**

B. Secondary Functions

1. **Storage -** Stems store food and water in some plants e.g. potato
2. **Perennation -** The underground stems help tide over the unfavourable growing periods e.g. ginger.
3. **Vegetative propagation -** Stem can be a means of vegetative propagation e.g. rose, and sugarcane.
4. **Photosynthesis-** in certain plants like xerophytes (desert plants) where leaves are reduced, the stem takes up the function of photosynthesis. These stems possess chlorophyll e.g. *Opuntia*
5. **Protection-** In some plants the axillary bud modifies into thorn and protects the plants from grazing animals e.g. citrus, *Duranta.*
6. **Climbing -** Tendrils or hooks are modified branches or buds. They coil around the support and help the plant to climb e.g. grape vine

INTEXT QUESTIONS 7.4

1. Give one primary function of stem.

   ....

2. How does sugarcane plant multiply?

   ....

3. Match the following in column A with column B

A		B	
(a)	*Opuntia*	(i)	Conduction
(b)	*Duranta*	(ii)	Storage of food
(c)	Ginger	(iii)	Photosynthesis
(d)	Potato	(iv)	Perennation
(e)	Stem	(v)	Protection

7.1.8 Internal (anatomical) structure of stem

The internal structure can be studied if you cut the stem transversely and observe it under a compound microscope.

A. Internal structure of dicot stem (e.g., Sunflower)

In a transverse section of a young dicot stem you will see the following structures (Fig. 7.5a and 7.5b)

1. **Epidermis -** Outermost single layered, covered with cuticle, bears multicellular hairs, protective function.

2. **Cortex** - Inner to epidermis, there are three regions.

- **Hypodermis -** 4-6 layers of collenchyma for mechanical support.
- **Middle layers -** Few layers of parenchyma.
- **Endodermis -** Innermost layer of cortex, has barrel shaped cells. As cells contain starch grains, it is also called **starch sheath.**

3. **Stele -** All the tissues lying internal to endodermis constitute the stele.

   (i) **Pericycle -** Inner to endodermis, multilayered, parenchymatous with patches of sclerenchyma.

   (ii) **Vascular bundles -** Arranged in a ring (Fig. 7.5a); each vascular bundle is **(a)conjoint** (xylem and phloem together in one bundle), (b) **collateral** (xylem and phloem on the same radius with phloem towards the periphery) and (c) open (cambium present in between xylem and phloem). Xylem is **endarch** (protoxylem towards centre and metaxylem towards periphery).

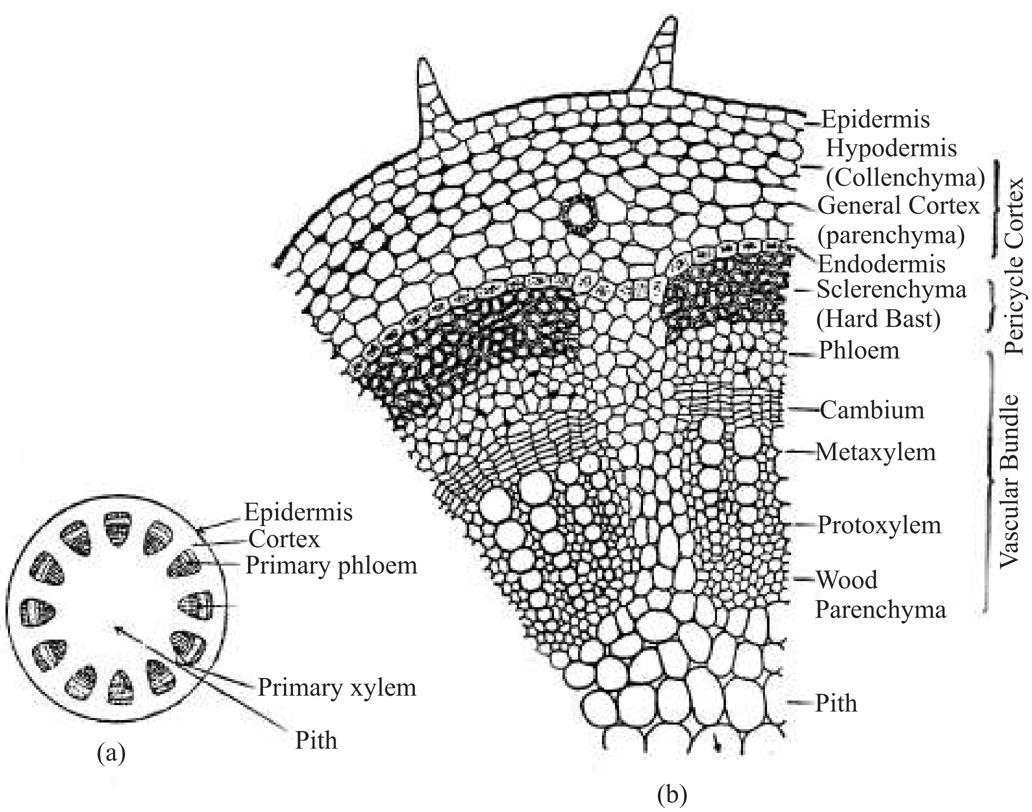


Fig. 7.5 T.S. Dicot stem. a-Diagrammatic b-A portion enlarged.

   (iii) **Medullary rays -** Narrow regions of parenchymatous cells in between the vascular bundles.

   (iv) **Pith -** The central parenchymatous zone with intercellular spaces.

B. Internal structure of monocot stem (e.g., maize)

A transverse section of monocot stem reveals the following structures (7.6a and b)

1. **Epidermis -** Single layered, covered with cuticle, stem hairs absent.
2. **Ground tissue-** A mass of parenchymatous tissue. Only a few peripheral layers below epidermis are sclerenchymatous called **hypodermis.**
    1. **Vascular bundle-** Numerous, scattered in the ground tissue each enclosed by sclerenchymatous bundle sheath. Each bundle is **(a) collateral** and **(b) closed** (no cambium strip between xylem and phloem) with **(c) endarch** xylem. Xylem occurs in the form of letter 'Y 'and innermost protoxylem disintegrates to form a water cavity.

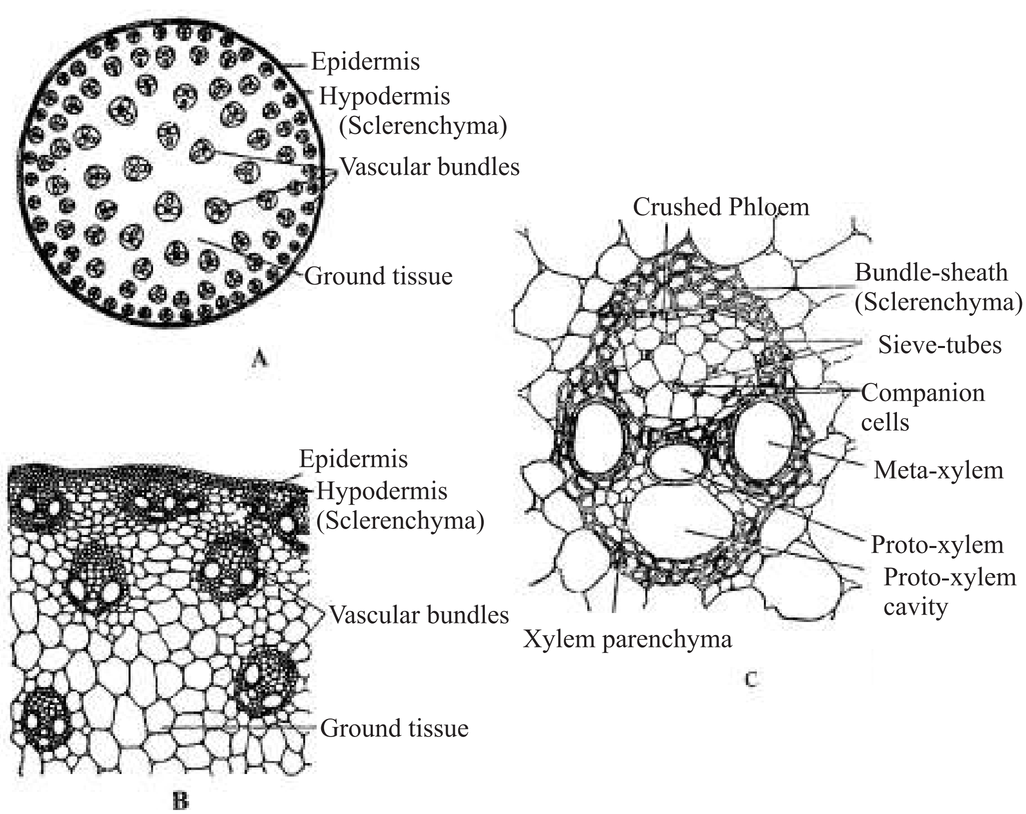


Fig. 7.6 T.S. Monocot stem. (a) Diagrammatic (b) A portion enlarged (c) A vascular bundle magnified.

Anatomical differences between dicot and monocot stem, and anatomical differences between root and stem are given in Tables 7.5 and 7.6

Table 7.5 Differences between monocot stem and dicot stem

Characters	Dicot stem	Monocot stem
1. Epidermal hairs	Present	Absent
2. Hypodermis	Collenchymatous	Sclerenchymatous
3. Ground tissue	Differentiated into cortex, endodermis, pericycle, pith and medullary rays	Undifferentiated
4. Vascular bundles	(i) Number not very large	(i) Numerous
	(ii) Uniform in size	(ii) smaller near periphery, bigger in the centre
	(iii) arranged in a ring	(iii) scattered
	(iv) open	(iv) closed
	(v) bundle sheath absent	(v) bundle sheath present
	(vi) xylem vessels arranged in a radial row	(vi) xylem vessels arranged in shape of letter "Y"
	(vii) water cavity absent	(vii) water cavity present
5. Secondary growth	Present	Mostly absent

Table 7.6 Anatomical differences between stem and root

Characters	Stem	Root
1. Cuticle	Present	Absent
2. Hair	Multicellular	Unicellular
3. Ground Tissue	Differentiated	Differentiated
4. Cortex	Narrow (dicot) or undifferentiated (monocot)	Wide
5. Pericycle	Many layered, of sclerenchymatous and parenchymatous cells	Single layered, of parenchymatous cells only
6. Vascular bundles	Many, conjoint and collateral	Fixed number, radial
7. Xylem	Endarch	Exarch

INTEXT QUESTIONS 7.5

1. Differentiate between conjoint and collateral vascular bundle.

   ....

2. What is the region between two vascular bundles in a dicot stem known as?

   ....

3. Where will you find radially arranged vascular bundles with exarch xylem?

   ....

4. If you want to study the internal structure of a monocot and a dicot stem, name the plants you would select for the study.

....

7.1.9 Secondary growth in stem

You have learnt in lesson 6 about the secondary growth in dicot roots and its importance, let us study it in stem. It occurs only in dicot stem a little away from the shoot apex and helps the plant to (a) grow in girth (thickness) and (b) makes it very strong to stand upright for many years. That is why you see that very tall trees can withstand strong winds, and lashing rains without falling down but monocot plants like wheat, rice, maize, and grasses bend easily due to absence of secondary growth in their stems.

Growth in thickness in dicot stem becomes possible due to the formation of new tissues entirely by the activity of two lateral meristems -(i) Vascular cambium and (ii) Cork cambium (Fig.7.7 a-d).These tissues thus formed are known as secondary tissues and growth in girth is referred as secondary growth.

(i) Activity of vascular cambium -Forms secondary vascular tissues as follows

- The strip of cambium present in the vascular bundle is called **Fascicular Cambium** (Fig 7.7a)
- Thecellsofmedullaryraysadjoiningthestripofvascular(Fascicular)cambium become meristematic and form **interfascicular cambium**(Fig. 7.7b).
- Both fascicular and inter-fascicular cambium join to form a continuous cambium ring (Fig. 7.7b,c)

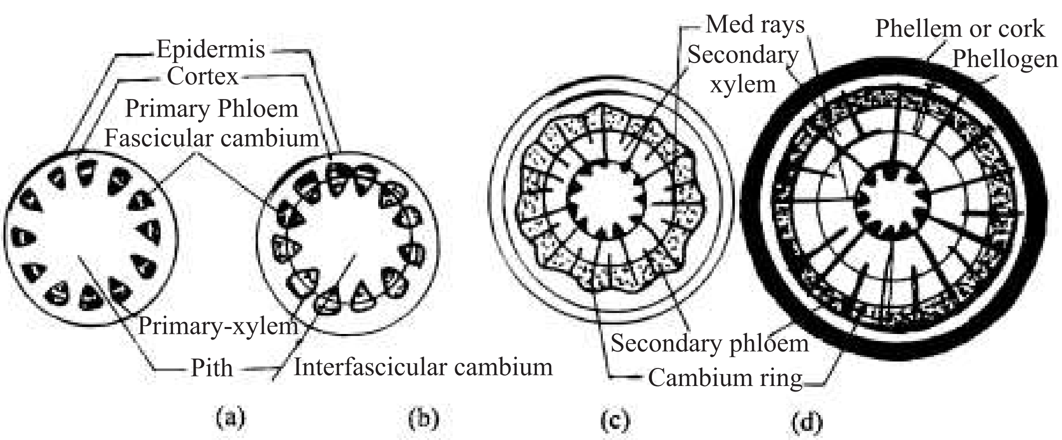


Fig. 7.7 (a-d) T. S. Dicot Stem- Various stages in secondary growth (Diagrammatic)

- Cambium divides and adds cells on internal side (towards pith) which mature into **secondary xylem** and cells added towards external side (periphery) mature into secondary phloem (Fig 7.7c).
- Amount of secondary xylem produced is comparatively comparatively more than secondary phloem (Fig7.7d)

(ii) Activity of cork cambium-Forms periderm as follows :

- Cork cambium or **phellogen** develops in the cortex.

- **Phellogen** divides and adds cells on both the inner and the outer side.
- The inner cells differentiate into **phelloderm** or **secondary cortex** while outer cells into **phellem** or **cork** (Fig.7.7d).
- Cork cells are compactly arranged and become dead and suberized (deposition of suberin) except in regions of **lenticels** (Fig. 7.8) where cells are loosely arranged **(complimentary cells)** and non-suberized. It is through the lenticels that woody branches and tree trunks can undergo gaseous exchange.
- Phellogen, phelloderm and phellem together constitute the **periderm** (Fig7.8).Due to internal increase in thickness, periderm replaces the epidermis, becomes protective in function.
- All the dead cells lying outside the active phellogen constitute the **bark.**

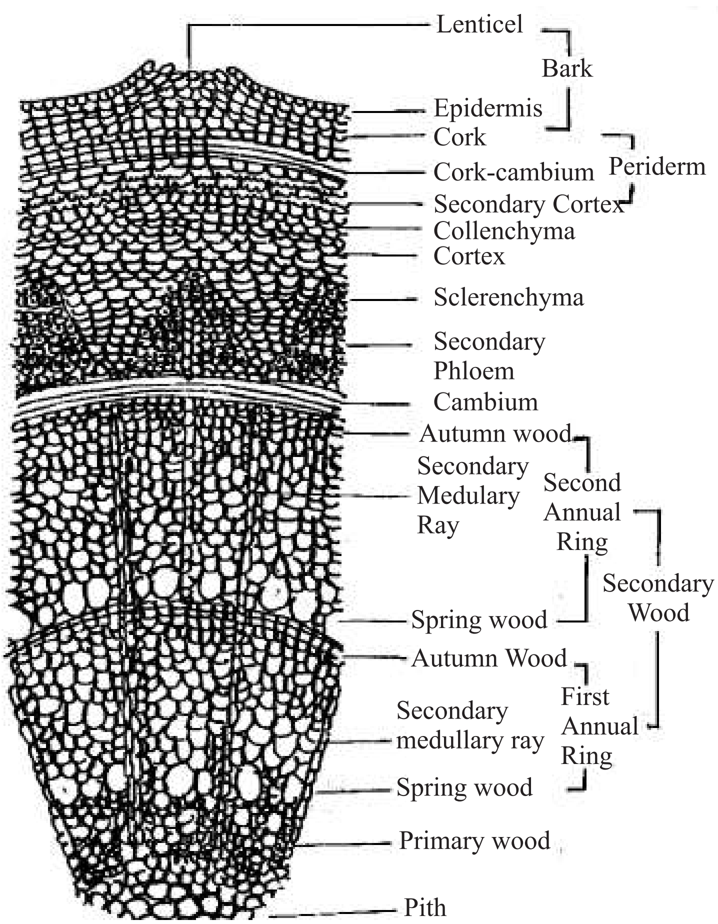


Fig. 7.8 T.S. of old stem, A Portion enlarged

In *Betula bhojpatra* bark peels off like sheets of paper. Ancient manuscripts are still preserved on them. Cork tissue becomes very thick in Cork tree *(Quercus suber)* and is used commercially as, bottle-stoppers, insulators, and shoe soles.

INTEXT QUESTIONS 7.6

1. Name the two lateral meristems which 'are responsible for increase in girth of stem.

 ....

2. From which region does the interfascicular cambium develop?

 ....

3. Define bark.

 ....

4. Why are lenticels, non suberized?

 ....

5. The stems of grasses, and rice, remain weak and thin, why?

 ....

6. Which layers constitute the periderm? What is it's function?

 ....

7.1.10 Wood

Wood is the secondary xylem produced by the activity of vascular cambium in dicot stem.

Annual Rings (A secret to know the age of tree)

In temperate regions, the climatic conditions show pronounced seasonal variations. The activity of vascular cambium also becomes periodical as a result, distinct growth layers are formed in xylem. In spring season cambium is very active and produces a greater number of vessels with wider cavities. The wood formed during spring is called **early wood** (or **spring wood).** In summer, cambium is less active and forms narrow vessels, this wood is called **late wood** (or **summer wood).** These two kinds of woods in a transverse view appear as alternate concentric rings together forming an **annual ring** (Fig 7.8). By counting the number of these annual growth rings we can know the age of a tree. Science dealing with predicting the age of a tree by counting the annual growth rings is called as **Dendrochronology.**

Sap Wood and Heart Wood

Outer part of wood which is functional and consists of recently formed secondary xylem having some living cells is called **sap wood.** As the plant ages in the central part of stem, the inner cells of sap wood that become non-functional and dark in colour constitute, **heart wood** (Fig 7.9)

Fig. 7.9 T.S. old stem showing Heart wood and Sap wood.

Table 7.7 enlists the main differences between sap wood and heart wood.

Table 7.7 Differences between sap-wood and heart wood

SAP WOOD	HEART WOOD
1. It is the outer light coloured wood of an old stem	It is the central dark colured wood of an old stem
2. Light coloured	Dark coloured due to presence of gums, resins, oils, tannin etc.
3. Contains living cells	Living cells are absent
4. Vessels not plugged and help in upward movement of water and minerals	Vessels are plugged with tyloses
5. Wood is lighter in weight	Heavier in weight
6. Less durable because of susceptibility to attack of pathogens	More durable, resistant to attack of the pathogens
7. Commercially less valuable	Commercially more valuable

Mechanical tissues in stem -The stem of a tall tree needs to i) resist against pulling forces of wind and ii) to stand erect against gravity. Stem gets this strength from - Sclerenchyma in hypodermis and it's patches in the pericycle and secondary phloem, abundant lignified vessels, tracheids and fibres in secondary xylem i.e. wood and sclereids in pith.

INTEXT QUESTIONS 7.7

1. Which type of wood is formed when the cambium is less active?

   ....

2. How can you determine the age of a tree?

   ....

3. Why is heart wood commercially more valuable?

   ....

4. Why does a tall tree stand erect even in strong wind and lashing rain?

   ....

5. Define wood.

   ....

7.2 LEAF

Leaf is a flattened and expanded lateral appendage of stem or branch developing from its node. It originates from leaf primordium formed by the shoot meristem and bears a bud in its axil called **axillary bud.** It is the seat of very important physiological processes like photosynthesis, transpiration and respiration. Besides protecting axillary buds ,leaf can get modified into structures for storing food and water, climbing, and vegetative propagation.

7.2.1 Structure of Leaf

A typical leaf has three parts (Fig. 7.9)

(i) **Leaf base -** Lower most part of leaf by which it is attached to the stem node. It may be expanded as sheath (in monocots) or bear lateral outgrowths (stipules) as in dicots.

(ii) **Petiole -** Is the stalk of leaf. Leaf can be **petiolate (** with petiole) as in many dicots or **sessile (** without petiole) as in most monocots. Petiole may get modified and swell (e.g. water hyacinth) or develop wings (e.g. orange) or become flat like a leaf (e.g. Australian Acacia)

(iii) **Lamina or leaf blade-** It is a green, thin, flattened and expanded part of leaf with veins and veinlets traversing through its surface. The most prominent vein running from base to apex and present in the middle of leaf blade is called **mid rib.** Veins provide support and conduct water, minerals and prepared food.

Leaf shows a lot of variation in -

(i) Shapes of lamina (Fig.7. 10) (ii) Leaf apices (Fig. 7.11), and

(iii) Leaf margins (Fig.7.12)

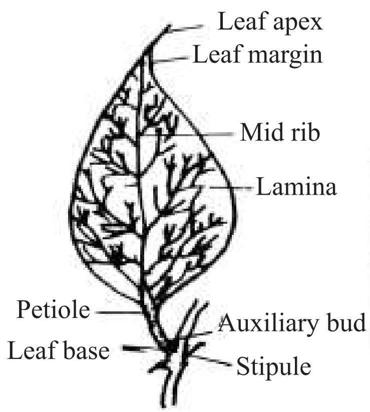


Fig. 7.9 Leaf and its parts

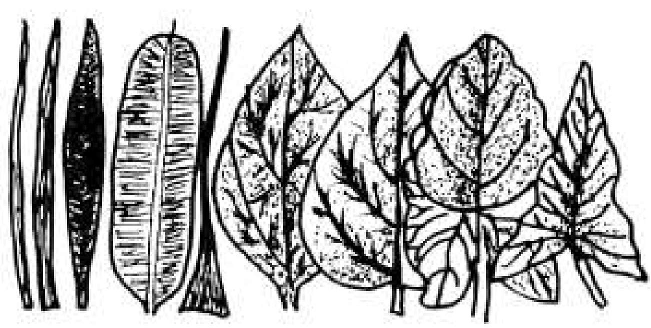


Fig. 7.10 Variations in leaf shape.

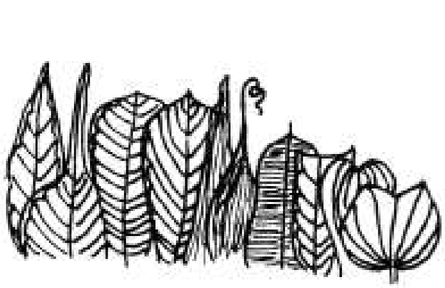


Fig. 7.11 Variations in Leaf apices

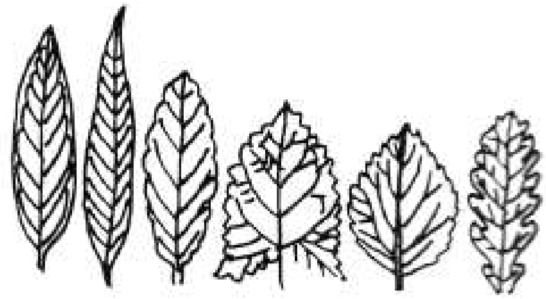
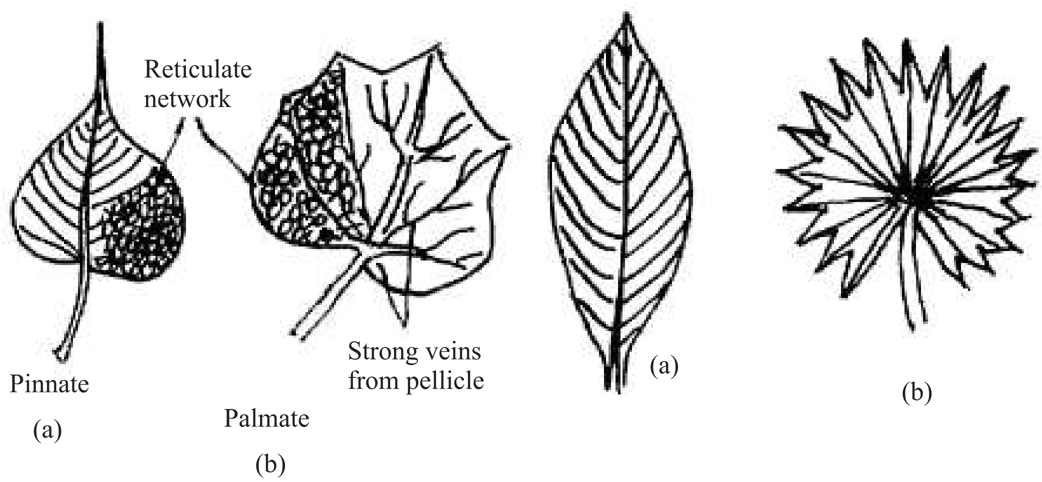


Fig. 7.12 Variations in Leaf margins

7.2.2 Venation in leaves

Arrangement of veins and veinlets in the lamina is known as **Venation.** It is of two types

- **Reticulate venation** -veins forming a network e.g. dicots (Fig.7.13A-a,b)
- **Parallel venation** -veins arranged in parallel rows e.g. monocots (Fig.7.13B c,d).
- Reticulate and parallel venation may be **unicostate** (Fig. 7.13 a,c) with one mid rib, giving out secondary veins like in feather, hence **pinnate** or, **multicostate** (Fig. 7.13 b, d) having many strong veins spreading out from a common point like fingers from palm, hence **palmate as seen** in Fig.7.13.



(A) Reticulate Venation
(a) Unicostate (Peepal)
(b) Multicostate(Grape vine)

(B) Parallel Venation
(a) Unicostate (Canna)
(b) Multicostate(Palm)

Fig. 7.13 Types of Leaf venation

INTEXT QUESTIONS 7.8

1. Define venation.

   ....

2. Differentiate between unicostate and multicostate venation.

   ....

3. What is the type of venation found in peepal and palm leaves?

   ....

4. Name the structure which arises in the axil of leaf

   ....

5. What is the prominent vein called which is present in the middle of lamina and runs from base to apex?

   ....

7.2.3 Types of leaves

There are two types of leaves **Simple** and **Compound.** Since a leaf bears a bud in its axil, you can recognize a compound leaf from a simple one by locating the axillary bud. A bud is present in the axil of both simple and a compound leaf but not in th axil of leaflets. The differences between the two types of leaves are given in table 7.7

Table 7.7 Differences between Simple and Compound leaf

Simple leaf	Compound leaf
1. The leaf has a single undivided lamina (Fig. 7.9)	The lamina is divided into many segments called **leaflets** (Fig. 7.14)
2. If divided, the incisions do not touch the mid rib (Fig. 7.13d)	Incisions touch the mid rib (Fig. 7.15)

Types of Compound leaves - They are of two types as shown in table 7.8

Table 7.8 Types of compound leaf

Pinnate	Palmate
1. Leaflets are attached to mid rib or rachis and are arranged laterally (Fig 7.15)	Leaflets radiate from the end of petiole like fingers of a palm (Fig. 7.14)
2. Leaflets and mid rib may get further divided to form compound leaves that are unipinnate, bipinnate, tripinnate and decompound (Fig. 7.15)	Depending upon the number of leaflets compound leaves are bifoliate, trifoliate, quadrifoliate and multifoliate (Fig.7.14)

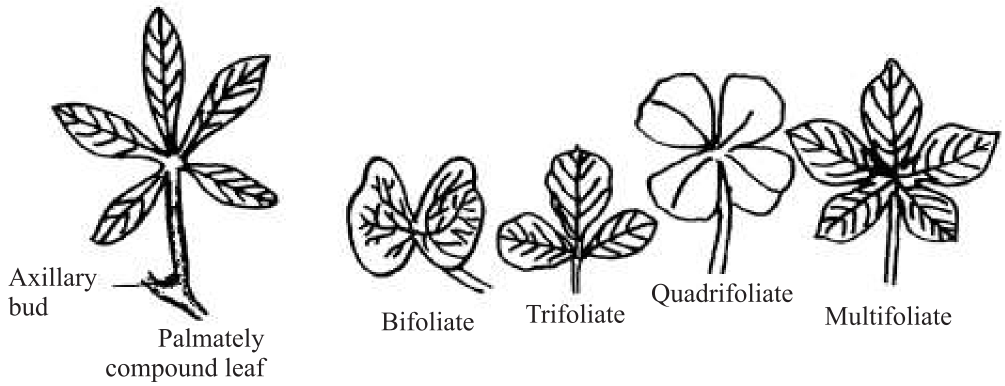


Fig. 7.14 Palmately compound leaf and its types

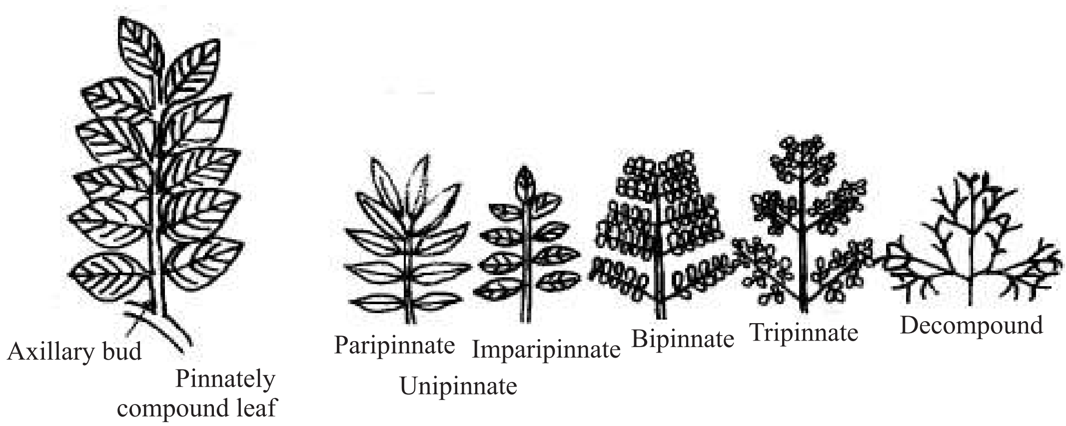


Fig. 7.15 Pinnately compound leaves and its types

INTEXT QUESTIONS 7.9

1. Name the structure to which the leaflets are attached in a compound leaf.

   ....

2. What is the structure which helps you differentiate a leaf from a leaflet?

   ....

3. What are the two types of compound leaves known as ?

   ....

You will enjoy doing the following activity

ACTIVITY 7.1

Aim - To collect and study a few leaves.

Material required — Collect leaves of peepal, neem, banana, palm, rose, grass, imli and tulsi.

Method - Observe the following features in the collected material

(i) Simple or compound leaf

(ii) Reticulate or Parallel venation.

On the basis of the type of venation, group the leaves into monocot and dicot leaves.

7.2.4 Phyllotaxy

It is the arrangement of leaves on stem or branch. The orientation and arrangement of leaves is such that they get appropriate amount of sunlight for photosynthesis. It is of three types

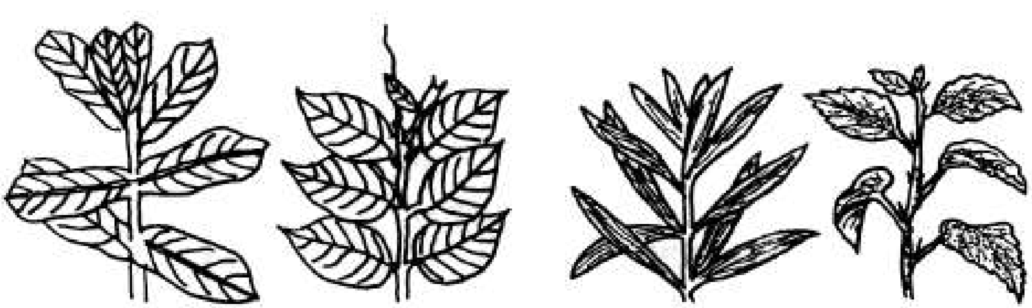
(i) **Alternate** (Fig. 7.16d) - a single leaf arising at each node e.g. china rose, mango.

(ii) **Opposite** (Fig. 7.16a-b) - Leaves occur in pairs at each node. This arrangement may be

   (a) **Decussate** (Fig. 7.16a) - When the successive pairs of leaves at upper and lower nodes are at right angles e. g .,"Tulsi", *Calotropis*

   (b) **Superposed** (Fig. 7.16b) - when the successive leaf pairs at upper and lower nodes are exactly in the same plane e.g. guava

(iii) **Whorled** (Fig. 7.16c) - When there are more than two leaves at each node arranged in a circle or whorl e.g. *Nerium.*



(a) (b) (c) (d)

Fig. 7.16 (a-d) Phyllotaxy- (a) Opposite-Decussate; (b) Opposite-Superposed; (c) Whorled; (d) Alternate

7.2.5 Modifications of leaves

Although the function of leaves is to synthesize food, in some cases they get modified into distinct structures to perform special functions like support and protection to plant, storage of food and water or to catch insects as in case of insectivorous plants (Table 7.9).

Table 7.9 Modifications of leaves

Type	Characters	Examples
1. **Leaf Tendril** (Fig.7.17a)	Here leaves or leaflets get modified to form thin wiry, closely coiled sensitive structure called the **tendril** that helps the plant to climb the support.	Pea, Glory lily
2. **Spines** (Fig 7.17b)	The leaves are modified into sharp and pointed structures which protect the plant and help in reducing transpiration.	Prickly poppy *(Argemone)* *Opuntia,* Aloe
3. **Phyllode** (Fig. 7.17c)	The petiole of compound leaf becomes flattened leaf like and helps in photosynthesis; the leaflets gradually disappear	Australian acacia
4. **Leaves of Insectivorous plants** (Fig. 7. 17d, e)	In pitcher plant the whole leaf gets modified into pitcher while in bladderwort some segmented leaves get modified into bladders. They help in trapping insects	Pitcher plant *(Nepenthes)* Bladderwort *(Utricularia)*

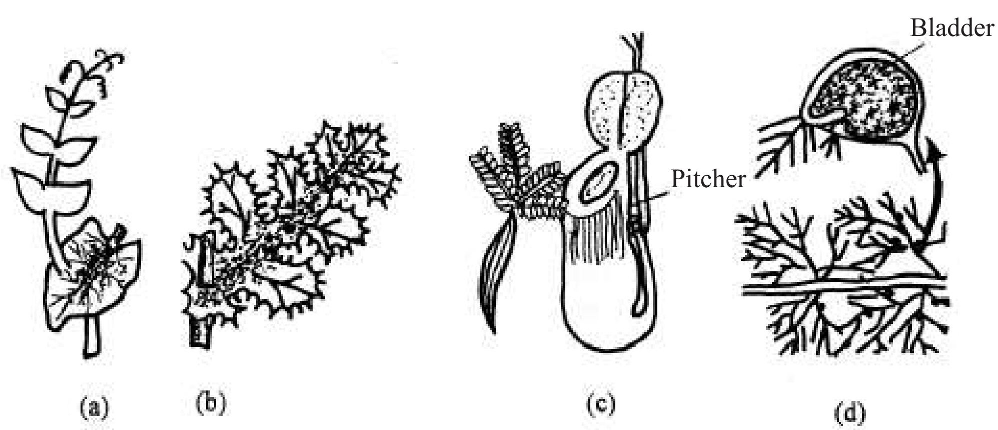


Fig. 7.17 Modifications of Leaf a-d (a) Leaf tendril; (b) Spines; (c) Pitcher plant; (d) Bladderwort

Heterophylly (heteros = different)- Some plants show more than one type of leaves in the same plant , this phenomenon is called heterophylly. It is found in some plants which remain partly submerged in water e.g. Water chestnut, and *Limnophila*

INTEXT QUESTIONS 7.10

1. What is the type of phyllotaxy found in mango, 'tulsi' and guava plants?

    ....

2. Match the following items of column A with those of column B

	A		B
(a)	Pitcher	(i)	Photosynthesis
(b)	Spines	(ii)	Climbing
(c)	Phyllode	(iii)	Trapping insects
(d)	Tendril	(iv)	Protection

3. Give two examples of insectivorous plants.

   ....

4. Water chestnut shows two different types of leaves on the same plant, what is such a condition known as?

   ....

7.2 6 Functions of Leaf

Leaf performs following functions :

(i) **Photosynthesis** - Leaves manufacture food in the presence of sunlight.

(ii) **Exchange of gases -** Stomata help in exchange of gases which are important for respiration and photosynthesis.

(iii) **Transpiration** - Evaporation of excess of water in vapour form takes place through stomata which helps in ascent of sap and cooling of leaf surface.

(iv) **Guttation -** Exudation of excess of water containing salts takes place in liquid form from leaf margins in plants growing in humid climate.

(v) **Modifications for special functions -** In certain plants leaves perform functions like manufacturing and storing food, providing support and protection, vegetative propagation and trapping insects.

7.2.6. Internal structure of leaf (Figs. 7.18-19)

A General features

- Leaves of most dicot plants are dorsiventral (oriented horizontally, with differentiated mesophyll) where as those of monocots are isobilateral (oriented vertically, mesophyll undifferentiated).
- V.S. of leaf shows three main parts (i) **Epidermis** (ii) **Mesophyll** (iii) **Vascular system.**

  (i) **Epidermis -** Present on **both** upper and lower surface of leaf. Some epidermal cells give rise to guard cells that get arranged to form openings called stomata which help in exchange of gases for photosynthesis, respiration and evaporation of water vapour during transpiration. In some monocot leaves, some epidermal cells in upper epidermis become enlarged to form bulliform cells which lose water so that leaves become tubular to reduce transpiration on hot sunny days.

  (ii) **Mesophyll -** Consists of chloroplast - containing parenchyma **(chlorenchyma)** and is responsible for carrying out photosynthesis. It is differentiated into **palisade** and **spongy** cells in dicot leaves. In monocot leaves, palisade tissue is lacking, thus, mesophyll has only spongy tissue.

- **Palisade cells -** occur below upper epidermis in dicot leaf.
  - Cells are radially elongated, compactly arranged.
  - Possess abundant chloroplasts
- **Spongy cells -** Occur below the palisade cells in a dicot leaf.
  - Cells irregular and loosely arranged - Contain fewer chloroplasts
  - Store gases in the inter cellular spaces

(iii) **Vascular Bundles -** They are **conjoint, collateral** and **closed**

- In each bundle, xylem is located on upper side (ventral) and phloem on lower side (dorsal)
- Most vascular bundles are surrounded by colourless parenchyma called **bundle sheath or border parenchyma.**

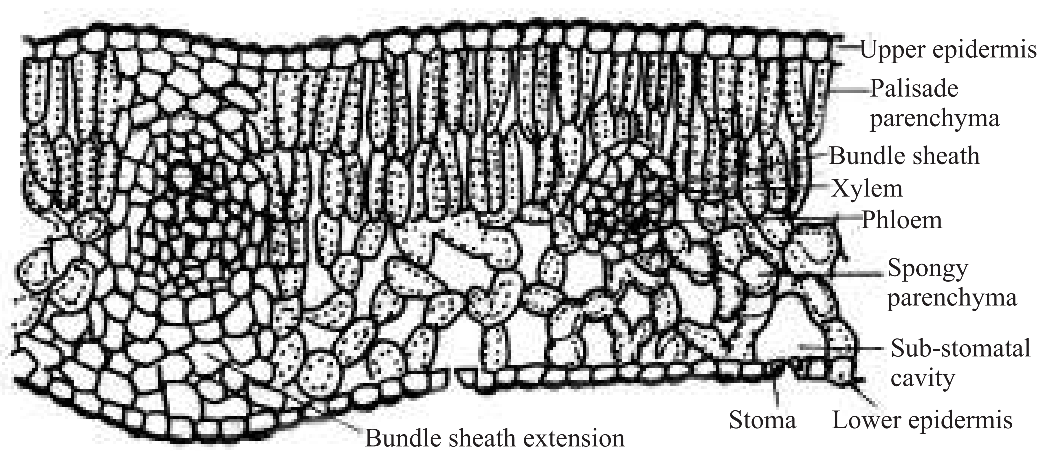


Fig. 7.18 V.S. of a dicot (Dorsiventral) Leaf

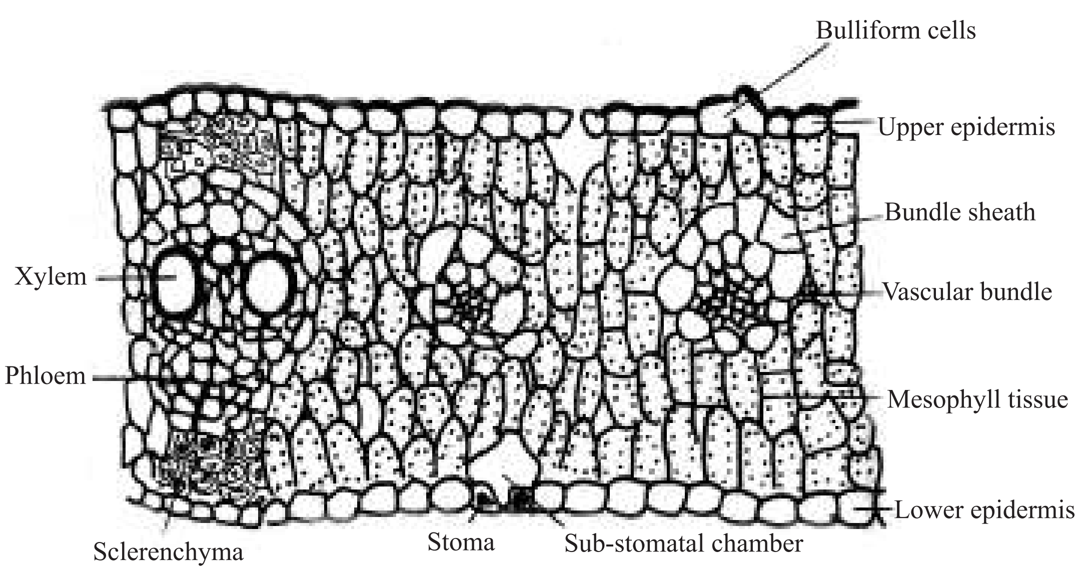


Fig. 7.19 V.S. of a Monocot (Isobilateral) Leaf

Structure of stomatal apparatus : In dicot leaves, stomatal apparatus is made up of two semi circular guard cells surrounding a pore-stoma (Fig. 7.21) The guard cells contain chloroplasts and regulate the opening and closing of stomata. Stomatal pore opens into the inter cellular spaces (substomatal cavity) of mesophyll (Fig. 7.19). The number, shape and distribution of stomata vary (Table 7.10) depending upon the plant whether it is xerophyte or mesophyte.

Table 7.10 Distribution of stomata.

Plants	Stomatal characters	Examples
1. Dicots	Guard cells semicircular reniform occur generally on lower surface	Mango, neem
2. Monocots	Guard cells dumbbell shaped, occur on both the surfaces	Maize
3. Xerophytes	To reduce transpiration- (i) occur only on lower surface, (ii) are absent or less in number on the upper surface (iii) may be sunken	*Nerium*
4. Hydrophytes		
– with floating leaves	Occur only on upper surface	Lotus
– with submerged leaves	Stomata absent	*Hydrilla*

Now you can compare the internal structures of dicot and monocot leaves from Figs. 7.18-19 and Table 7.11

Table 7.11 Difference between internal structure of Dicot and Monocot Leaf

Tissue	Dicot leaf (Dorsiventral leaf)	Monocot leaf (Isobilateral leaf)
1. Epidermis		
(i) Stomata	Occur generally in lower epidermis	Occur both in upper and lower epidermis
(ii) Bulliform cells	Absent	Present in upper epidermus
2. Mesophyll	Differentiated into palisade and spongy parenchyma	Only spongy parenchyma present
3. Vascular system	(i) in the form of network (ii) vascular bundle in mid rib region is large, rest of the vascular bundles decrease in size towards the leaf-margin.	(i) in rows (ii) vascular bundle of midrib is large, but other vascular bundles are small generally of same size.

B. Special features

(i) **Bulliform Cells** (Fig 7.19)

- These are special type of cells **(motor cells)** found on upper leaf surface of some monocots (e.g. maize, bajra, jowar).

- They help the leaf to roll and unroll due to change in their turgidity.
- Leaf rolls when these cells lose water due to high rate of transpiration especially at Mid-day on hot sunny days.
- Thus, under dry conditions they help in reducing the loss of water vapour through stomata.

(ii) **Hairs**

- Hairs are present especially on leaves of plants growing in dry conditions. They check the rate of transpiration.
- They protect the leaf from bright sunlight, high temperature and air pollution.

(iii) **Hydathodes (water stomata)**

- These are specialised structures (Fig.7.20) present in leaves of angiosperms (garden nasturtium) occurring in humid climate.
- Through these openings excretion of water and minerals plus simple organic compounds in liquid form **(guttation)** takes place. When water absorption by a plant is more and transpiration is less.

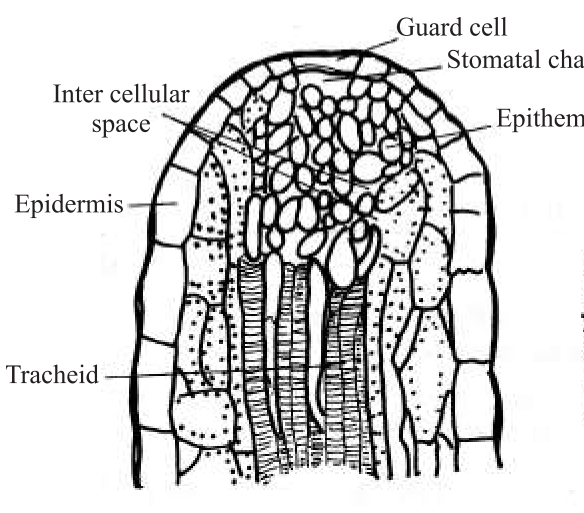


Fig. 7.20 Hydathode

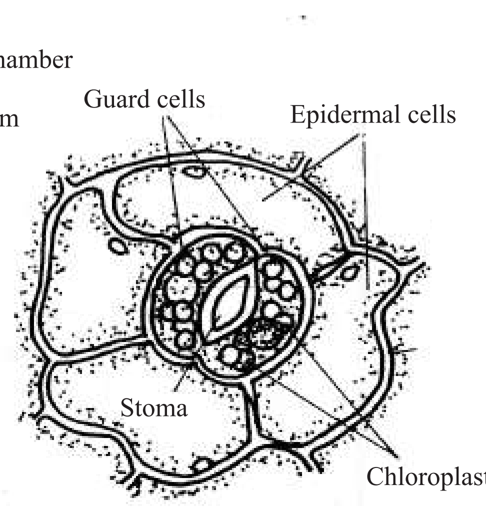


Fig. 7.21 Stomatal apparatus from a dicot leaf

Table 7.12 Difference between Stomata and Hydathode

Characters	Hydathode	Stomata
1. Size	Large	Small
2. Location	Located at vein endings near leaf margins only	Present throughout the leaf surface
3. Structure	Always remain open	They open and close depending upon light intensity
4. Loss of water	Water comes out in liquid form and contains dissolved salts & sugars	Water loss is in vapour form
5. Occurrence	Found in plants of humid areas	In plants occurring in all climates
6. Physiological process	Guttation	Transpiration

INTEXT QUESTIONS 7.11

1. How is the mesophyll tissue of dicot leaf different from that of monocot leaf? What is it's function?

   ....

2. Where are stomata located in a grass leaf?

   ....

3. Name the structure through which plants growing in humid areas get rid of excess of water in liquid form.

   ....

4. Match the following item of column A with that of column B

	A		B
(a)	Bulliform cells	(i)	Protection
(b)	Transport of water and mineral salts	(ii)	Guttation
(c)	Stomata only on lower surface	(iii)	Monocot leaf
(d)	Hydathode	(iv)	Dicot leaf
(e)	Hair	(v)	Stomata
(f)	Exchange of gases	(vi)	Xylem

7.3 FLOWER

Flowers are a thing of beauty for us but for the plants they are vital as they are the seat of sexual reproduction. They produce fruits and seeds.

A flower is a modified shoot because it has (i) nodes very close to one another and (ii) floral leaves arranged in successive whorls.

7.3.1 Parts of a typical flower (Fig 7.22)

Take a flower of any colour or size growing in your area, you'll find it's basic plan to be the same i.e. the flower is borne on a stalk called **pedicel.** The pedicel has a swollen tip known as **thalamus** or **receptacle** on which are borne four whorls successively in definite order as given below :

Accessory whorls

1. **Calyx** (collection of sepals) - The outer most whorl of green sepals whose main function is protection.
2. **Corolla** (collection of petals) - The next whorl of variously coloured petals. They help in attracting insects for pollination.

Reproductive whorls

3. **Androecium** (male reproductive part) consists of collection of stamens. Each stamen has a long slender **filament** with a bilobed **anther** at it's tip with a **connective.** Anthers produce pollen grains for pollination.

4. **Gynoecium** (female reproductive part) - centrally located. It consists of a collection of one or more **carpels** which organise to form one or more **pistils.** Each pistil has three parts -

- **Ovary -** It is the swollen basal part, one to many chambered (called **locules)** containing ovules which get fertilized to form seeds and the, fertilized ovary forms the fruit.

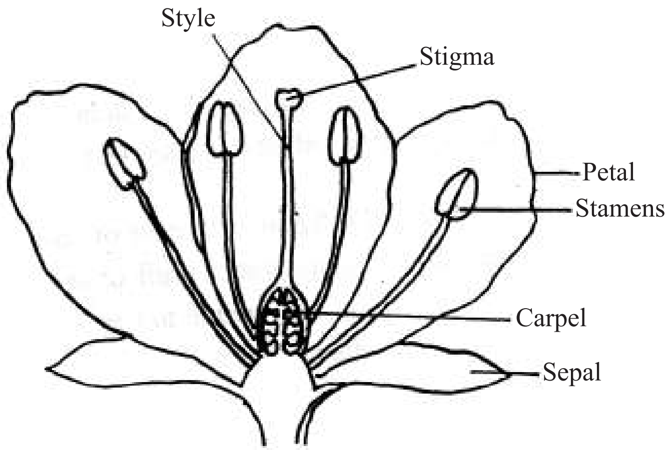


Fig.7.22 A typical flower

- **Style-** It is the elongated tube connecting the upper part of ovary to stigma.
- **Stigma-** It is the receptive surface for pollen.

Common variations in flower and its floral parts -Flowers show a lot of variation, some of which you can study from the Table 7.13

Table 7.13 Variations in flower

Variation	Characters
1. **Complete/Perfect** flower	All 4 floral whorls present
2. **Incomplete/Imperfect** flower	Any one or more of floral whorls are absent
3. **Bisexual** (Hermaphrodite)	Both reproductive organs i.e. stamens and carpels present
4. **Unisexual**	Only one reproductive organ present
(i) **Staminate** or male flower	Only stamens present
(ii) **Pistillate** or female flower	Only pistil present
(iii) **On** the basis of occurrence of unisexual flowers, plant is	
(a) **Monoecious**	Both male and female flower occur on same plant e.g., cucumber
(b) **Dioecious**	Male and female flower occur on different plants e.g., papaya
5. **Neuter** flower	Both stamens and carpels are absent
6. **Actinomorphic (Regular)** flower	If it can be divided into two equal halves through any vertical plane e.g., mustard
7. **Zygomorphic** (irregular bilateral)	If it can be divided into two similar halves only through one particular plane e.g., pea
8. **Asymmetrical (Irregular)**	It cannot be divided into two similar halves in any vertical plane *e.g., Canna*

A. Variations in sepals and petals

(i) **Polysepalous** and **Polypetalous** (poly - free)- sepals or petals are free respectively.

(ii) **Gamosepalous** and **Gamopetalous** (gamo - united)- all sepals or petals are fused, respectively.

(iii) **Perianth -** Sepals and petals not distinguishable e.g. onion

B. Variations in Stamens (Fig. 7.23)

The stamens show variation in their **cohesion** (fusion).

(i) **Monadelphous -** filaments fused into one bundle but anthers are free e.g. china rose

(ii) **Diadelphous** – filaments fused to form two bundles e.g. pea

(iii) **Polyadelphous**–filaments fused to form many bundles e.g., lemon

(iv) **Syngenecious** – filaments are free but anthers are fused e.g. sunflower

(v) **Synandrous** – stamens are fused throughout the length e.g., cocks-comb.

Other variations in stamens are as follows

(vi) **Epipetalous** – stamens are attached to petals by their filaments but anthers are free e.g., brinjal

(vii) **Didynamous** – four stamens, two short and two long e.g. tulsi

(viii) **Tetradynamous** – six stamens, inner four are long and outer two are short e.g., mustard

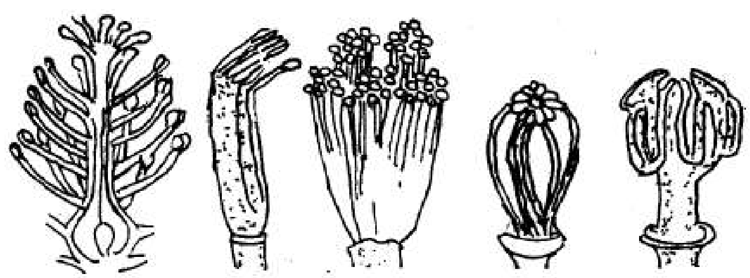


Fig. 7.23 Cohesion (fusion) of stamens.

C. Variation in Carpel

On the basis of number of carpels in a pistil, flowers may be

(i) **Monocarpellary** – If in a Gynoecium pistil has only one carpel e.g. pea.

(ii) **Polycarpellary** – If the Gynoecium has many carpels (e.g. china rose). It may be

(a) **syncarpous** - two or more carpels are fused to form a pistil. e.g. tomato, mustard

(b) **apocarpous** – carpels are free e.g. *Ranunculus*, lotus.

7.3.1a Position of floral whorls on thalamus with respect to ovary

Flower could be of three kinds (Fig, 7.24)

(i) **Hypogynous** - ovary occupies the highest position on thalamus, other three whorls are sucessively below it. Ovary is said to be superior e.g. china rose, and mustard.

(ii) **Perigynous** - The thalamus is disc-like on which the ovary is borne in the centre and rest of floral whorls are located on rim of thalamus. Ovary is said to be half inferior e.g. peach, and plum.

(iii) **Epigynous** -thalamus forms a cup- shaped structure; and encloses the ovary completely and fuses with it. The other whorls are positioned above the ovary. The position of ovary is now inferior e.g. sunflower, cucumber.

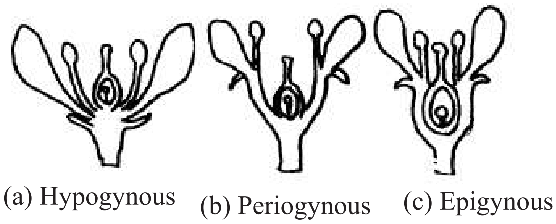


Fig. 7.24 Position of floral parts on thalamus

> **Do you know**
> Some plants like cashew nuts and mango have neuter, bisexual and unisexual flowers on the same tree.

7.3.2 Placentation

It is the manner in which placentae are distributed in the ovary. Placenta is the point of attachment of ovules (or future seed) in the ovary.

Types of placentation (Fig. 7.26)

(i) **Marginal** - The ovary is monocarpellary and one chambered and ovules are arranged along the fused margins of the single carpel. e.g. pea, gram.

(ii) **Axile** - Ovary is polycarpellary syncarpous, having many chambers and ovules present on the placenta develop from the central axis formed by the fusion of the margins of two or more carpels e.g. China rose, tomato, bhindi,

(iii) **Parietal** - Ovary is polycarpellary and syncarpous, having one chamber and ovules are attached on its inner wall where margins of adjoining carpels meet e.g, mustard, cucumber,

(iv) **Basal** – Ovary is bi-or polycarpellary, syncarpous, having one chamber and placenta develops at the base of ovary and bears a single ovule e.g. sunflower.

(v) **Free central** – Ovary is syncarpous and polycarpellary but unilocular as septae are absent. In the central part of the ovary the placenta bears many groups of ovules e.g. *Dianthus*, *Primula*.

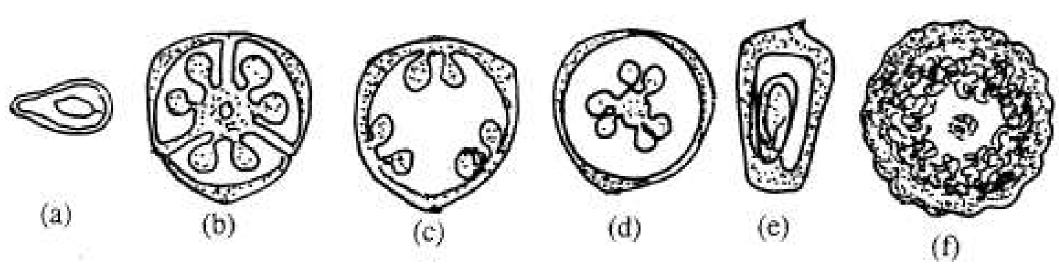


Fig. 7.25 Types of placentation (a) Marginal, (b) Axile, (c) Parietal, (d) Free central, (e) Basal, (f) Superficial

(vi) **Superficial** - Ovary is polycarpellary syncarpous and multilocular in which entire inner walls of chambers are lined with placental tissue so that ovules develop all around e.g.,water lily (*Nymphaea*)

INTEXT QUESTIONS 7.12

1. What is the collection of sepals and petals respectively known as?

   ....

2. Match the following items of column A with those of column B

	A		B
(a)	Flower	(i)	China rose
(b)	Polycarpellary	(ii)	Pollination
(c)	Petals	(iii)	Reproductive organ
(d)	Monodelphous	(iv)	Many carpels
(e)	Carpel	(v)	Modified shoot

3. Define placentation.

   ....

4. Name the type of placentstion where ovary is many chambered and ovules are arranged on the central axis.

   ....

7.4 INFLORESCENCE

Inflorescence is the arrangement of flowers on the floral axis called peduncle. :Inflorescence could be terminal or axillary.

7.4.1 Types of inflorescence

The various types of inflorescence depend upon the type of branching of peduncle and arrangement of flowers. There are two major types of inflorescence

(i) **Racemose.** The main axis does not end in a -flower but continues to grow.

(ii) **Cymose.** The main axis ends in a flower and the growth is limited.

The major differences between the two are given in table 7.14

Table 7.14 Differences between Racemose and Cymose inflorescence

Racemose	cymose
1. Main axis shows unlimited growth	Growth is limited
2. Axis does not terminate in a flower	Axis ends in at flower
3. Flowers occur in acropetal order (oldest flower below and youngest near the apex)	Flowers in basipetal order (terminal flower is older)

Table 7.15 Types of Racemose Inflorescence (Fig. 7.20)

A. With main axis elongated

Type	Characters	Examples
1. Raceme	Flowers present on the floral axis are stalked and arranged acropetally.	Mustard
2. Spike	Like raceme but the flowers are sessile	*Achyranthes* ('Latzira')
3. Spikelet	Cluster of one or more flowers (florets' and their associated bracts	Wheat
4. Catkin	Like spike but the axis is pendulous bearing unisexual flowers	Mulberry
5. Spadix	Like spike but the axis is fleshy and enclosed by a large showy bract (Spathe)	Colocassia, banana

B With main axis shortened

Type	Characters	Examples
6. Corymb	Lower (older) flowers have longer stalks than the upper younger ones, thus all flowers come to lie at same level	Candytuft
7. Umbel	Flower with stalks of equal length arising from the same, point	Coriander

C. With main axis flattened

Type	Characters	Examples
8. Head or capitulum	Main axis is flattened into convex receptacle on which sessile flowers (florets) are arranged in centripetal order (older towards periphery). Whole inflorescence is surrounded by involucre of bracts	Sunflower

Notes

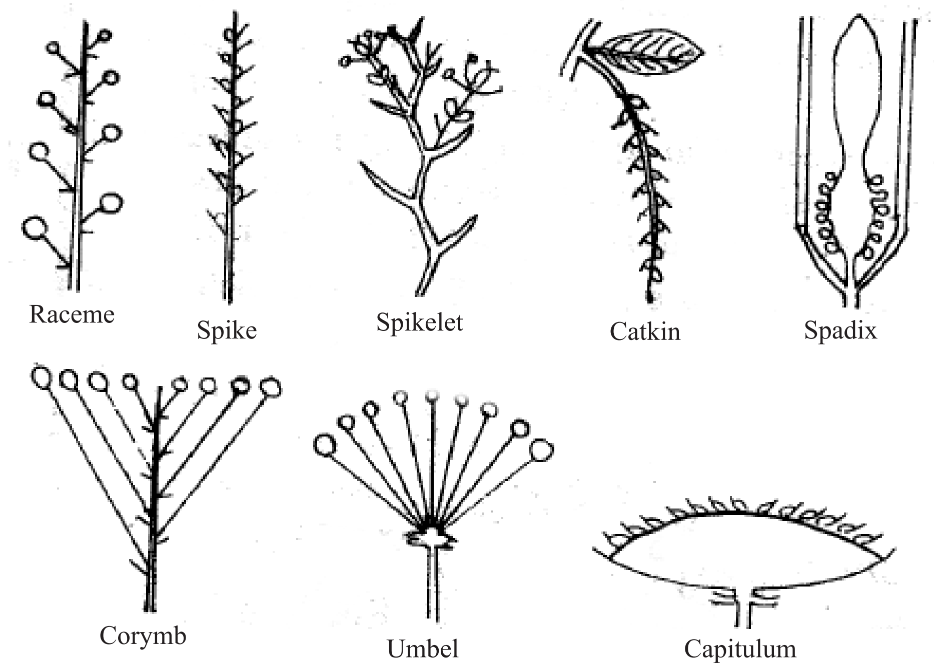


Fig. 7.26 Types of Racemose Inflorescence

Table 7.16 Types of cymose inflorescence (Fig. 7.27)

Type	Characters	Examples
1. Monochasial cyme (Fig. 7.27a)	Main axis ends in a flower. A lateral branch comes from one side and ends in a flower	Cotton
2. Dichasial cyme (Fig. 7.27b)	Two lateral branches develop form either side of terminal flower and each branch ends in a flower	*Dianthus, jasmine*
3. Multichasial cyme (Fig. 7.27c)	Number of lateral branches come from the sides of terminal flower, each lateral branch ends in a flower.	*Calotropis*

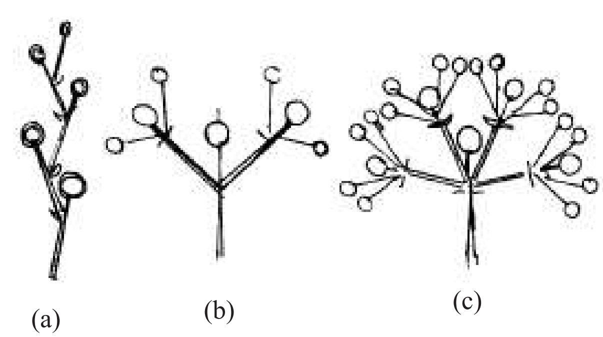


Fig. 7.27 Types of Cymose inflorescence (a) Monochasial, (b) Dichasial, (c) Polychasial

7.4.2 Special types of inflorescence

1. **Hypanthodium** (Fig.7.28a) - The fleshy receptacle forms a cup like cavity and has an apical opening. The male and female flowers are borne on the inner wall of the cavity e.g. Fig, Peepal
2. **Cyathium** (Fig. 7.28b) - A type of inflorescence characteristic of Euphorbia, in which a cup shaped involucre encloses a single female flower surrounded by a number of male flowers. A nectary is present at the rim of involucre,
3. **Verticillaster** (Fig. 7.28c)- It is a series of condensed dichasial cyme at each node with a cluster of sessile flowers in the axil of leaves e.g. *Ocimum* (Tulsa), *Salvia*,

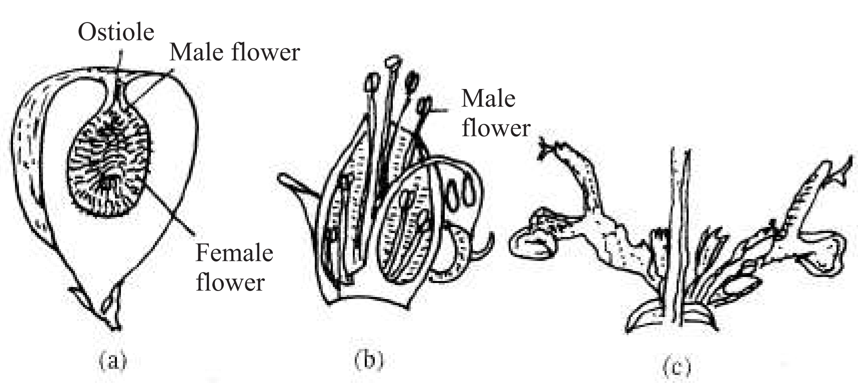


Fig.7.28 Special type of Inflorescence- (a) Hypanthodium, (b) Cyathium, (c) Verticillaster

INTEXT QUESTIONS 7.13

1. What is a cyamose inflorescence?

   ....

2. Give one difference between Raceme and Spike.

   ....

3. Define inflorescence.

   ....

4. Name the type of inflorescence found in sunflower and Fig.

   ....

7.5 FRUIT

A true fruit is a ripened ovary that develops after fertilization. Ovules develop into seeds and the ovary wall matures into fruit wall which is now called pericarp. The pericarp may be thick or thin. In fleshy fruits like mango, pericarp is thick and differentiated into three regions-(a) **epicarp** forms the skin of the fruit (b) **mesocarp**, middle pulpy and (c) **endocarp** inner hard and stony (coconut, mango) or often thin membranes (orange). In **dry fruits** pericarp, is thin, dry, papery or thick and woody but not divided into three regions.

Sometimes along with ovary other floral parts like thalamus, receptacle or calyx may develop as part of fruit, such fruits are-called false fruits. e.g. apple, pear (thalamus), fig (receptacle).

Parthenocarpic fruit -It is a fruit that develops without fertilization. It is seedless or has non-viable seeds e.g, banana, grapes. Horticulturists are producing such fruits artificially.

7.5.1 Kinds of fruits - There are three basic types

1. **Simple fruit** - Develops from single mono-to polycarpellary, syncarpous (fused) ovary e.g, pea, tomato.

2. **Aggregate fruit** - Collection (etaerio) of simple fruits or fruitlets on same thalamus developing from polycarpellary, apocarpous (free carpels) ovary e.g. *Calotropis* and *Ranunculus*.

3. **Composite or multiple fruit** - Fruit develops from a number of flowers juxtaposed together or from inflorescence e.g. mulberry, pineapple.

Table7.17 Major categories of fruits

1. Simple	Dry	Dehiscent	(i) Legume - pea, bean, groundnut
			(ii) Siliqua - mustard
			(iii) Follicle - *Calotropis*
			(iv) Capsule - cotton, poppy, 'bhindi'
		Indehiscent	(i) Caryopsis - wheat, rice
			(ii) Nut - almond, cashewnut
			(iii) Cypsella - sunflower, marigold
			(iv) Samara - yam, hiptage
	Fleshy		(i) Drupe - mango, coconut
			(ii) Berry - tomato, banana, date palm
			(iii) Pepo - cucumber, watermelon
			(iv) Hesperidium - lemon, orange
			(v) Pome - apple, pear
2. Aggregate			(i) Etaerio (cluster) of drupes - Raspberry
			(ii) Etaerio of achenes - Strawberry, rose
			(iii) Etaerio of berries - Custardapple
			(iv) Etaerio of follicles - periwinkle, larkspur
3. Multiple or composite			(i) Sorosis - pineapple, mulberry, jackfruit
			(ii) Syconus - Fig, peepal

Table 7.18 **Common Fruits and their edible parts.**

Names	Types	Edible Parts
1. Banana	Berry – simple, fleshy	Mesocarp and endocarp
2. Apple	Pome – simple, fleshy	Fleshy thalamus
3. Coconut	Fibrous Drupe – simple, fleshy	Endosperm
4. Custard Apple	Etaerio of Berries – aggregate	Pericarp
5. Date Palm	Berry – simple, fleshy	Pericarp
6. Cashew Nut	Nut – simple, dry indehiscent	Peduncle and Cotyledons
7. Mango	Drupe – simple, fleshy	Mesocarp
B. Orange	Hesperidium – simple, fleshy	Juicy hairs from endocarp,
9. Tomato	Berry – simple, fleshy	Pericarp and Placentae
10. Pear	Pome – simple, fleshy	Fleshy thalamus
11. Pineapple	Sorosis – composite	Outer portion of receptacle, bracts and perianth
12. Fig	Syconous – composite	Fleshy receptacle
13. Litchi	Nut – simple	Juicy aril
14. Wheat	Caryopsis – simple dry indehiscent	Starchy endosperm
15. Strawberry	Etaerio of achenes- aggregate	Succulent thalamus

INTEXT QUESTIONS 7.14

1. Define Fruit.

....

2. Give two examples of false fruits.

....

3. What is the fruit wall known as which is formed by the ovary wall?

....

4. Give the names of three layers of pericarp of a fleshy fruit.

....

5. Match the following of column A with that of column B

A	B
(a) Apple	(i) Berry
(b) Hesperidium	(ii) Mesocarp
(c) Mango-edible part	(iii) Endosperm
(d) Coconut -edible Part	(iv) Orange
(e) Tomato	(v) False Fruit

WHAT YOU HAVE LEARNT

- Stem is aerial, upright, positively phototropic part of plant and bears nodes, internodes leaves and buds.
- It has a terminal apical meristem which gives rise to leaves and axillary buds
- The stems are variously modified into underground, subaerial and aerial stems for performing special functions.
- Dicot and monocot stems are different anatomically.
- The internal structure of dicot stem shows epidermis, differentiated ground tissue, multilayered pericycle and vascular bundles arranged in a ring. Each vascular bundle is conjoint, collateral and open with endarch xylem.
- Monocot stem differs in having undifferentiated ground tissue, scattered vascular bundles which are closed.
- Secondary growth takes place only in dicot stem.
- Wood is of two types- heartwood (dark and non functional) and sap wood (light and functional)
- The differential activity of vascular cambium during secondary growth forms annual growth rings.
- Origin of lateral stem branches is exogenous.
- The primary function of stem is conduction of water and minerals through xylem and food through phloem; support and orient leaves towards sunlight for better photosynthesis ; bear flowers and fruits.
- Stem undergoes modifications for various special functions like food storage, perennation, protection, climbing, photosynthesis and vegetative propagation.
- Leaf is a specialised organ for photosynthesis.
- It has three parts -leaf base, petiole and lamina traversed by parallel or reticulate venation. The arrangement of leaves on stem is called phyllotaxy
- Leaves can be simple or compound.
- Leaves are modified into tendrils, spines, phyllode, pitcher or bladder to perform special functions.
- Internal structure of leaf shows three main tissues - epidermis with stomata, mesophyll differentiated into spongy and palisade tissue in dicot leaf but only spongy tissue in monocot leaf and vascular system.
- In dicot leaves each stomatal apparatus consists of kindney shaped guard cells surrounding a pore. In monocot leaves stoma is surrounded by two dumbbell shaped guard cells. Guard cells regulate the opening and closing of stomata, depending upon the presence or absence of sunlight.

- Stomata help in gaseous exchange and allow loss of water vapour during transpiration.
- Special structures like bulliform cells, hydathodes and hairs occur in leaves of some plants.
- Flower is a modified shoot.
- A typical flower has accessory whorls i.e., calyx and corolla and reproductive or essential whorls i.e., androecium (male) and gynoecium (female).
- Flowers may be bisexual, unisexual or neuter; actinomorphic or zygomorphic; hypogynous, perigynous or epigynous.
- Variations occur in floral parts.
- Placentation is the manner in which placentae bearing ovules are distributed in the ovary. It is of many types.
- Inflorescence is the arrangement of flowers on the floral axis.
- It has two major types - racemose and cymose.
- Hypanthodium, verticillaster and cyathium are special types of inflorescence.
- Fruit is a ripened ovary that develops after fertilization
- Ovules develop into seeds and the ovary wall matures into fruit wall called the pericarp which may be thin or differentiated into epicarp, mesocarp and endocarp.
- Fruits may be true or false and categorized into simple, aggregate or composite types.
- Simple fruits may be dry (dehiscent or indehiscent) or fleshy.
- A fruit that develops without fertilization is called parthenocarpic fruit.

TERMENAL EXERCISES

1. Differentiate between
   (i) Dicot stem and monocot stem
   (ii) Root and stem
   (iii) Racemose and cymose inflorescence
   (iv) Stoma and hydathode
   (v) True fruit and false fruit
   (vi) Dicot and monocot leaf
2. Explain the different types of underground modified stem?
3. Explain the process of secondary growth in dicot stem.
4. Draw and label the vertical section of dicot leaf.
5. Define the following

(a) Flower (b) Actinomorphic (c) Heterophylly
(d) Phyllotaxy (e) Hypogynous (f) Parthenocarpic fruit
(g) Venation.

6. What is cork cambium? State its functions.
7 Draw labelled diagrams of the following
   (a) Raceme and corymb inflorescence
   (b) Axile and parietal placentation
8. What is a fruit? Enlist the various types of simple- fleshy fruits giving one example of each type.
9. What are the edible parts of the following fruits
   (a) Mango (b) Orange (c) Apple
   (d) Banana (e) Coconut (f) Cashew nut
10. Match the following of column A with that of column B

	A		B
(a)	Tendril	(i)	Protection
(b)	Stolon	(ii)	Food, storage
(c)	Thorn	(iii)	Reproduction
(d)	Tuber	(iv)	Photosynthesis
(e)	Capitulum	(v)	Climbing
(f)	Phylloclade	(vi)	Sunflower

11. Name the type of modification of an underground, non-green structure bearing nodes and internodes and 'eyes'.
12. If a section of stem shows scattered vascular bundles which are closed, have 'Y' shaped xylem and are surrounded by bundle sheath; what group of plant is it?
13. What is the region ouside the phellogen known as?
14. When the cambium is less active which type of wood does it produce?

ANSWERS TO INTEXT QUESTIONS

7.1 1. Stem, 2. Axillary bud
3. Because lateral roots originate from inner layer, that is, pericycle (endogenous origin)
4. Stem is positively phototropic and negatively geotropic

7.2 1. Corpus 2. Procambium
3. Axillary bud, exogenous 4. Root cap

7.3 1. Creeper 2. Sub-aerial
3. Cladode 4. Rhizome, Bulb
5. (a) - (v) (b) - (iii) (c) - (i) (d) - (ii) (e) - (iv)

7.4 1. Conduction of water and minerals from root to leaf and manufactured food from leaf to other parts of plant

2. Stem cuttings

3. (a) - (iii) (b) - (v) (c) - (iv) (d) - (ii) (e) - (i)

7.5 1. Conjoint is when xylem and phloem are together in one bundle, collateral is when xylem and phloem are on the same radius

2. Medullary ray (3) Root

4. Maize stem for monocot and sunflower for dicot stem

7.6 1. Cork cambium (phellogen) and vascular cambium

2. Medullary ray parenchyma

3. All the tissues outside the functional cork cambium is called bark

4. For gaseous exchange in branches

5. Phellem, Phellogen, Phelloderm, Protection

7.7 1. Late or summer wood

2. By counting the annual rings

3. Durable, resistant to attack of pathogen

4. Presence of abundant mechanical tissue like sclerenchyma and secondary xylem

5. Wood is secondary xylem produced by the activity of vascular cambium in dicot stem

7.8 1. Venation is the arrangement of veins and veinlets in lamina of leaf

2. Unicostate has one strong midrib while multicostate has many strong veins

3. Reticulate, parallel 4. Axillary bud 5. Midrib

7.9 1. Rachis

2. Presence of axillary bud in leaf but not in leaflet

3. Pinnately and palmately compound leaf

7.10 1. Alternate, opposite-decussate; opposite-superposed;

2. (a) - (iii) (b) - (iv) (c) - (i) (d) - (ii)

3. Pitcher plant; bladderwort 4. Heterophylly

7.11 1. Mesophyll differentiated into palisade and spongy tissue in dicot leaf but composed of only spongy tissue in monocot leaf; photosynthesis

2. In both surfaces of leaf 3. Hydathodes

4. (a) - (iii) (b) - (vi) (c) - (iv) (d) - (ii) (e) - (i) (f) - (v)

7.12 1. Calyx, Corolla

2. (a) - (v) (b) - (iv) (c) - (ii) (d) - (i) (e) - (iii)

3. Placentation is the manner in which placentae are distributed in the ovary

4. Axile

7.13 1. When the main axis ends in a flower and the growth is limited

2. Flowers are stalked in raceme but sessile in spike

3. Arrangement of flowers on floral axis

4. Capitulum, Hypanthodium

7.14 1. Fruit is a ripened ovary that develops after fertilization

2. Apple, pear 3. Pericarp 4. Epicarp, mesocarp, endocarp

5. (a) - (v) (b) - (iv) (c) - (ii) (d) - (iii) (e) - (i)

8

ABSORPTION, TRANSPORT AND WATER LOSS (TRANSPIRATION) IN PLANTS

Water is the most important component of living cells. It enters the plants through roots and then moves to other parts. It is also lost by transpiration through the aerial parts of plants, mainly through the leaves. There are several phenomena involved in the movement of water about which you will study in this lesson.

OBJECTIVES

After completing this lesson, you will be able to :

- *define the terms permeability, diffusion, osmosis and plasmolysis;*
- *define and differentiate between the active and passive absorption;*
- *explain imbibition, water potential, turgor pressure and wall pressure, wilting;*
- *describe the pathways of water from root hair up to leaf;*
- *describe the mechanism of translocation of solutes in plants;*
- *explain the process and significance of transpiration;*
- *list the factors affecting the rate of transpiration;*
- *explain the opening and closing mechanism of stomata (potassium ions theory) and list the factors affecting stomatal movement;*
- *explain the process of guttation and list the factors affecting rate of guttation.*

8.1 FOUR BASIC PHENOMENA-PERMEABILITY, DIFFUSION, OSMOSIS AND PLASMOLYSIS

8.1.1 Permeability

Permeability is the property of a membrane to allow the passage of the substances through it. The plant cell wall is **permeable** because it allows both solvent and solute molecules to pass through it. Cuticle layer is impermeable. All biological membranes (cell membrane, mitochondrial membrane, nuclear membrane etc.) are **selectively permeable** as they allow penetration of only solvent molecules but not the solute molecules.

8.1.2 Diffusion

If a can containing volatile substance, such as ethyl ether, is opened in a room, their molecules will soon be distributed in the room until their concentration is the same throughout the room. In other words, ether molecules diffuse into the air in the room. Similarly the fragrance of incense sticks or agarbatti spreads from one corner of the room to the other due to diffusion. Another example is placing a small crystal of a water soluble dye (copper sulphate) at the bottom of a test tube and then pouring water carefully over the crystal. Dye molecules will dissolve and the colour will spread slowly throughout water, partly because of the movement of dye molecules through the water and partly because of the movement of water molecules into a region close to the crystal.

Thus diffusion is the intermingling of molecules of the same or different substances as a result of their random movement. It is dependent on the difference in concentration of molecules of different substances in the adjacent areas and this difference is called **diffusion gradient**.

Diffusion is an effective method of transport of matter over short distances. For diffusion to take place no membrane is required. If a membrane is present, it should be fully permeable. The cell membranes are permeable to both gases CO_2 and O_2 and hence the two gases are able to diffuse freely (Fig. 8.1).

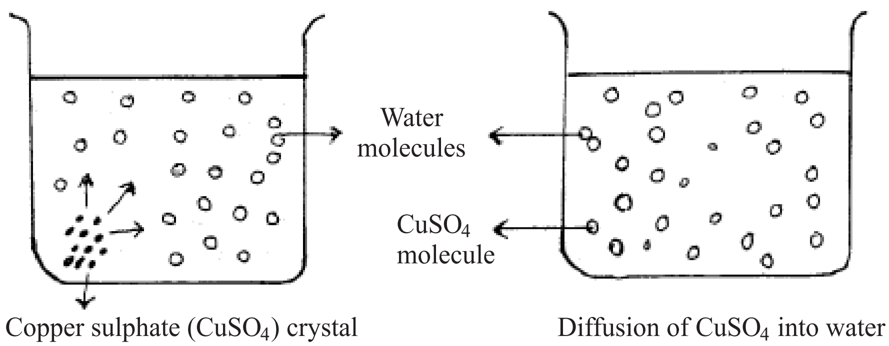


Fig. 8.1 Diffusion of copper sulphate (CuSO4) in water.

8.1.3 Osmosis

Osmosis can be regarded as a special kind of **diffusion of water molecules** from a region of their high concentration to their region of low concentration through a semipermeable membrane (Fig. 8.2). In osmosis, the water molecules move, and the presence of a semipermeable membrane is essential.

Experiment to demonstrate Osmosis

Experiment : To demonstrate the phenomenon of osmosis through plant membrane with the help of potato osmoscope (Fig. 8.3)

Requirements. A large potato tuber, 10% sugar solution, beaker, water, scalpel, pin.

Method. Take a large potato tuber and peel off its outer skin with the help of scalpel. Cut its one end to make the base flat. Now make a deep hollow cavity on the opposite side. Pour some sugar solution to fill half of the cavity and mark the level by inserting a pin in the wall of the tuber. Put the potato in the beaker containing a small amount of water and allow the apparatus to stand for some time. Make sure that the level of water in the beaker is below the level of sugar solution in the cavity of potato osmoscope. (Fig. 8.3)

Observation and Conclusion. The level of sugar solution in the cavity rises. It is because of the movement of water molecules into the cavity from pure water in the beaker. This experiment shows the phenomenon of osmosis.

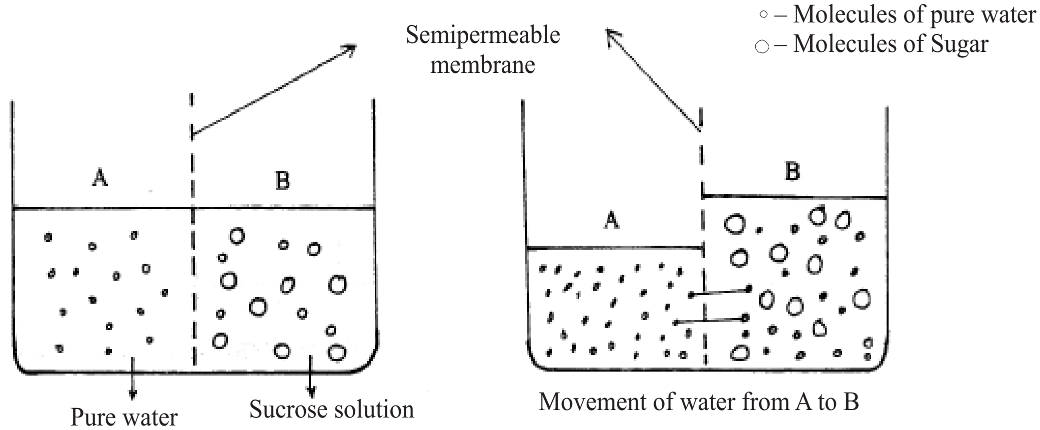


Fig. 8.2 Osmosis - Movement of water molecules through a semipermeable membrane.

Explanation. The living cells of potato tuber collectively act as differentially permeable membrane (membrane which permits movement of certain molecules only through it). The two solutions i.e. pure water in the beaker and sugar solution in the cavity are separated by living cells of potato. Water molecules continue to move through the cell-membranes, into the sugar solution till the concentration of water molecules in the beaker becomes equal to that in the cavity of the osmoscope. If sugar solution is taken in the beaker and pure water in the cavity, the result will be reversed. The movement of water will not occur if the skin of potato is not removed because the skin, being waxy, is impermeable to water.

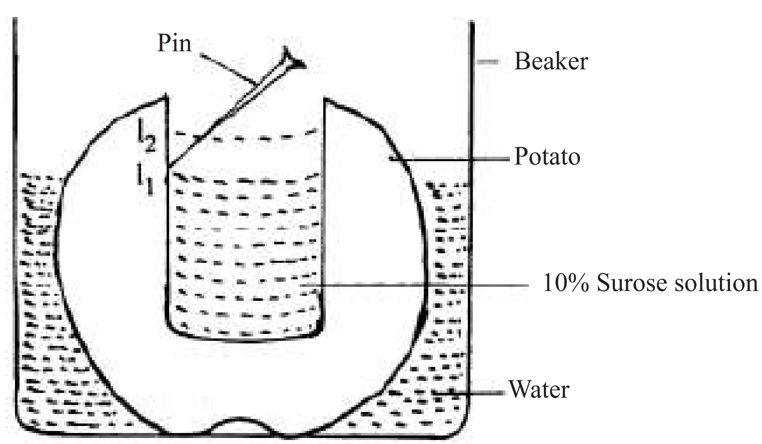


Fig. 8.3 Experiment to demonstrate osmosis by using potato osmoscope.

Difference between Diffusion and Osmosis

Diffusion	Osmosis
1. Diffusion is the movement of a given substance from the place of its higher concentration to an area of its lesser concentration, irrespective of whether separated or not separated by a semipermeable membrane.	**1.** Osmosis is a special type of diffusion of solvent molecules such as water from lower concentration of solution to higher concentration of solution when the two are separated by a semi permeable membrane.
2. The diffusion may occur in any medium. The moving particles may be solid, liquid or gas.	**2.** It occurs in liquid medium and only the solvent molecules such as water move from one place to another.

If you place a cell in a solution, it may shrink, swell or remain unchanged on the basis of relative concentration of water and solutes with respect to their concentration in the cell. On the basis of which solution can be of 3 types:

- **Isotonic** **solution** has the same concentration of water and solutes as inside a cell. Cell remains stable in isotonic solution or there is no entry or exit of water from the cell.
- **Hypotonic** **solution** outside has lower solute concentration than inside the cell. The cell swells as water enters the cell, through the process called **endosmosis**.
- **Hypertonic** **solution** outside has higher solute concentration than inside the cell. Water from cell moves out so the protoplasm of the cell shrinks and collects in the centre of the cell, through the process called **exosmosis**.

Osmotic Pressure and Osmotic Potential

When pure water is separated from a solution by a semipermeable membrane, pure water tends to enter the solution by osmosis. Now the maximum pressure required to prevent the osmotic entry of water in a solution even though the concentration of water in the solution is low as compared to that in pure water, is called **osmotic pressure**.

Imbibition

Before cooking chick pea or gram, it is soaked in water overnight. Next morning the dry chick pea looks well swollen as it has imbibed water.

Imbibition in plant cells refers to the absorption and **adsorption** of water by protoplasmic and cell wall constituents. Water is absorbed as a result of both diffusion and capillary action. Imbibition is a process that accounts for only when solid plant material (dry wood, dead or living air dried seeds) comes in contact with water. In case of living dry seeds water is initially adsorbed by imbibition and thereafter water entering into the inner tissues, is absorbed by osmosis.

Imbibition produces a large pressure, so much so that dry wood can even break a piece of rock in the presence of water. Because of imbibition, the wooden doors, during rainy season, swell up and it becomes difficult to close the door.

Importance of Imbibition

- Imbibition is the initial step in the germination of seeds.
- It causes swelling of seeds and breaking of seed coat.

8.1.4 Plasmolysis

When a cell is placed in a solution, it will either shrink, swell or will remain unchanged depending upon the concentration of the bathing solution or the solution in which the cell is placed.

(i) When a cell is placed in a **hypertonic** solution i.e. when the concentration of the outer solution is higher than the cell sap, water from the cell move out resulting in shrinkage of the protoplasm in the centre of the cell. This phenomenon is known as **plasmolysis.** The space between the cell wall and the protoplast is occupied by the bathing solution as the cell wall being dead, is permeable to the outer solution.

(ii) When such a plasmolysed cell is placed in a **hypotonic** or dilute solution or pure water, water moves into the cell causing the protoplasm to stretch and get back to its original shape. This phenomenon is known as deplasmolysis. The cell after deplasmo-lysis, becomes fully turgid.

(iii) When a cell is placed in an **isotonic** solution or a solution with similar concentration as that of the cell sap, there is no change in the shape of the protoplasm or the cell.

Plasmolysis is a physical phenomenon. A cell can become plasmolysed and deplasmolysed depending upon the concntration of the outer solution in which the cell is placed. No chemical change is caused to the cell. Plasmolysis is a kind of defense mechanism against adverse (stress) conditions such as hypertonic soil solution.

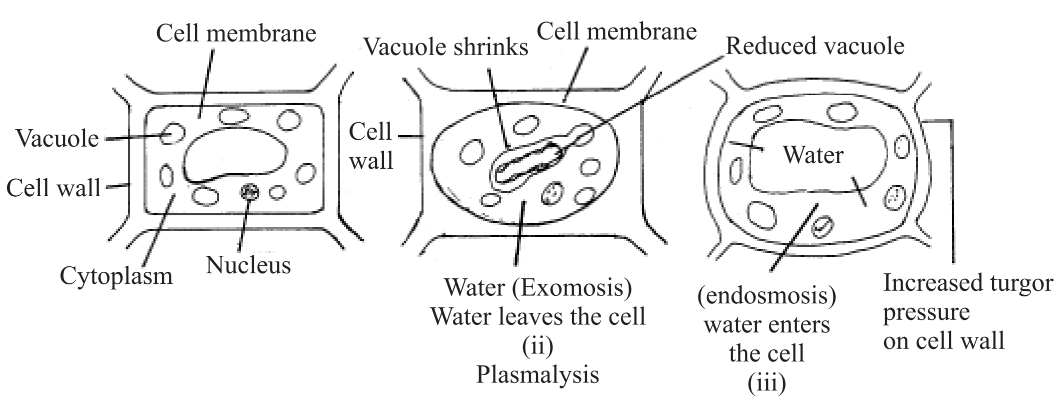


Fig. 8.4 Changes in a plant cell when placed in hypertonic isotonic (i), (ii) and hypotonic solution (iii).

INTEXT QUESTIONS 8.1

1. Define diffusion.

   ....

2. Give one point of difference between osmosis and diffusion.

   ....

3. Name the process because of which crystals of $KMnO_4$ added to water makes it purple.

   ....

4. If blood cells are placed in salt water what will happen to them ? Based on your answer state if salt solution is isotonic, hypotonic or hypertonic?

   ....

5. When does plasmolysis occur in plant cells?

   ....

6. Name the phenomenon which makes it difficult to close a wooden door after monsoon?

   ....

8.2 WATER POTENTIAL

Water-Potential or chemical potential of water is the energy of water molecules or tendency of water to leave a system or the ability of free water molecules to do work or move. Water moves from a region of high water potential to a region of low water potential.

Water-Potential of pure water is taken as zero. When solutes are dissolved in pure water or in a solution some water molecules are used in dissolving the solutes thus less number of the water molecules are available to do the work. Hence a solution has less energy or potential as compared to pure water. The water potential of a dilute solution is more than that of a concentrated solution. The value of water potential of a solution is less than that of pure water or zero i.e. a negative number. Water potential is designated by a Greek letter ψ (psi). Pure water has highest water potential or $\psi = 0$ for pure water.

Water potential determines the water status in plant cells and tissues. The lower the water potential in a plant cell or tissue, the greater is its ability to absorb water. Conversely, the higher the water potential, the greater is the ability of the tissue to supply water to other more desiccated cells or tissues.

8.3 TURGOR PRESSURE

Turgor Pressure is the pressure exerted by the protoplasm against the cell wall.

In a turgid cell, the turgor pressure is equal to the back pressure exerted by the cell wall against the protoplasm. This back pressure exerted by the cell wall onto the protoplasm or the cell contents, is called as **wall pressure (WP).** These two pressures are equal and opposite in direction (Fig. 8.5). When TP becomes more than the WP the cell or will burst.

Turgor pressure is maximum when the cell wall cannot stretch any more. Such a cell is said to be fully turgid. At this point a dynamic equilibrium reaches i.e. the amount of water entering the cell is equal to amount of water leaving the cell.

Turgor pressure develops in the plant cells only because of the presence of cell wall which is able to resist the pressure generated by the protoplasm due to entry of water. It is a real pressure not a potential one and can occur to a great extent. In case of animal cells, where the cell wall is lacking, the plasma membrane bursts if the turgor pressure increases.

Turgor pressure plays a very important role in plants:

- Turgor pressure helps in maintaining the shape and form of the plant.
- The stems of herbaceous plants and the ones with non-woody tissues like maize, sugarcane and banana are held straight by fully turgid cells packed tightly together.
- Turgor pressure holds the leaves in a flat and horizontal position by keeping the mesophyll cells turgid.
- Turgor pressure helps in cell enlargement and consequently in stretching of the stems.
- Opening and closing of stomata is governed by turgidity and flaccidity of the guard cells.
- Certain plants like bean and Touch Me Not plant- *Mimosa pudica* show quick response of leaves due to change in light intensity or by touch stimulus followed by changes in the turgidity of cells present at the bases of leaves and leaflets.

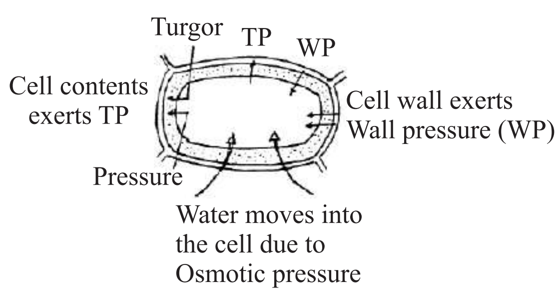


Fig. 8.5 A turgid cell showing osmotic pressure, turgor pressure and wall pressure.

Availability of water in the soil

The plants absorb water through the root hairs from the soil. The soil contains water in three forms (Fig. 8.6)

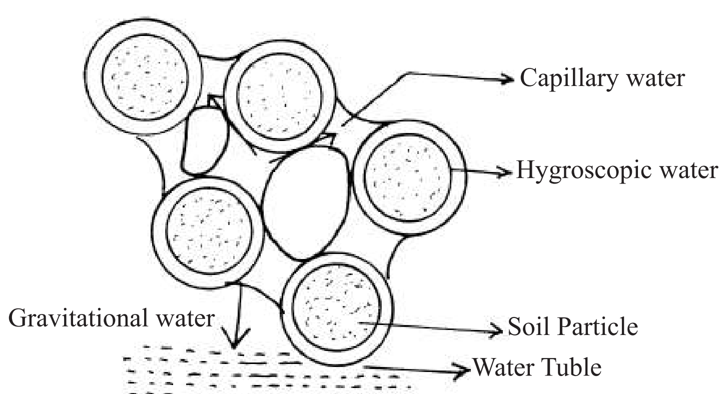


Fig. 8.6 Types of soil water.

(i) **Gravitational Water.** It is the water that drains downwards through the soil. The level to which it drains is called the water table. The water table of a place differs in depth due to rainfall.

The gravitational water lies far below and is generally not available to plant roots. It is of extreme importance as it causes washing out of minerals and nutrients from the soil through the process called leaching.

Part of water that is retained by soil could be hygroscopic water and/or capillary water.

(ii) **Hygroscopic Water.** It is the water that is retained as a thin film around the individual soil particles. Strong adhesive forces between the soil particles and the water molecules hold this water tightly. This is the water least available to the plant and is generally the water left in the dry soils. In the clay soils, it amounts to about 15% and in the sandy soils, it amounts to about 0.5%.

(iii) **Capillary Water.** The soil particles always have very fine pores in between, forming a very fine capillary system As the water spreads, it fills the finer pores and is held round the soil particles by capillary forces against the force of gravity, due to high surface tension of water. It is this water, which is readily available and is easily utilized by the plant roots. The clay soil being very fine textured holds much more water than sandy soil. When a soil rich in organic matter, is watered, it retains good amount of capillary water and this condition is known as **field capacity.**

8.4 ABSORPTION OF WATER BY PLANTS

- Major portion of water required by plants is absorbed by roots but in some cases water may be absorbed by leaves and stems also.
- Root hair is a specially modified epidermal cell meant for absorption of capillary water of the soil.
- The plasma membrane and the vacuolar membrane (tonoplast) act as semipermeable membranes and water is absorbed by osmosis.
- Soil solution should have a higher water potential as compared to root hair cell, then only water will enter the root hair cell. Once into the root hair, water will pass into cortical cells, endodermis, pericycle and into the xylem vessel. The movement of water is purely dependent on water potential gradient.
- Water movement into the plant follows two pathways – **symplast** and **apoplast** (Fig. 8.7a).
- Cytoplasm of the entire plant is connected through plasmodesmata which are the protoplasmic strands forming the **symplast system**. Water movement through the cells take this symplast pathway by osmosis.

  The cell wall and the intercellular spaces form the apoplast pathway which allows water movement inside the plant by the phenomenon of capillarity and adsorption.
- The water absorbed through the roots is transferred radially to the xylem, from where it reaches to all the other parts of the plant body by vertical conduction of water through the xylem vessels (Fig. 8.7b).

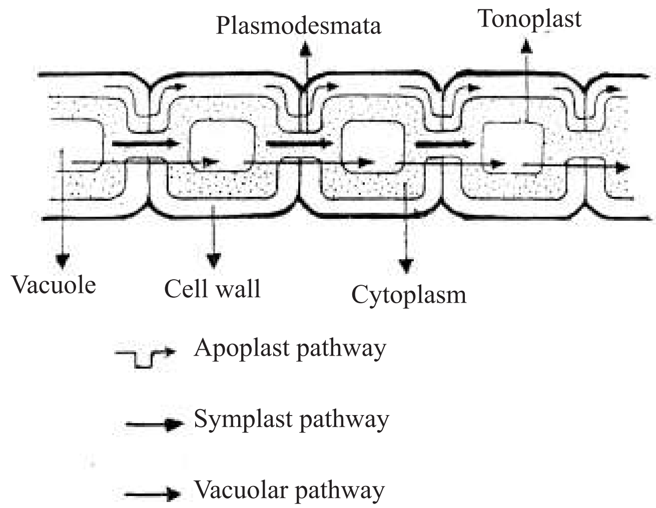


Fig. 8.7a various pathways of water movement

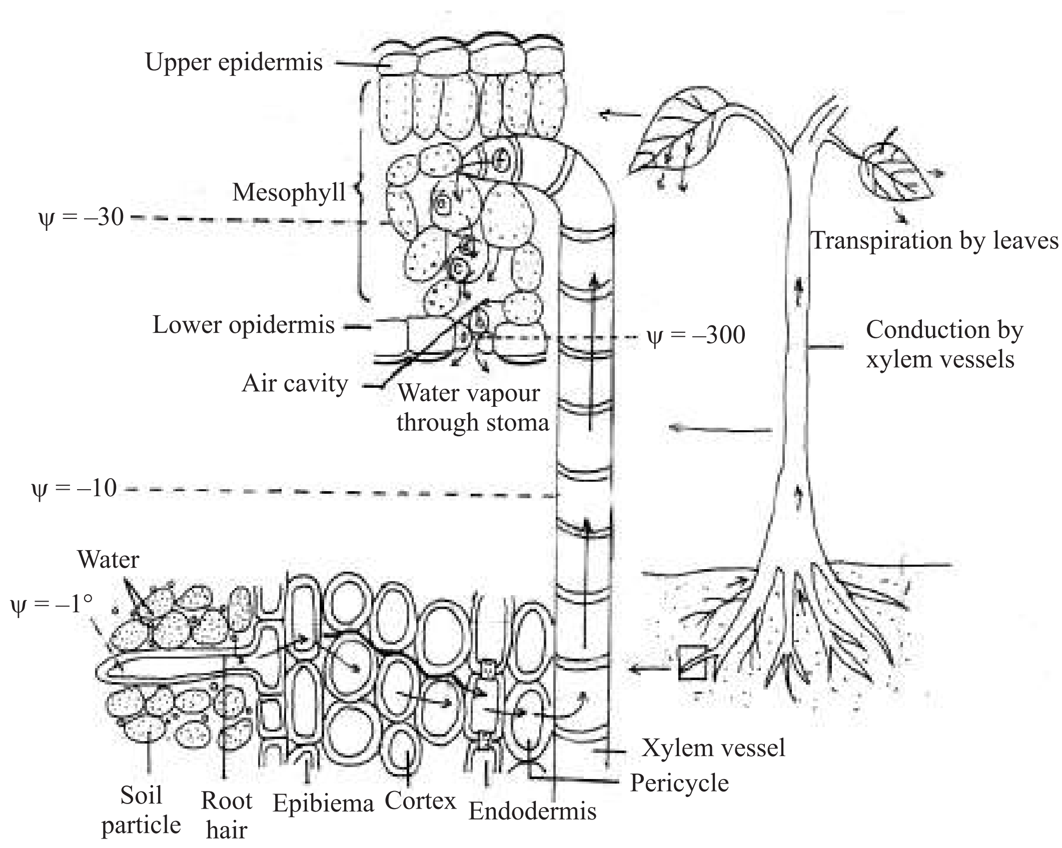


Fig. 8.7b Diagram to show absorption of water bvy root hair, its radial transport to cortex, and upward transport to leaves through xylem

Conduction of water through the xylem

The content of xylem vessels is known as xylem sap. Various theories have been postulated to describe the lifting of the xylem sap or ascent of sap in the xylem.

Root Pressure Theory

If a stem is cut few inches above from the ground with a sharp knife, xylem sap is seen flowing out through the cut end. This phenomenon is known as **exudation** and this is due to the positive pressure developed within the root system due to continuous absorption of water by osmosis which develops a positive pressure known as root pressure. This pressure can be measured and ranges from 3 to 5 atmospheres. But this pressure is enough to raise water to small heights in herbaceous plants, but it does not explain rise of water in stems of tall trees that are taller measuring 10 to 100 meters.

Physical Force Theory or Cohesion Theory

This theory takes into account the physical forces which explain uplift of water to great heights in very tall trees. The three forces that act together are force of cohesion (attraction between water molecules), force of adhesion (attraction between water and lignocellulose walls of xylem) and transpiration pull which lifts the water column by creating a tension inside the xylem vessel. Water forms an unbroken column starting from the intercellular space of the leaf mesophyll to the xylem of the leaf, through stem and root to the water in the soil. A water potential gradient exists between the leaf to the root and transpiration causes a pull of the entire water column. So long as the column is an unbroken one from the outer atmosphere, through the plant upto the soil, water is lifted up by the force of **transpiration pull.**

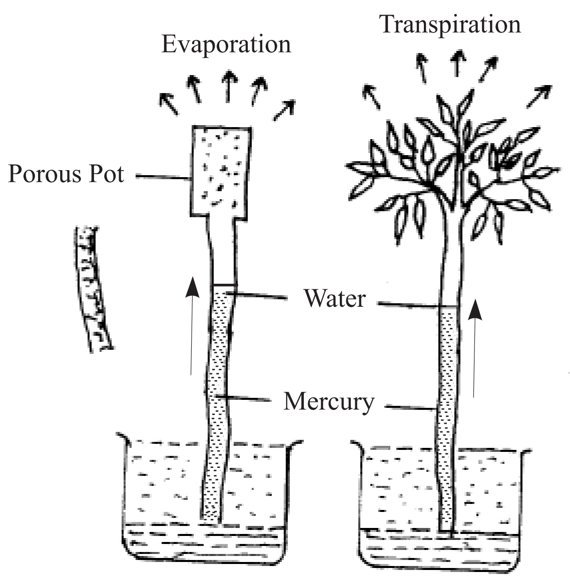


Fig. 8.8 Effect of evaporation and transpiration on absorption of water

8.5 TRANSLOCATION OF ORGANIC SOLUTES

Movement of organic and inorganic solutes from one part of the plant to another is known as translocation, e.g. transport of sugar in sieve tubes of leaves to stem or fruit.

There are experimental evidences to suggest that phloem is the tissue involved in translocation of products of photosynthesis i.e. sugars.

Sugar is produced in photosynthesis in the leaves and then sent to all part of the plants for the growth and development of the plant. Leaf is known as the "source", where the food is produced and all other parts of the plant which receive this food is known as the "sink". Sink can be root, stem, fruits and storage organs like tuber, bulbs and, rhizomes. Thus unlike conduction of water in xylem which takes place in one direction from the root to upwards in the aerial parts of the plant, phloem translocation from a leaf takes place in all directions.

Mechanism of translocation

Sugar solution in the phloem sieve tube moves along the water potential gradient created between the source (leaf) and sink (storage) cells

Here we find a mass movement of sugar solution from the leaf mesophyll to sieve tubes of leaf, and then, to all parts of the plant.

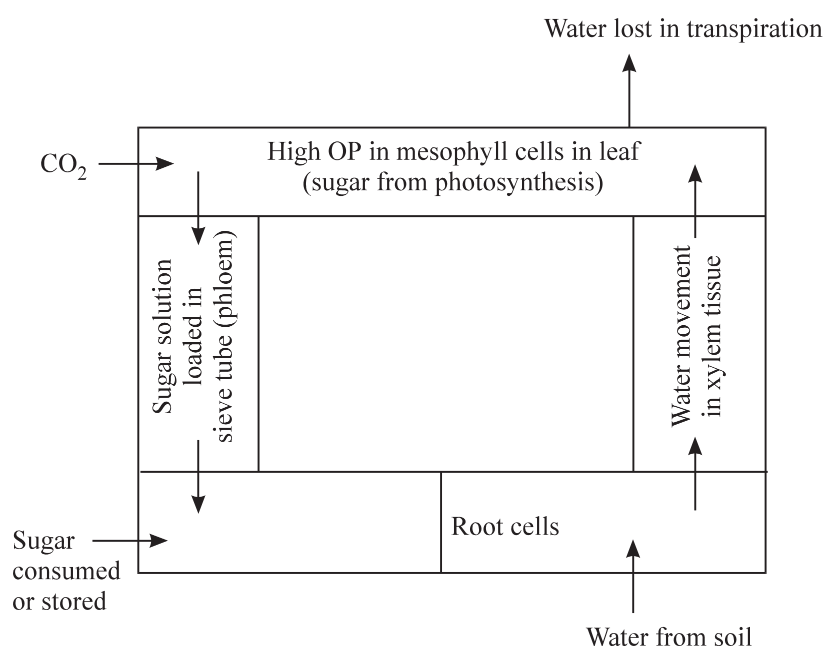


Fig. 8.9 Mechanism of translocation

This model known as Munch hypothesis or Mass flow theory is most acceptable model for phloem translocation.

INTEXT QUESTIONS 8.2

1. Which part of the plant absorbs water and minerals?

   ....

2. What are plasmodesmata?

   ....

3. How does translocation occur in plants?

   ....

4. What is the process of ascent of sap?

   ....

5. Which are three different forms in which water is present in the soil?

   ....

8.6 TRANSPIRATION

8.6.1 What is transpiration

The loss of water from aerial parts of the plant in the form of water vapour is termed **transpiration** and, when transpiration is low and absorption of water by roots is high, loss of water from leaves in the form of liquid is termed **guttation**.

Transpiration may occur through three main sites in the plant : 1. cuticle 2. lenticels and, 3. stomata.

(i) **Cuticle :** Cuticle is the waxy covering of the epidermis of leaves and green herbaceous stems. Though it is meant to check transpiration, still about 10% of the total transpiration may take place through fine cuticular pores, and he process is known as cuticular transpiration.

(ii) **Lenticels :** Lenticels are areas in the bark of stems, branches and fleshy fruits which are made up of loosely arranged cells that account for about 0.1 percent of water loss. It is known as lenticular transpiration.

(iii) **Stomata :** Stomata are minute pores on the epidermis of leaves, or tender green stems, whose opening and closing are controlled by guard cells. About 90 percent of water loss from plants takes place through stomata by the process known as stomatal transpiration.

8.6.2 Mechanism of transpiration

Transpiration occurs in two stages :

(i) Evaporation of water from the cell walls of mesophyll cells into the intercellular spaces.

(ii) Diffusion of this water vapour of the inter cellular spaces into the outside atmosphere, through cuticles, lenticels and stomata, when the outside atmosphere is drier.

8.6.3 Factors affecting transpiration

There are many external and internal factors that affect the process :

(i) Temperature : The increase in temperature increases the rate of transpiration by increasing the rate of evaporation of water from cell surface and decreasing the humidity of the atmosphere.

(ii) Wind velocity : The increase in wind velocity increases the rate of transpiration by removing the water vapour of the atmosphere and lowering the relative humidity, around the aerial parts of a plant.

(iii) Light : Light has got no direct effect on the rate of transpiration but indirectly it affects the rate in two ways, firstly by controlling the stomatal opening and secondly by affecting the temperature. With increase in intensity of light rate of transpiration increases because stomata get opened and the temperature increases.

(iv) Water supply : Deficiency of water supply in the soil decreases the rate of transpiration by decreasing the rate of absorption. When the deficiency of water in the soil becomes too much then the plants wilt and do not recover from wilting unless water is supplied in the soils. This is known as **permanent wilting**. When in a hot and dry summer day the plant transpires more causing higher water loss by the leaves than the roots are able to absorb, even though there is enough water in the soil, the plants wilt exhibiting **temporary wilting** as the plant recovers from such wilting in the late afternoon or at night.

(v) Atmospheric pressure : Reduction of atmospheric pressure reduces the density of external atmosphere thus permitting more rapid diffusion of water. Plants growing on high altitudes will show higher rate of transpiration hence they develop xerophytic characters.

(vi) Atmospheric humidity : Humidity means the amount of water vapour present in the atmosphere. The diffusion and evaporation of water depends on the vapour pressure gradient or the difference of water potential gradient between the atmosphere and the inside of the leaf. More the difference more will be the rate of transpiration.

Internal plant factors

Certain plant adaptations reduce transpiration

– Reduced size of the leaves, thereby reducing transpiring surface. Some xerophytic plants have needle like or spine like leaves (*Pinus* and *Opnuntia*)
– thick deposition of cutin (wax like substance) on the leaf surface.
– stomata found sunken in the cavities surrounded by epidermal hairs as in *Nerium* and *Cycas*.
– root shoot ratio, when there is more root and less of shoot system or leaves, there will be more of transpiration. Root is the water absorbing surface and shoot or leaves represent the transpiring surface; high root shoot ratio will cause more transpiration.

8.6.4 Role of Stomata in Transpiration

Since most of the water is lost through stomata, plants regulate the degree of stomatal opening and closing to reduce the water loss, with the help of guard-cells.

It has been seen that stomata show periodic opening and closing during the day (diurnal variation) depending upon the heat and light, water content of the cell and humidity. The stomata are generally closed during the night, and remain open during the day in the presence of sunlight.

From early morning till midday, the stomata are open and hence the transpiration increases till midday.

During the sunny mid-day, the stomata are closed and leaves get wilted to transpiration. From late afternoon till evening, the stomata are open again and hence the transpiration increases. At night, the stomata are closed and hence the transpiration is very low.

8.6.5 Stomatal-Apparatus

Structure of Stomatal-Apparatus

Each stoma represents a minute pore surrounded by two **guard cells**. Which in turn, are closely surrounded by two or more subsidiary cells. The stoma acts as a *turgor-operated valve,* which closes and opens according to alternate change in the flaccidity and the turgidity of guard cells and subsidiary cells. The guard cells have unevenly thickened walls. The cell wall **around stoma is tough and flexible** and the one away from stoma is thinner. The shape of guard cells differs in dicots and monocots, though the mechanism remains the same.

Mechanism of Stomatal action

The opening and closing of stomata depends upon the turgidity and flaccidity alternately in the guard cells and subsidiary cells. When the **guard cells are turgid, and subsidiary cells are flaccid, the stoma opens,** and, when **guard cells lose water** into subsidiary cells so that guard cells become flaccid and subsidiary cells become turgid, the **stoma closes.** The mechanism of opening and closing of stomata in dicots and monocots is as give below:

(a) The **dicotyledonous** plants have kidney shaped guard cells. The inner walls around the stoma are thicker than the outer walls.

A. When guard cells get distended by turgor pressure → Guard cells expand → Tough inner walls become convex → Stomata open

B When the turgor pressure in guard cells decreases → Guard cells sag → Inner cell walls come closer. → Stomata close

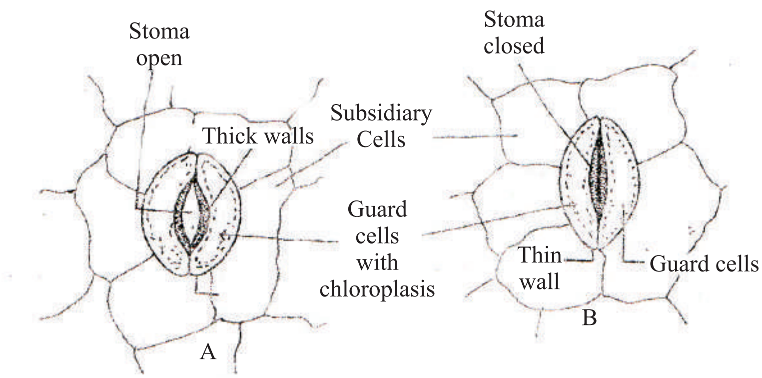


Fig. 8.10 Stomatal action in Dicots.

(b) In **monocotyledonous** plants, the guard cells are **dumb bell shaped** with thickened walls towards and nearest the stoma and thinner walls towards the inflated region.

A. When the guard cells become turgid → The region with thin walls bulges and gets inflated → The thick walls move apart → Stoma opens

B. When the guard cells lose water → The inflated part sags → The thick walls collapse → Stoma close

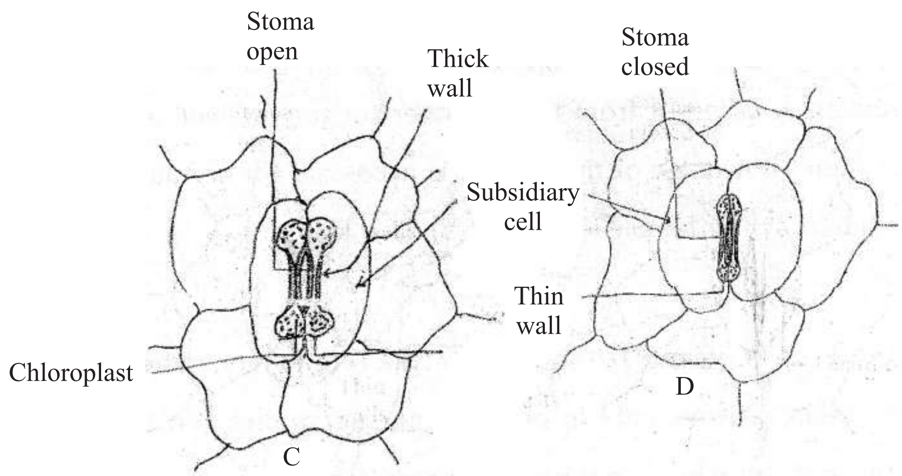


Fig. 8.11 Stomatal action in monocot.

Changes in turgidity and flaccidity, alternately involving guard cells and subsidiary cells, in bringing about opening and closing of stomata has been known for a long time but the mechanism that leads to turgidity needs to be explained.

(i) Starch- Sugar Hypothesis

This hypothesis goes by the basis that the increase in sugar concentration due to photosynthesis in guard-cells and hence endosmosis of water during the day leads to turgidity of guard cells leading to opening of stomata and the reverse i.e. decrease in sugar concentration followed by exosmosis leads to closing of the stomata at night. The changes in guard cells during the day i.e. in light and at night in the dark are as given below.

Reaction in Light

Utilization of CO_2 during photosynthesis in guard cells
↓
Drop in CO_2 leads to increase in pH or protoplasm becoming alkaline
↓
Conversion of starch into sugar
↓
Increased concentration of solute
↓
Endosmosis of water from subsidiary cells to the guard cells
↓
Increased turgor pressure of the guard cells leads to turgidity of guard cells accompanied by flaccidity of subsidiary cells
↓
Stoma opens
↓
A. Stoma opens during light

Reaction in Dark

Accumulation of CO_2 due to absence of photosynthesis in guard cells
↓
Increased acidity or decrease in pH due to formation of carbonic acid
↓
Conversion of sugar into starch
↓
Decreased concentration of solutes in guard cells
↓
Exosmosis of water from guard cells to subsidiary cells
↓
Decreased turgor pressure in guard cells leads to flaccidity of guard cells, accompanied by increased T.P. and turgidity of subsidiary cells.
↓
Stoma closed
↓
B. Stoma closed at dark

This theory can not explain stomatal movement where starch is absent in the guard cells or guard cells lack chloroplasts and opening of stomata at night and closing by the day in some plants like succulents (e.g. cacti).

(ii) Effect of potassium ions (K^+) on stomatal opening and closing

It has been convincingly proved that the accumulation of K^+ ions in guard cells brings about the opening of stomata and loss of K^+ ions from guard cells into subsidiary cells brings about, the closing of stomata.

During Day Light	During Night/Dark
Accumulation of K^+ ions by the guard cells	Loss of K^+ ions by the guard cells
↓	↓
Increased solute concentration	Decreased solute concentration
↓	↓
Endosmosis of water	Exosmosis of water
↓	↓
Increased turgidity	Decreased turgidity
↓	↓
Stoma opens	Stoma closes

The uptake of K^+ ions is balanced by one of the following.

(a) **Uptake of chloride (Cl^-) ions** as anions. The subsidiary cells lack chloroplast and take up Cl^- ions as anions to balance the influx of K^+ ions.

(b) **Transport of H^+ ions released from organic acids.** In some plants the guard cells contain starch, There is accumulation of organic acid like malate by conversion of starch into malic acid in light. The organic acid dissociates into malate and H^+. Potassium reacts with malate to form potassium malate which increases the solute concentration.

(c) Entry of K^+ is balanced by exit of protons (H^+).

(iii) Role of Abscisic Acid (ABA)

It has been observed that during water shortage in the soil or by intense solar radiation, a plant hormone abscisic acid accumulates in the leaves leading to closing of stomata, thus preventing an excessive water loss. Under experimental conditions also, when abscisic acid is applied to the leaves, stomata get closed and check water loss.

8.6.6 Significance of transpiration

(i) **Absorption of water.** Transpiration pull influences the rate of absorption of water from the soil.

(ii) **Water movement.** By transpiration, water moves upwards and as it passes into the cell vacuoles, it makes the cells turgid. This gives a form and shape to the cells and to the plants as a whole.

(iii) **Mineral salt transport.** The water stream moving upwards also carries the dissolved minerals required for the development of the plant. Transpiration also helps in distributing these minerals through out the plant body.

(iv) **Cooling.** The evaporation of water during transpiration cools the leaves.

(v) **Protection from heat injury.** Some plants like Cacti retain water by reducing transpiration. This saves the plants from high temperatures and strong sunlight.

Transpiration is a necessary evil

Stomata remain open during day time for the absorption of carbon dioxide and release of oxygen for a very important process of photosynthesis. When the stomata remain open for this important gaseous exchange, escape of water vapour cannot be controlled. Thus loss of water is a wasteful process which cannot be avoided because stomata must remain open to do some thing more important that is absorption of carbondioxide during day time for photosynthesis. It is for this reason that Curtis in 1926 has referred transpiration as a necessary evil.

Factor affecting stomatal movement : Any condition which causes turgidity of the guard cell will cause stomatal movement.

1. Increased Solute concentration of the guard cells, which will allow endosmosis of water into the guard cells making them turgid.
2. Light causes photosynthesis in guard cell by the chloroplasts and hence accumulation of sugar in the guard cells would increase concentration of solutes in guard cells.
3. Entry of potassium ions from subsidiary cells into guard cells would further increase solute concentration in guard cells.

8.6.7 Anti-transpirants

Many crop plants give poor yield in dry seasons, as the water lost by transpiration is much more than the water uptake by the roots. The rate of transpiration can be reduced by the application of certain chemicals known as anti transpirants. These chemicals however, should not affect the CO_2 uptake. The reduction in transpiration is achieved by two means.

(i) Chemicals like phenyl mercuric acetate – PMA and abscisic acid –ABA cause partial closure of stomata checking transpiration to some extent.

(ii) Some waxy substances like silicon emulsions form a thin film over the leaf and cover the stomata without affecting the uptake of CO_2.

Guttation. It is seen in early morning in the form of water-drops at the margins or tips of leaves of herbaceous plants (Fig.8.12a). The plants in which transpiration is low and the root pressure is high, the liquid water droplets are seen at the vein ending.

– It occurs through specialized pores called hydathodes present near the vein endings (Fig. 8.12b).

– It is quite common in young grass seedlings and in the tropical rain forests due to warm and humid nights. Tomato and *Nasturtium* are some common examples.

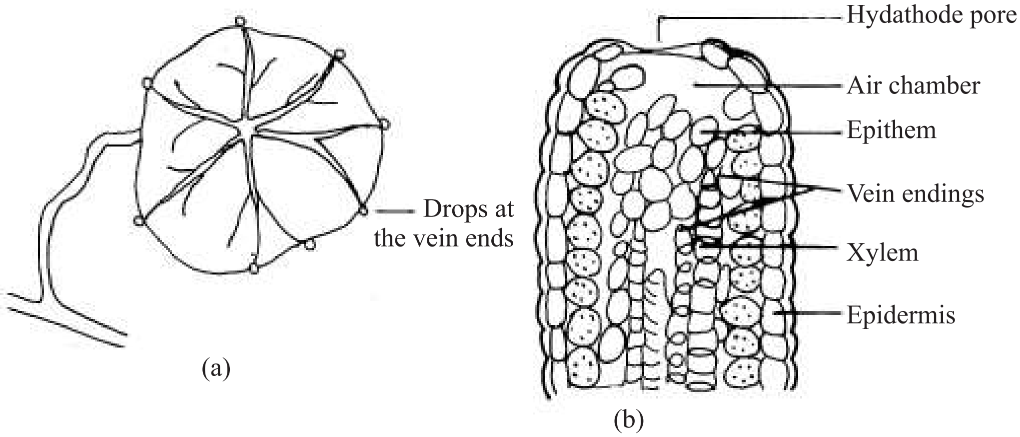


Fig. 8.12 (a) *Nasturtium* leaf showing guttation at the margin of leaf (b) A vertical section of a leaf showing hydathode.

8.6.8 Difference between Transpiration and Guttation

Transpiration	Guttation
(i) Water is lost in the form of water vapor.	(i) Water is lost in the form of water drops.
(ii) Occurs through stomata, cuticle and lenticels.	(ii) Occurs through special pores, called hydathodes.
(iii) Occurs during day time and at high temperature.	(iii) Occurs at night and early in the mornings at low temperature.
(iv) Water vapour lost is pure water and does not contain minerals.	(iv) Water lost has substances dissolved in water. It contains sugars, salts and amino acids.
(v) Increased transpiration is physical process (see cohesion physical force theory)	(v) It is due to increased root pressure that develops in the aerial shoot system when water absorption by roots is more and transpiration by aerial plant parts is low.

INTEXT QUESTIONS 8.3

1. Name the pressure in guard cells responsible for opening and closing of stomata.
   ....
2. Mention the shape of guard cells in monocots and dicots.
   ....
3. Give a point of difference between a stoma and a hydathode
   ....

WHAT YOU HAVE LEARNT

- The movement of water from one cell to another depends upon the water potential of the cells.
- Water always moves from a region of lower solute concentration (higher water potential) to the region of higher solute concentration (lower water potential) i.e. along the water potential gradient.
- A more concentrated solution has a higher osmotic potential (earlier termed osmotic pressure).
- Osmotic pressure is expressed in terms of energy. Water always moves from a region of higher free energy to a region of lower free energy.
- Water potential is the capacity of a solution to give out water. It is represented by the word Psi ψ. It is affected by the solute concentration and external pressure.
  - ψ of pure water = zero.
  - More solute means low water potential.
  - A solution has lower water potential than pure water.
  - Water potential of a solution is a negative number i.e. less than zero.
- Plants absorb water by their roots (mainly by root hair) from the soil through osmosis. The increased water content inside the protoplasm exerts a turgor pressure on the cell wall.
- The equal and opposite force exerted by the cell wall onto the cell contents is termed as wall pressure.
- Water is present in the soil as gravitational water, hygroscopic water (least available to the plant) and capillary water (most readily available to the plant).
- The water absorbed by root hairs flows to the xylem vessels mainly by the apoplast pathway.
- The water moves up through the xylem vessels to the leaf along the water potential gradient as explained by the cohesion- tension theory (most acceptable). Transpiration or evaporation of water from the plant through stomata, causes a pull and water moves up like a water column due to the force of cohesion and tension created by transpiration.
- Certain plants show guttation due to high root pressure and low transpiration.
- Turgidity of guard cells is explained by the increased conversion of starch into sugar and by the accumulation of K^+ ions.

- Various environment factors like temperature, light, wind, humidity and internal factors like structure of leaf and root-shoot ratio affect the transpiration.
- Transpiration not only brings about ascent of sap but also has a cooling effect and saves the plant from heat injury.
- When the transpiration rate exceeds the water absorption rate, it leads to **temporary wilting** of the plant.
- When a plant undergoes wilting due to water deficit in the soil, it is called **Permanent Wilting.**

TERMINAL EXERCISES

1. Name two types of passive absorption in plants.
2. In what ways diffusion is important to a plant ?
3. Name various factors that affect osmosis in plants.
4. Differentiate between turgor pressure and wall pressure.
5. Discuss the mechanism of stomatal opening in dicot plants.
6. Explain any four factors that affect transpiration in plants.
7. Describe an experiment to demonstrate osmosis by potato osmometer.
8. Discuss the cohesion tension theory for uptake of water in plants.
9. Describe the mechanism of translocation of solutes. Name the most appropriate theory for the translocation of solutes in plants. Who proposed this theory ?
10. Differentiate between symplast and apoplast pathway of water movement in plants.
11. Define transpiration.
12. Name the holes in the bark through which transpiration in the bark of old trees takes place ?
13. Why is transpiration considered to be a necessary evil ?
14. Give one way by which desert plants prevent transpiration.
15. State one point of difference between transpiration and guttation.

ANSWERS TO INTEXT QUESTIONS

8.1

1. Movement of molecules from their region of higher concentration to the region of lower concentration.
2. A semipermeable membrane is required for osmosis and not necessarily for diffusion.
3. Diffusion

4. Water will move out from the blood cells and they will shrink.
5. When the cell is placed in a hypertonic solution.
6. Imbibition

8.2
1. Root
2. Cytoplasmic connections between plant cells
3. Through the phloem
4. Movement of water and minerals from roots to leaves, that is from the ground to tip of plant.
5. Gravitational, Hygroscopic and capillary

8.3
1. Turgor pressure
2. Dicot : Kidney shaped

   Monocots : Dumb bell shaped
3. Stomata – are pores on the leaf surface through which water diffuses as vapour

   Hydathodes – special pores in leaf margins through which water is lost as water droplets.

9

NUTRITION IN PLANTS – MINERAL NUTRITION

Sometimes you may observe that a potted plant kept in sunlight and provided with sufficient water does not grow. Its leaves look pale and weak. Plant may not even flower properly. Such a situation is an indication, that the plant may not be getting all that is required for normal growth and development.

In most of such situations one or more minerals required may be lacking in the soil. You might have seen farmers adding some extra manure (khad) to the soil. In this lesson you will learn the importance of mineral nutrition in plants.

OBJECTIVES

After completing this lesson, you will be able to :

- *define the terms mineral nutrition, macro and micro nutrients;*
- *explain the functions of minerals with reference to the techniques of hydroponics and aeroponics;*
- *list the role of macro and micro nutrients;*
- *mention the deficiency symptoms of macro and micro nutrients;*
- *differentiate between autotrophic and heterotrophic nutrition in plant;*
- *describe the saprophytic and parasitic modes of nutrition in plant.*

9.1 WHAT IS PLANT NUTRITION

As you know that all living organisms require food to survive, grow and reproduce so every organism takes in food and utilizes the food constituents for its requirements of growth. A series of processes are involved in the synthesis of food by plants, breaking down the food into simpler substances and utilization of these simpler substances for life processes. **Nutrition** in plants may thus be defined as a process of synthesis of food, its breakdown and utilisation for various functions in the body.

The chemical substances in food are called nutrients e.g. CO_2, water, minerals, carbohydrate, protein, fats etc. Green plants can make their own organic food from simple substances like water and carbon dioxide through the process of photosynthesis and are called autotrophs (auto : self; trophos : feeding). But the non-green plants and other organisms which cannot prepare their own food and obtain nutrition from green plants are called **heterotrophs** (heteros : different).

9.2 MINERAL NUTRITION

Now we will discuss how plants get the nutrients. You already know that carbohydrates are synthesised by the process of photosynthesis. What are the elements present in these carbohydrates?

Carbon, hydrogen and oxygen are the main elements in carbohydrates, fats and proteins. In addition to these three elements, plants need a variety of elements for their survival. These are generally referred to as mineral elements. They are absorbed by the root system of plants in the form of their salts.

The study of how plants get mineral elements and utilize them for their growth and development is called **mineral nutrition.**

If the minerals are not available to plants, specific symptoms appear due to the deficiency of a particular element. There are methods to determine the requirement of minerals by plants. Some such methods are given below.

9.3 METHODS TO DETERMINE THE REQUIREMENT OF MINERALS FOR PLANT

Minerals are absorbed by plants in **solution form.** So it is possible to grow plants in water containing the desired amount of mineral salts taking care that the aerial parts are exposed to air and light.

> This technique of growing plants in a nutrient solution in complete absence of soil is known as **Hydroponics/water culture.**
>
> It was demonstrated for the first time by a German Botanist Julius Von Sachs in the year 1980.

In water culture experiments, seedlings are made to grow in water containing the known nutrients in a particular proportion. Vigorous bubbling of the air is routinely done to provide sufficient oxygen to the root system. The culture solutions may contain all essential nutrients except the one whose importance is to be identified. Then the plant growing in it is compared to the one growing with all essential nutrients (**control experiment**).

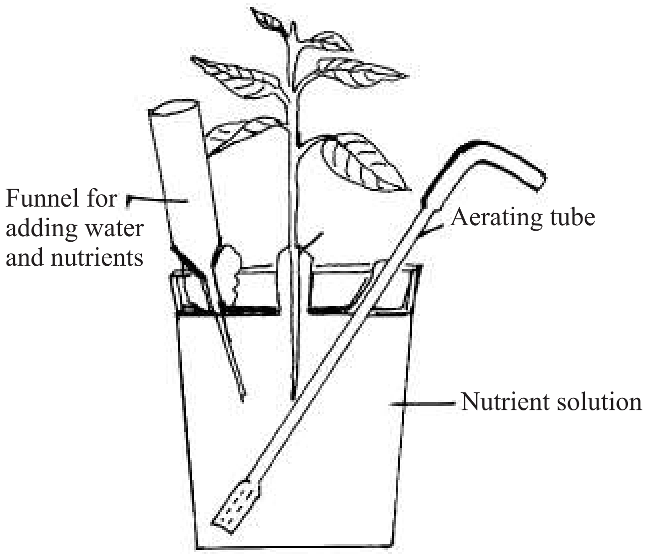


Fig. 9.1 Experimental set up for nutrient solution culture of plants.

Water culture experiments help us to understand :

(i) which element is essential for normal growth of the plant.

(ii) which element is not essential and is absorbed along with other nutrients.

(iii) how much quantity of each mineral is essential.

Hydroponics has been successfully employed for the commercial production of seedless cucumber, tomato and lettuce.

> **Aeroponics :** Like hydroponics, aeroponics is another technique of growing plants in an air/mist environment without the use of soil.

Aeroponics is a technique of growing plants with their roots supplied with moisture present in the air. Rooted plants are placed in a special type of box. The shoots of the rooted plants are exposed to air and the roots are inside the box having computer controlled humid atmosphere. The roots are sprayed/misted for short durations with a hydro-atomized pure water/nutrient solution. This method has been developed recently. Since plants cultured by this technique get a very good growth of root hairs, it is very useful method for research purposes. Citrus plants and olives have been successfully grown through aeroponics.

INTEXT QUESTIONS 9.1

1. What are nutrients ?

   ....

2. Define aeroponics.

   ....

3. Why is it necessary to aerate nutrient solution in water culture?

   ....

9.4 ESSENTIAL MINERAL ELEMENTS

You know that 112 elements have been discovered until now. So you might be wondering whether plants require all 112 elements for their mineral nutrition. Most of the mineral elements present in soil are absorbed by roots of the plant. But all are not essential. Only **17 elements** are considered as essential for the plants. Let us now discuss the criteria for the essentiality of an element for normal plant growth.

9.4.1 Criteria for Essentiality of Elements

The nutrients or elements which are essential for the healthy growth of the plant are called **essential nutrients or essential elements.** The roots absorb about 60 elements from the soil. To determine which one is an essential element, the following criteria are used :

(i) An essential element is absolutely **necessary for normal growth** and **reproduction** of the plant, and should be a part of essential metabolite for plant growth.

(ii) The requirement of the element is very specific and it **cannot be replaced** by another element.

(iii) The element is **directly** or indirectly **involved** in the metabolism of a plant.

(iv) In the deficiency of an essential element, the plant would exhibit specific symptoms of deficiency, and the plant would recover from its symptoms, if supplied with the deficient element.

Example : Magnesium is said to be an essential element because it is essential for the formation of chlorophyll molecule. Its deficiency causes yellowing of leaves.

9.4.2 Types of Essential Elements

Essential elements may be required in small amounts or large amounts. Accordingly they have been grouped into two categories

Essential Elements

Micro elements/Micronutrients	Macro elements/Macro nutrients
Required in minute quantities like 0.1 mg per gram of dry matter or less than that. Also called as **trace elements.**	Required in relatively large quantities like one to 10 milligram per gram of dry matter
Examples : Manganese, Boron, cobatt Copper, Molybdenum, Iron, Zinc and Chlorine are required in very small quantities	**Examples :** Carbon, Hydrogen, Oxygen Phosphorous, Potassium, Calcium and magnesium, Nitrogen, Sulphur

9.4.3 Sources of Essential Elements for Plants

After studying the types of essential elements we will now discuss about their sources. Most of the essential elements are taken from soil, and some from the atmosphere. The table given below focuses on the sources of different essential elements.

Table 9.1 **Sources of Essential Elements**

Elements	Sources of the elements
Carbon	Taken as CO_2 from the atmosphere (air)
Oxygen	Absorbed in the molecular form from air or from water. It is also generated within a green plant during photosynthesis.
Hydrogen	Released from water during photosynthesis in the green plant
Nitrogen	Absorbed by the plants as nitrate ion (NO_3^-) or as ammonium ion (NH_4^+) from the soil. Some organisms like bacteria and cynobacteria can fix nitrogen from air directly.
Potassium, calcium iron, phosphorus, sulphur magnesium	absorbed from the soil (are actually derived from the weathering of rocks. So they are called mineral elements). They are absorbed in the ionic forms e.g. K^+, Ca^{2+}, Fe^{3+}, $H_2PO_4^-$/ HPO_4^{2-} etc.

INTEXT QUESTIONS 9.2

1. In which form do plants get oxygen?

   ....

2. Molybdenum is a micronutrient. Give reason.

   ....

3. Why are carbon, oxygen, potassium and sulphur called macronutrients?

   ....

9.5 ROLE OF MACRO AND MICRO NUTRIENTS

Essential elements perform various functions. They carry out several metabolic processes in the plant cells like the maintenance of turgidity of cell, transportation of electrons, membrane permeability and enzyme activity. Essential elements also act as important constituents of the biomolecules and co-enzymes. Various functions of the macro and micro nutrients are given in the following table.

The forms in which the elements are taken in and their functions are described in the table given below -

Table 9.2 Essential Elements and their Functions

Element	Form in which the element is taken in	Region of the plant that requires the element	Function
Nitrogen, N	NO_2^-, NO_3^- or NH_4^+ ions	All tissues, particularly in meristematic tissues	Required for the synthesis of amino acids, proteins nucleic acids, vitamins, hormones, coenzymes, ATP and chlorophyll.
Phosphorus, P	$H_2PO_4^-$ or HPO_4^{2-}	Young tissues from the older metabolically less active cells	Required for the synthesis of nucleic acids phospho-lipids, ATP, NAD and NADP. Constituent of cell membrane and some proteins.
Potassium, K	K^+	Meristematic tissues buds, leaves and root tips.	Activates enzymes, associated with K^+/Na^+ pump in active transport, anion-cation balance in the cells. Brings about opening and closing of stomata. Common in cell sap in plant cell vacuole and helps in turgidity of cells.
Calcium, Ca	Ca^{2+}	Meristematic and differentiating tissues Accumulates in older leaves	Present as calcium pectate in the middle lamella of cell walls that joins the adjacent cells together. Activates enzymes needed for the growth of root and shoot tip. Needed for normal cell wall development. Required for cell division, cell enlargement.
Magnesium, Mg	Mg^{2+}	Leaves of the plant	Forms part of the chlorophyll molecule. Activates enzymes of phosphate metabolism. Important for synthesis of DNA and RNA. Essential for binding of ribosome subunits.
Sulphur, S	SO_4^{2-}	Stem and root tips young leaves of the plant	As a constituent of amino acids cysteine and methionine and of some proteins. Present in co-enzyme A, vitamin thiamine, biotin and ferredoxin. Increases root development. Increases the nodule formation in legumes.

Iron, Fe	Fe^{3+}	Leaves and seeds	Needed for the synthesis of chlorophyll. As a constituent of ferredoxin and cytochromes. Activates the enzymes catalase.
Manganese Mn	Mn^{2+}	All tissues. Collects along the leaf veins.	Activates many enzymes of photosynthesis, respiration and N_2 metabolism. Acts as electron donor for chlorophyll b. Involved in decarboxylation reactions during respiration.
Molybdenum Mo	MoO_2^{2+}	All tissues particularly in roots	Required for nitrogen fixation. Activates the enzyme nitrate reductase.
Boron, B	BO_3^{3-} or $B_4O_7^{2-}$	Leaves and seeds	Increases the uptake of water and calcium. Essential for meristem activity and growth of pollen tube. Involved in translocation of carbohydrates
Copper, Cu	Cu^{2+}	All tissues	Component of oxidase enzymes and plastocyanin. Involved in electron transport in photosynthesis.
Zinc, Zn	Zn^{2+}	All tissues	Component of indoleacetic acid – a plant hormone. Activates dehydrogenases and carboxylases. Present in enzyme carbonic anhydrase
Chlorine, Cl	Cl^-	All tissues	Essential for oxygen evolution in photosynthesis. Anion-cation balance in cells.

INTEXT QUESTIONS 9.3

1. State any two metabolic processes for which mineral nutrition is required.

   ....

2. Which element is provided by NO_2 and NH_4 when taken up by plants?

   ....

3. State any two functions of Ca^{2+} in plants?

   ....

9.6 SYMPTOMS OF MINERAL DEFICIENCY IN PLANTS

The absence or deficiency (not present in the required amount) of any of the essential elements leads to **deficiency symptoms.** The symptoms can be studied by hydroponics. Under natural conditions, these symptoms can be taken as indicators of the mineral deficiencies in the soil.

Some common deficiency symptoms are :

- **Chlorosis** - It is the loss of chlorophyll leading to yellowing in leaves. It is caused by the deficiency of elements like K, Mg, N, S, Fe, Mn, Zn and Mo.
- **Necrosis** or death of tissues, particularly leaf tissue is caused by deficiency of K, Ca, Mg
- **Inhibition of cell division** is caused due to lack or deficiency of N, K, B, S and Mo.
- Stunted/Retarded plant growth caused by the deficiency of N, P, K, Zn, Ca
- Premature fall of leaves and buds is caused by deficiency of K, P.
- Delay in flowering is caused due to deficiency of N, S, Mo.

9.7 UPTAKE OF MINERAL ELEMENTS

Plants absorb a large number of minerals from soil. The uptake of mineral ions by the roots may be **passive** or **active**.

(a) **Passive Absorption** : It is the initial and rapid phase wherein ions are absorbed into the “outer space” of the cells, through the apoplast (Recall from lesson No. 08) pathway. It does not require use of any metabolic energy.

(b) **Active Absorption :** It is the second phase of ion uptake. The ions are taken in slowly into the ‘inner space’ the symplast of cells (Lesson No. 08). It needs the expenditure of metabolic energy.

The movement of ions is called **flux.** When the ions move into the cells, it is called **influx** and the outward movement of ions is called **efflux**.

The mineral ions absorbed by the root system are translocated through the xylem vessels to other parts of the plant.

INTEXT QUESTIONS 9.4

1. What is meant by ‘passive absorption’ of minerals by plants.

   ....

2. Name the minerals whose deficiency affects normal cell division.

   ....

3. “Deficiency of K, Ca and Mg causes necrosis of leaves”. What does this statement mean ?

   ....

9.8 MODE OF NUTRITION IN PLANTS

Nutrition is plants is classified into two main categories : autotrophic and heterotrophic. Heterotrophic plants are further classified into saprophytes, parasite and insectivores.

Nutrition in Plants

- Autotrophic Nutrition (Auto = self; trophos = feeder)
- Heterotrophic Nutrition (Hetero = other; trophos = feeder Heterotrophic plant)
  - Saprophytic plants/ Saprophytes (Sapros = rotten; Phyton = plant
  - Parasitic plants/Parasites (Para = beside; sites = food)
  - Insectivorous plants/ Insectivores (eat insects)

1. Autotrophic Nutrition

It is a type of nutrition in which the living organisms manufacture their own organic food from simple inorganic raw materials. The green plants exhibit autotrophic mode of nutrition and hence called the autotrophs. The autotrophs require external energy source for the manufacture of organic substances. Green plants obtain energy from sunlight and therefore are called **photoautotrophs**. The process of synthesizing food in plant in the presence of sunlight is called **photosynthesis**. The insectivores are autotrophic but they develop specific structures to trap insects to overcome N_2 deficiency because they grow in soils having acute N_2-deficiency.

2. Heterotrophic nutrition

Certain non green organisms like fungi and many bacteria fail to synthesize their own organic nutrients from inorganic substances. These organisms are thus dependent on some other external sources for their organic nutrition. Such plants are called **heterotrophic plants** and the mode of nutrition is called **heterotrophic nutrition.**

The heterotrophic plants are broadly categorised into two main groups depending upon the source from which they get their nourishment. Saprophytes, and parasites.

(a) **Saprophytes** are those plants which grow and live on dead organic matter including animal and plant remains. Most of these plants secrete some extracellular enzymes (enzymes secreted and poured out on food) which break down the complex organic compounds into simple forms. The simple form are then absorbed by the plants. Saprophytes include mainly fungi and bacteria. Also among higher plants the Indian pipe plant *Monotropa* found in khasi hills of our country (Fig. 9.2) is a saprophyte.

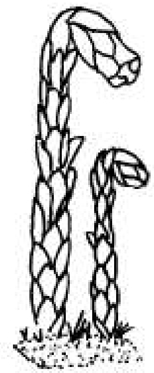


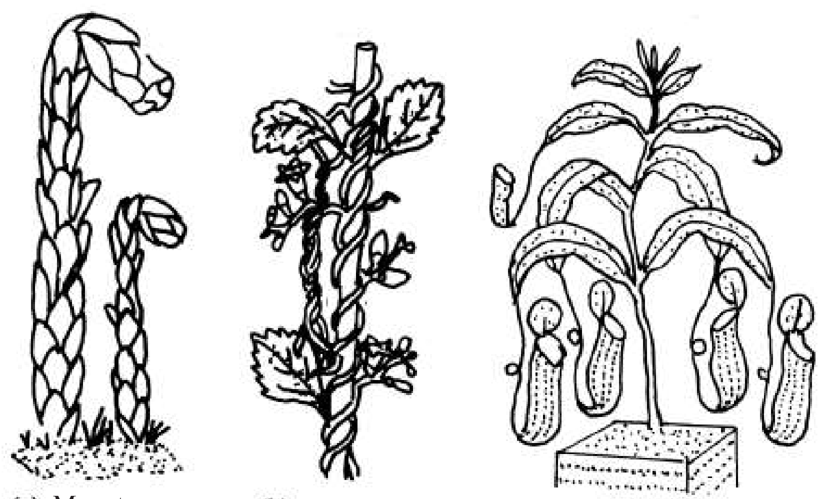
Fig. 9.2 A Monotropa, a saprophyte.

(b) **Parasitic Plants** : *Dodder* (*Cuscuta*) known locally as Amarbel/Akashbel is a parasitic plant that lacks both chlorophyll and leaves. It is a yellow colour climber that attaches itself to the host. It gives out haustoria or the suckers that get attached to the phloem of the host and derive nutrition. *Cuscuta* does not have roots in the mature condition. It produces bunches of whitish or yellowish bell shaped flowers.

Insectivorous Plants : These are plants which are autotrophic but develop adaptations to trap insects in order to **supplement the deficiency of Nitrogen in the soil**. They feed on insects. They are generally found in nitrogen deficient habitats and hence to compensate the loss, they use insects as a source of nitrogen. Some examples are given below :

(i) Pitcher plant : *Nepenthes* (ii) Sundew : *Drosera*

(iii) Venus flytrap : *Dionaea* (iv) Bladderwort : *Utricularia*



(a) Monotropa (b) Cuscuta (c) Nepenthes

Fig. 9.3 Heterotrophic plants : (a) *Monotropa* (Indian pipe plant (b) *Cuscuta* (dodder) and (c) *Nepenthes* (pitcher plant)

Pitcher plant (Nepenthes) : It is found in north eastern India, Borneo and in many regions of North America.

These plants grow well in wet soils. The leaves are modified in the form of pitchers. The pitcher has nectar producing glands below its rim. Shiny surface of the pitcher and nectar secreted by nectar glands attract the insects. Insects once trapped can not escape due to the presence of numerous downward pointing hairs in the pitcher. The digestive glands present at the base of pitcher secrete enzymes. The insects are digested by the enzymes and the products which are mainly aminoacids are absorbed by the inner surface of leaves (pitcher).

INTEXT QUESTIONS 9.5

1. Give one point of difference between autotrophic and heterotrophic nutrition.

   ....

2. Name a plant which exhibits parasitic mode of nutrition.

   ....

3. Why does pitcher plant eat insects when it is capable of carrying out photosynthesis?

   ....

WHAT YOU HAVE LEARNT

- Plants have the nutritional requirement of various inorganic and organic raw materials for building their structure and maintaining body functions.
- Nutrition is the sum total of processes involving intake or synthesis of food and its utilisation.
- Plants generally derive their inorganic nutrients from soil, water and atmosphere.
- The absorption, distribution and metabolism of various mineral elements by plants is called mineral nutrition.
- Plants require 17 essential elements. They are C, H, O, N, P, K, S, Mg, Ca, Fe, B, Mn, Cu, Zn, Mo, Cl and Co.
- The essentiality of minerals may be determined by employing the technique of hydroponics and aeroponics.
- Inorganic nutrients are broadly classified into two categories-micronutrients and macronutrients on the basis of the amount required by plant.
- Absence of any one element may cause deficiency symptoms in plants. These symptoms include reduction in growth, delaying of flowering, chlorosis, necrosis, early leaf fall, wilting etc.

- The minerals are taken by the roots through passive or active absorption.
- Basically, there are two modes of nutritioin autotrophic and heterotrophic.
- In autotrophic nutrition the organisms (plants) manufacture their own food from inorganic raw materials by photosynthesis or chemosynthesis.
- In heterotrophic nutrition the organism is dependent on other external sources for its organic nutrition.
- Heterotrophic plants are broadly categorised into two main groups: saprophytes, and parasites.
- Insectivorous plants are special type of autotrophic plants which grow in N_2-deficient soils and develop adaptations to trap insects to overcome N_2-deficiency.

TERMINAL EXERCISES

1. Which element can be obtained from both mineral and non-mineral sources.
2. Deficiency of which essential element causes yellowing of leaves in certain plants and why?
3. Why is magnesium included among essential elements?
4. What are the criteria of essentiality of elements?
5. Differentiate between micro and macro nutrients.
6. Why do biologists grow plants by hydroponics technique?
7. Explain the uptake of mineral nutrients by the plants.
8. Give the deficiency symptoms of nitrogen, phosphorus and potassium.
9. Differentiate between the different modes of heterotrophic nutrition in plants.
10. Write notes on :

    (i) Aeroponics

    (ii) Insectivorous plants

    (iii) Active absorption of minerals by plants

ANSWERS TO INTEXT QUESTIONS

9.1 1. Nutrients are the chemical substances in food

2. A technique of growing plants with roots supplied with moisture present in the atmosphere.

3. To supply oxygen in sufficient quantity

9.2 1. Molecular form from air or water

2. Required by plant in very small quantity. 0.1 mg per gram of dry matter or less.

3. They are required in large quantities 1-10 mg per gram of dry matter.

9.3 1 Membrane permeability, turgidity of cell, transport of electrons, enzyme activity (any two)

2. Nitrogen

3. See table 9.2

9.4 1. Without expenditure of energy

2. N, K, S, Mo (any two)

3. The deficiency causes death of leaf tissues

9.5 1. Autotrophs synthesize their own food, heterotrophs depend on others for food

2. *Cuscuta* (dodder)

3. Because it grows in a nitrogen deficient habitat.

10

NITROGEN METABOLISM

All the living organisms are basically composed of carbon, hydrogen, oxygen, nitrogen and many other forms of chemical elements. These elements contribute to finally organize various biomolecules present in a cell. Nitrogen is next to carbon in importance in living organisms. In a living cell, nitrogen is an important constituent of amino acids, proteins, enzymes, vitamins, alkaloids and some growth hormones. Therefore, study of nitrogen metabolism is absolutely essential because the entire life process is dependent on these nitrogen-containing molecules. In this lesson, you will learn about various aspects of nitrogen metabolism including nitrogen fixation and nitrogen assimilation in plants.

OBJECTIVES

After completing this lesson, you will be able to:

- *describe the modes of nitrogen fixation (both biological and abiological);*
- *explain the steps involved in nitrogen fixation by free living organisms;*
- *explain the mode of symbiotic nitrogen fixation in leguminous plants;*
- *describe the assimilation of nitrate and ammonia by plants;*
- *describe amino acid synthesis in plants.*

10.1 MOLECULAR NITROGEN

Nitrogen is primarily present in the atmosphere freely as dinitrogen or nitrogen gas. It is present in the combined form as Chile saltpetre or sodium nitrate and Chile in South America is the major source of this nitrate nitrogen.

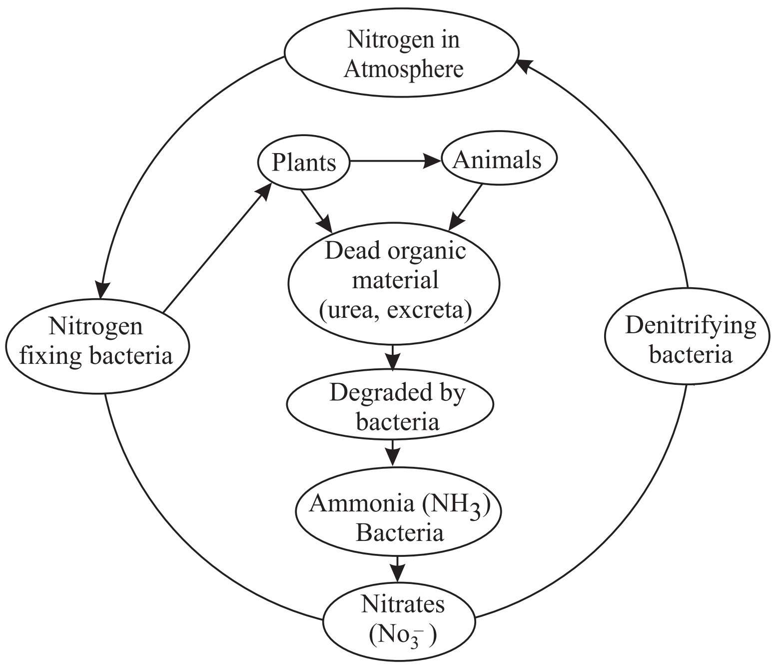
Molecular Nitrogen or diatomic nitrogen (N_2) is highly stable as it is triple bonded ($N\equiv N$). Because of this stability, molecular nitrogen as such is not very reactive in the atmosphere under normal conditions. In the atmosphere molecular nitrogen is 78.03% by volume and it has a very low boiling point (-195.8°C) which is even lower than that of oxygen. Proteins present in living organisms contain about 16% nitrogen.

10.1.1 Nitrogen Cycle

Nitrogen is an essential constituent of living beings. Nitrogenous bases are part of nucleic acids and proteins are made up of amino acids of which Nitrogen is an important consituent. You already know about the importance of these two biomolecules.

Air has 78% N_2 but most of the living beings cannot utilize this atmospheric Nitrogen. Nitrogen cycle converts this nitrogen into a usable form. Lightning fixes Nitrogen to NH_3, and nitrogen fixing bacteria like *Rhizobium* (which live in roots of leguminous plants like pea, rajma, beans, pulses etc.) also convert N_2 into NH_3. Most plants absorb nitrates from soil and reduce it to NH_3 in the cells for further metabolic reactions. Dead organisms and their excreta like urea are decomposed by bacteria into NH_3 and by a different set of bacteria into nitrates. These are left in the soil for use by plants. In this way Nitrogen cycle is self regulated but human activities have caused steady loss of soil Nitrogen.

NITROGEN CYCLE



INTEXT QUESTIONS 10.1

1. What is the percent by volume of nitrogen gas in the atmosphere?

   ....

2. Name two biomolecules that contain nitrogen in plants.

   ....

3. Why nitrogen is a stable molecule?

   ....

4. What is the percentage of nitrogen in protein?

   ....

5. What is the boiling point of nitrogen?

   ....

6. Choose the correct option:

   Nitrogen fixation is the conversion of :

   (a) atmospheric Nitrogen $\xrightarrow{\text{into}}$ Nitrates

   (b) atmospheric Nitrogen $\xrightarrow{\text{into}}$ Ammonia

   (c) atmospheric Nitrogen $\xrightarrow{\text{into}}$ Amino acids

   (d) both (a) and (b)

7. Nitrogen content of biosphere remains constant because of :

   (a) Nitrogen cycle

   (b) Nitrogen fixation

   (c) Industrial pollution

   (d) Absorption of nitrogen

8. Nitrates are converted into nitrogen by microbes called ....

10.2 NITROGEN FIXATION (BIOLOGICAL AND ABIOLOGICAL)

The conversion of molecular nitrogen into compounds of nitrogen especially ammonia is called **nitrogen fixation**. Nitrogen fixation, is a reductive process i.e., nitrogen fixation will stop if there is no reducing condition or if oxygen is present. This nitrogen fixation may take place by two different methods – abiological and biological.

10.2.1 Abiological nitrogen fixation

In abiological nitrogen fixation the nitrogen is reduced to ammonia without involving any living cell. Abiological fixation can be of two types : industrial and natural. For example, in the Haber's process, synthetic ammonia is produced by passing a mixture of nitrogen and hydrogen through a bed of catalyst (iron oxides) at a very high temperature and pressure.

$$N_2 + 3H_2 \xrightarrow[\text{1000 atmosphere}]{500°C} 2NH_3$$

This is industrial fixation wherein nitrogen gets reduced to ammonia.

In natural process nitrogen can be fixed especially during electrical discharges in the atmosphere. It may occur during lightning storms when nitrogen in the atmosphere can combine with oxygen to form oxides of nitrogen

$$N_2 + O_2 \longrightarrow 2NO \xrightarrow{O_2} 2NO_2$$

These oxides of nitrogen may be hydrated and trickle down to earth as combined nitrite and nitrate.

10.2.2 Biological nitrogen fixation

Chemically, this process is same as abiological. Biological nitrogen fixation is reduction of molecular nitrogen to ammonia by a living cell in the presence of enzymes called nitrogenases.

INTEXT QUESTIONS 10.2

1. Define nitrogen fixation.

   ....

2. Which industrial process is utilized for converting nitrogen to ammonia?

   ....

3. Distinguish between biological and abiological nitrogen fixation.

   ....

4. Name the enzyme that helps in nitrogen fixation in living cells.

   ....

5. Which gas prevents nitrogen fixation?

   ....

10.3 NITROGEN FIXATION BY FREE LIVING ORGANISMS AND SYMBIOTIC NITROGEN FIXATION

Nitrogen fixation is a distinctive property possessed by a select group of organisms, because of the presence of the enzyme nitrogenase in them.

The process of nitrogen fixation is primarily confined to microbial cells like bacteria and cyanobacteria. These microorganisms may be independent and free living (Table 10.1).

Table 10.1 : Some free living microbes which fix nitrogen

Organisms	Status
Clostridium	Anaerobic bacteria (Non-photosynthetic)
Klebsiella	Facultative bacteria (Non-photosynthetic)
Azotobacter	Aerobic bacteria (Non-photosynthetic)
Rhodospirillum	Purple, non-sulphur bacteria (Photosynthetic)
Anabaena	Cyanobacteria (Photosynthetic)

Some microbes may become associated with other oragnisms and fix nitrogen. The host organism may be a lower plant or higher plant. The host organism and the nitrogen fixing microbes establish a special relationship called **symbiosis** and this results in symbiotic nitrogen fixation (Table 10.2).

Table 10.2 : Some symbiotic nitrogen fixing organisms

System	Symbionts
Lichens	Cyanobacteria and Fungus.
Bryophyte	Cyanobacteria and *Anthoceros*.
Pteridophyte	Cyanobacteria and *Azolla.*
Gymnosperm	Cyanobacteria and *Cycas.*
Angiosperms	Legumes and *Rhizobium.*
Angiosperms	Non leguminous plants and actinomycete (Such as *Alnus*, *Myrica*, *Purshia*).
Angiosperm	Brazilian grass (*Digitaria*), Corn and *Azospirillum*.

10.3.1 Mechanism of Biological Fixation of Nitrogen

Nitrogen fixation requires

(i) the molecular nitrogen

(ii) a strong reducing power to reduce nitrogen like reduced FAD (Flavin adenine dinucleotide) and reduced NAD (Nicotinamide Adenine Dinucleotide)

(iii) a source of energy (ATP) to transfer hydrogen atoms from $NADH_2$ or $FADH_2$ to dinitrogen and

(iv) enzyme nitrogenase

(v) compound for trapping the ammonia formed since it is toxic to cells.

The reducing agent ($NADH_2$ and $FADH_2$) and ATP are provided by photosynthesis and respiration.

The overall **biochemical process** involves stepwise reduction of nitrogen to ammonia. The enzyme nitrogenase is a Mo-Fe containing protein and binds with molecule of nitrogen (N_2) at its binding site. This molecule of nitrogen is then acted upon by hydrogen (from the reduced coenzymes) and reduced in a stepwise manner. It first produces diamide (N_2H_2) then hydrazime (N_2H_4) and finally ammonia ($2NH_3$).

NH_3 is not liberated by the nitrogen fixers. It is toxic to the cells and therefore these fixers combine NH_3 with organic acids in the cell and form amino acids.

The general equation for nitrogen fixation may be described as follows:

$$N_2 + 16ATP + 8H^+ + 8e^- \longrightarrow 2NH_3 + 16ADP + 16Pi +$$

Notes

Molecular nitrogen is a very stable molecule. Therefore, sufficient amount of cell energy in the form of ATP is required for stepwise reduction of nitrogen to ammonia.

In legumes, nitrogen fixation occurs in specialized bodies called **root nodules**. The nodules develop due to interaction between the bacteria *Rhizobium* and the legume roots (see diagram 6.4c). The biochemical steps for nitrogen fixation are same. However, legume nodules possess special protein called LEGHEMOGLOBIN. The synthesis of leghemoglobin is the result of symbiosis because neither bacteria alone nor legume plant alone possess the protein. Recently it has been shown that a number of host genes are involved to achieve this. In addition to leghemoglobin, a group of proteins called **nodulins** are also synthesized which help in establishing symbiosis and maintaining nodule functioning.

Leghemoglobin is produced as a result of interaction between the bacterium and legume roots. Apparently, Rhizobium gene codes for Heme part and legume root cell gene codes for Globin moiety. Both the coded products together consitute the final protein leghemoglobin. During N_2-fixaion, function of Leghemoglobin is to act as Oxygen-scavenger so that the enzymes, Nitrogenages then, convert N_2 to NH_3 under anaerobic condition.

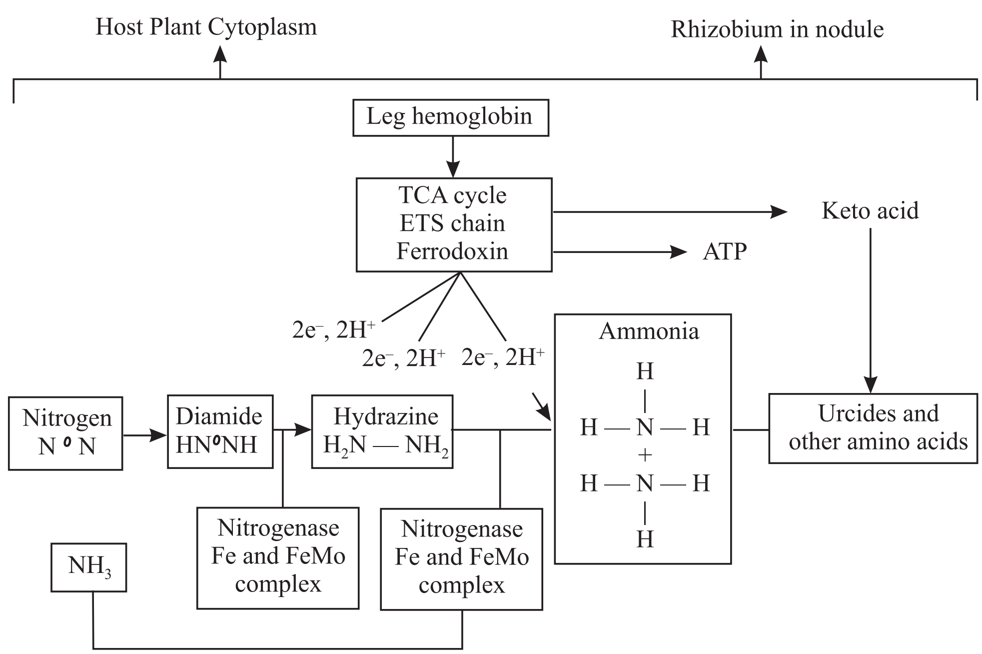


Fig. 10.1 Simplified flowsheet of biochemical steps for nitrogen fixation

Leghemoglobin is considered to lower down the partial pressure of oxygen and helps in nitrogen fixation. However, this function is specific for legumes only because free living microbes do not possess nitrogen fixing leghemoglobin. Moreover, it has also not been found in cyanobacterial symbiosis with other plants, which fix N_2 under aerobic condition.

INTEXT QUESTIONS 10.3

1. Match the following:

	A		B
(i)	*Azotobacter*	(a)	anaerobic nitrogen fixer.
(ii)	*Clostridium*	(b)	aerobic nitrogen fixer
(iii)	*Lichens*	(c)	aerobic nitrogen fixing cyanobacterium
(iv)	*Anabaena*	(d)	symbiotic nitrogen fixer.

2. Which Gymnospermous plant fixes nitrogen?

   ....

3. Is there any other gas evovled during nitrogen fixation? If yes, name the gas evolved.

   ....

4. How many ATP molecules are required to reduce a single molecule of nitrogen?

   ....

5. What is the major source of electrons for reduction of nitrogen?

   ....

6. Match the following:

	A		B
(i)	Leghemoglobin	(a)	cyanobacterium
(ii)	*Anabaena*	(b)	Legumes
(iii)	Reductive process	(c)	nitrogen fixation

7. Name the proteins that help in establishing symbiosis and maintain root nodule functioning in legumes.

   ....

10.4 NITRATE AND AMMONIA ASSIMILATION BY PLANTS

As pointed out in the previous section, nitrogen fixation is confined to selected microbes and plants. But all plants require nitrogen because it has a role to play in the general metabolism. Therefore, plants which do not fix nitrogen, use other combined nitrogen sources such as nitrate and ammonia for carrying on metabolic activity.

Nitrate is absorbed by most plants and reduced to ammonia with the help of two different enzymes. The first step conversion of nitrate to nitrite is catalyzed by an enzyme called nitrate reductase. This enzyme has several other important constituents including FAD, cytochrome, NADPH or NADH and molybdenum.

$$NO_3^- + NADH + H^+ \xrightarrow{\text{Nitrate reductase}} NO_2^- + NAD^+ + H_2O$$

The overall process of nitrate reduction take place in the cytosol and is an energy dependent reaction.

The enzyme nitrate reductase has been studied in many plants and it is observed that the enzyme is continuously synthesized and degraded. The enzyme nitrate reductase is inducible. This means that increase in nitrate concentration in the cytosol induces more of nitrate redutase to be synthesized. However, when excess NH_4^+ is produced then it has a negative effect on the synthesis of nitrate reductase. In plants, it has also been observed that light also increases nitrate reductase when nitrate is available.

In the second step the nitrite so formed is further reduced to ammonia and this is catalyzed by the enzyme nitrite reductase. Nitrite present in the cytosol is transported into chloroplast or plastids where it is reduced to ammonia.

$$NO_2^- + 3NADPH + 3H^+ \xrightarrow{\text{Nitrite reductase}} NH_3 + 3NADP^+$$

The enzyme nitrite reductase is able to accept electrons from sources such as NADH, NADPH or $FADH_2$. Besides, reduced ferredoxin has also been shown to provide electrons to nitrite reductase for reducing nitrite to ammonia. Ammonia so formed has to be utilized quickly by plants because accumulation of ammonia has a toxic effect. Some plants including algae leach out excess ammonia which can further be oxidized to nitrite and nitrate by microorganisms in the soil or water.

INTEXT QUESTIONS 10.4

1. Which is the most reduced form of inorganic nitrogen?

   ....

2. Match the following:

A		B	
(*i*)	Nitrate reductase	(a)	nitrogen fixation
(*ii*)	Nitrite reductase	b)	nitrate reduction
(*iii*)	Nitrogenase	c)	nitrite reduction

3. In which part of the cell, reduction of nitrate to nitrite occurs?

   ....

4 Which is the most oxidized form of inorganic nitrogen?

   ....

5 In which plant organelle reduction of nitrite to ammonia is catlyzed by the enzyme nitrite reductase?

   ....

10.5 AMINO ACID SYNTHESIS BY PLANTS

As you have noticed that ammonia formation is achieved by plants either by (i.) nitrogen fixation or (ii) by reduction of nitrate to nitrite. Ammonium (NH_4^+) is the most reduced form of inorganic combined nitrogen. This ammonium now becomes the major source for the production of amino acids, which are the building blocks of enzymes and proteins. Amino acids have two important chemical groups. (i) amino group (NH_2) and (ii) carboxy1 group (-COOH).

$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ R & — & C & — & COOH \\ & & | & & \\ & & NH_2 & & \end{array}$$

Fig. 10.2 A typical amino acid with functional groups. R represents alkyl group.

Ammonium so produced is the major source of amino group. However, the carboxyl group has to be provided by other organic molecule synthesized by the plants. There are two major reactions for amino acid biosynthesis in plants:

10.5.1 Reductive amination reaction:

In this reaction, ammonia combines with a keto acid. The most important keto acid is the alpha ketoglutaric acid produced during the operation of Krebs cycle (see lesson 12 Plant Respiration). The keto acid then undergoes enzymatic reductive amination to produce an amino acid.

$$\underset{\text{(keto acid)}}{\alpha\text{-ketoglutaric acid}} + NH_3 \xrightarrow{\text{glutamate dehydrogenase}} \underset{\text{(amino acid)}}{\text{Glutamic}}$$

Similarly another amino acid called aspartic acid is produced by reductive amination of oxaloacetic acid.

> It has been noted that reductive amination respresents the major 'port of entry' for ammonia into the metabolic stream in plants. This initiates synthesis of glutamic acid followed by other amino acids.

10.5.2 Transamination reaction

This is another very important reaction for amino acid biosynthesis. The reaction involves transfer of amino group, from already synthesized amino acid, to the keto acid.

$$\underset{\text{(Keto acid)}}{\alpha\text{-Ketoglutaric acid}} + \underset{\text{(Amino acid)}}{\text{Aspartic acid}} \xrightarrow{\text{Transaminase}} \underset{\text{(Amino acid)}}{\text{Glutamic acid}} + \underset{\text{(Keto acid)}}{\text{Oxaloacetic acid}}$$

In the above reaction, aspartic acid has transferred its amino group (NH_2) to the α-ketoglutaric acid to synthesize glutamic acid and release keto acid. The reaction is catalyzed by enzymes called **transaminases**. A large number of amino acids are synthesized by this transamination reaction. Amino acids are organic molecules containing nitorgen. The incorporation of amino group, from ammonium, into keto acids represents the major step for synthesis of nitrogenous organic biomolecules.

INTEXT QUESTIONS 10.5

1. Match the following:

	A	B
(i)	Amino acid	(a) keto acid
(ii)	Glutamic acid	(b) amino group and carboxyl group
(iii)	α-ketoglutaric acid	(c) amino acid

2. Name two biochemical reactions for biosynthesis of amino acids in plants.

   ....

3. Which group of enzymes catalyzes transamination reaction?

   ....

4. What is the source of amino group for amino acid synthesis in reductive amination reaction?

   ....

5. Which keto acid is the source for synthesis of glutamic acid?

   ....

WHAT YOU HAVE LEARNT

- Nitrogen is an important constituent of several biomolecules such as amino acids, proteins and enzymes.
- Molecules such as vitamins, alkaloids, nucleic acids, pigments and some growth hormones also contain nitrogen.
- Molecular nitrogen is triple bonded and stable.
- Nitrogen fixation is the reduction of nitrogen to ammonia.
- Abiological nitrogen fixation is an industrial process (Haber's process)
- Biological nitrogen fixation takes place in a living cell.
- The enzyme that catalyzes nitrogen fixation is Nitrogenase.
- Nitrogen fixation may take place in free living organisms or in symbiotic systems.
- There are many symbiotic nitrogen fixation systems such as Lichens, Pteridophytes, Bryophytes, Gymnosperms and Legumes.
- Cyanobacteria is the symbiotic component in Lichens, Bryophytes, Pteridophytes and Gymnosperms.
- In Legumes, the symbiont is a species of bacterium *Rhizobium*.
- Source of electrons and energy for nitrogen fixation is generally pyruvic acid after it enters Krebs' cycle during cell-respiration.
- Hydrogen gas evolution may also accompany nitrogen fixation process.

- Nitrate is the most oxidized form and ammonium is the most reduced form of nitrogen.
- Nitrate is reduced to nitrite by an enzyme nitrate reductase.
- Amino acids have two functional groups, namely, amino group and carboxyl group.
- Amino acids may be produced by reductive amination of keto acids.
- Amino acids may be produced by transamination reaction.
- Reductive amination reactions are catalyzed by dehydrogenases.
- Transamination reactions are catalyzed by transaminases.

TERMINAL EXERCISES

1. Define nitrogen fixation.
2. Which form of combined nitrogen may be formed during lightening storms?
3. Name three biomolecules other than enzymes and proteins, which contain nitrogen.
4. Name one aerobic and one anaerobic bacterium, which fixes nitrogen.
5. Which amino acid is synthesized due to reductive amination of α-ketoglutaric acid?
6. Differentiate between biological and abiological nitrogen fixation.
7. What is required for biological nitrogen fixation?
8. How does human hemoglobin differ from leghemoglobin?
9. What is the function of leghemoglobin?
10. What are the functional differences between nitrate reductase and nitrite reductase?
11. What is the difference between nitrogen fixation and nitrogen assimilation? Describe in brief the process of abiological nitrogen fixation.
12. Describe in brief various steps involved in biological nitrogen fixation.
13. Enumerate various free living and symbiotic nitrogen fixing systems with suitable examples.
14. What are the major differences between free living and leguminous nitrogen fixing organisms?
15. Describe in brief nitrate and nitrite reduction in plants..
17. Describe in brief the reductive amination reactions for synthesis of amino acids in plants.
18. Describe the transamination reaction for synthesis of amino acids in plants. How does this differ from reductive amination?

ANSWERS TO INTEXT QUESTIONS

10.1
1. 78.03 percent
2. proteins and enzymes.
3. Because it is triple bonded.
4. 16 percent.
5. $-195.8°C$.
6. (b)
7. (a)
8. Denitrifying Bacteria

10.2
1. Conversion of molecular nitrogen to ammonia.
2. Haber's process.
3. Biological nitrogen fixation takes place in a living cell and abiological fixation without a living cell.
4. Nitrogenase.
5. Oxygen.

10.3
1. (i) b (ii) a (iii) d (iv) c
2. Cycas.
3. Yes, Hydrogen gas.
4. 16 ATP
5. Reduced coenzymes such as Ferrodoxin
6. (i) b (ii) a (iii) c
7. Nodulins.

10.4
1. NH_4
2. (i) b (ii) c (iii) a
3. Cytosol.
4. Nitrate.
5. Chloroplast.

10.5
1. (i) b (ii) c (iii) a
2. Reductive amination and transamination.
3. Transaminases.
4. Ammonia.
5. Alpha ketoglutaric acid.

11

PHOTOSYNTHESIS

Photosynthesis (Photo = light; synthesis = to join) is the single most important process on earth on which depends the existence of human beings and almost all other living organisms. It is a process by which green plants, algae and chlorophyll containing bacteria utilize the energy of sunlight to synthesize their own food (organic matter) from simple inorganic molecules. Innumerable number of organic molecules which compose the living world are derived directly or indirectly from the photosynthetic organic matter. The oxidation of organic compounds releases stored energy to be utilized by the living organisms to carry out essential metabolic processes. It is important to note that photosynthesis is the only natural process which liberates oxygen to be used by all living forms for the process of aerobic respiration.

You have studied in lesson 4, that chloroplasts are the organelles that carry out photosynthesis or in other words they act as solar cells producing carbohydrates. In this lesson you will learn how green plants carry out photosynthesis.

OBJECTIVES

After completing this lesson, you will be able to :

- *define photosynthesis;*
- *name the different pigments found in chloroplasts;*
- *explain the main aspects of the process of photosynthesis;*
- *enumerate the steps involved in the light and dark reactions of photosynthesis;*
- *define the terms absorption spectrum, action spectrum, electron acceptor and photophosphorylation;*
- *distinguish between, absorption spectrum and action spectrum; light and dark reactions, cyclic and non-cyclic photo-phosphorylation,* C_3 *and* C_4 *photosynthesis;*
- *list the environmental variables and internal factors affecting photosynthesis;*
- *describe the principle of limiting factor giving suitable graphs.*

11.1 PHOTOSYNTHESIS

11.1 Let us look into the significance of the process

Significance

1. Green plants possess the green pigment, chlorophyll which can capture, transform, translocate and store energy which is readily available for all forms of life on this planet.
2. Photosynthesis is a process in which light energy is converted into chemical energy.
3. Except green plants, no other organism can directly utilise solar energy to synthesize food, hence they are dependent on green plants for their survival.
4. Green plants which can prepare organic food from simple inorganic elements are called autotrophic while all other organisms which cannot prepare their own food are called heterotrophic.
5. During photosynthesis, oxygen liberated into the atmosphere makes the environment livable for all aerobic organisms.
6. Simple carbohydrates produced in photosynthesis are transformed into lipids, proteins, nucleic acids and other organic molecules.
7. Plants and plant products are the major food sources of almost all organisms on the earth.
8. Fossil fuels like coal, gas, and oil represent the photosynthetic products of the plants belonging to early geological periods.

11.1.1 What is photosynthesis?

Photosynthesis is the process by which green plants, in the presence of light combine water and carbon dioxide to form carbohydrates. Oxygen is released as a by product of photosynthesis. Current knowledge of photosynthesis has resulted from discoveries made over 300 years of work. Some landmark experiments are given in the box below.

- Joseph Priestley (1772) and later Jan Ingenhousz (1779) showed that plants have the ability to take up CO_2 from the atmosphere and release O_2.
- Ingenhousz also discovered that release of O_2 by plants was possible only in presence of sunlight and by the green parts of the plant.
- Robert Hill (1939) demonstrated that isolated chloroplasts evolve O_2 when they are illuminated in the presence of electron acceptor which gets reduced. This reaction called Hill reaction accounts for the use of water as a source of electrons and protons for CO_2 fixation and release of O_2 as bye-product.

Photosynthesis is represented by the following overall chemical equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

In photosynthesis, CO_2 is fixed (or reduced) to carbohydrates (glucose $C_6H_{12}O_6$). Water is split in the presence of light (called photolysis of water) to release O_2. Note that O_2 released comes from the water molecule and not from CO_2.

11.1.2 Where does photosynthesis occur?

Photosynthesis occurs in green parts of the plant, mostly the leaves, sometimes the green stems and floral buds. The leaves contain specialised cells called mesophyll cells which contain the chloroplast– the pigment containing organelle. These are the actual sites for photosynthesis.

Look at the figure 11.1 that shows leaf Cell Structure and Function.

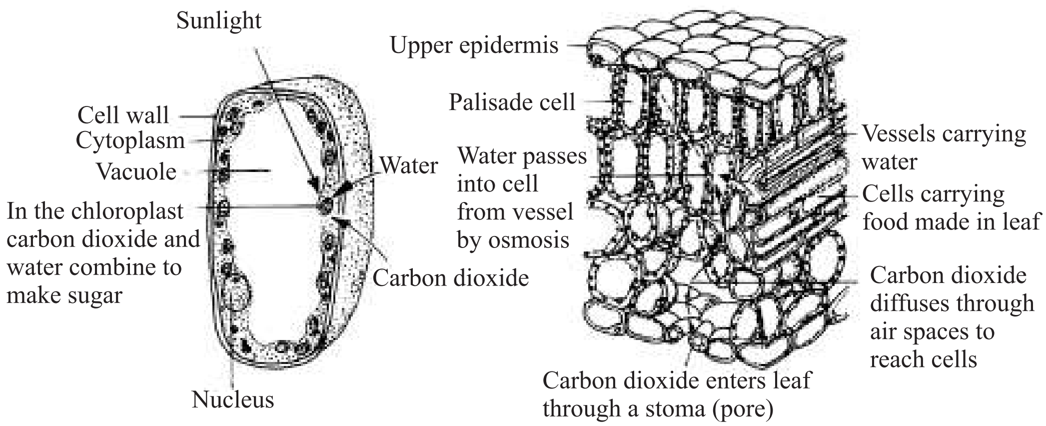


Fig. 11.1 Diagram to show structure of leaf cells

11.2 PHOTOSYNTHETIC PIGMENTS

The thylakoids of the chloroplast contain the pigments which absorb light of different wavelengths and carry out the photochemical reaction of photosynthesis.

The role of the pigments is to absorb light energy, thereby converting it to chemical energy. These pigments are located on the thylakoid membranes and the chloroplasts are usually so arranged within the cells that the membranes are at right angles to the light source for maximum absorption. The photosynthetic pigments of higher plants fall into two classes the chlorophyll and carotenoids.

The photosynthetic pigment **chlorophyll** is the principle pigment involved in photosynthesis. It is a large molecule and absorbs light maximally in the violet blue and in the red region of the visible spectrum and reflects green light and thus leaves appear green in colour. **Carotenoids** (carotene and xanthophyll) absorb light in the regions of the spectrum not absorbed by the chlorophylls and transfer that energy to chlorophyll to be used in photosynthesis.

Chlorophyll-a (a special type of chlorophyll) is the main pigment that traps solar energy and converts it into chemical energy. Chlorophyll-a is present in all autotrophic plants except photosynthetic bacteria. Thus Chl-a is called the essential photosynthetic pigment responsible for representing the **reaction centre.**

All other pigments such as chlorophyll b and carotenoids are collectively called accessory pigments since they pass on the absorbed light energy to chlorophyll a (Chl-a) molecule to be utilized for photosynthesis. These pigments, that is the reaction centres (Chl-a) and the accessory pigments (**harvesting centre**) are packed into functional clusters called **photosystems**. Photosystems are of two types **PSI** and **PSII**.

About 250-400 Chl-a molecules constitute a single photosystem. Two different photosystems contain different forms of chlorophyll a in their reaction centres. In photosystem I (PSI), chlorophyll– a with maximum absorption at 700 nm (P_{700}) and in photosystem II (PSII), chlorophyll– a with peak absorption at 680 nm (P_{680}), act as reaction centres. (P stands for pigment). The primary function of the two photosystems, which interact with each other is to trap the solar energy and convert it into the chemical energy also called **assimilatory power** (ATP and $NADPH_2$). The differences between them are given in the following Table 11.1.

Table 11.1 Differences between Photosystem I and Photosystem II

Photosystem I	Photosystem II
• PS I has a reaction centre of chlorophyll 'a' molecule with maximum light absorption at 700 nm wavelength. This reaction centre is referred to as P_{700}. • Primary electron acceptor is an iron protein (Fe-S-protein) • A set of electron carriers are plastocyanin, ferredoxin and cytochrome	• PS II has a reaction centre of chlorophyll 'a' molecule with maximum light absorption at 680 nm. This reaction centre is also referred to to as P_{680}. • Primary electron acceptor, pheophytin, is a modified chlorophyll-a molecule with 2 hydrogen atoms in place of magnesium ion. • A set of electron carriers are pheophytin plastoquinone, cytochromes.

11.3 ROLE OF SUNLIGHT IN PHOTOSYNTHESIS

Light consists of small particles or packages of energy called "photons". A single photon is also called **quantum.** What does the chlorophyll do? It absorbs light energy.

> Chlorophyll molecules absorb light energy and get into an excited state and lose an electron to the outer orbit. No substance can remain in an excited state for long, so the energised and excited chlorophyll molecule comes down to a low energy state known as **ground state** and releases the extra amount of energy. This energy can be lost as heat, or as light (fluorescence) or can do some work. In photosynthesis, it works by splitting water moelcule to produce H^+ and OH^- ions.

Carotene is orange-yellow pigment present along with chlorophylls in the thylakoid membrane. A carotene molecule breaks down into the vitamin A molecules. It is this pigment which gives carrot its colour.

Absorption and Action Spectra

For investigating a process such as photosynthesis that is activated by light, it is important to establish the action spectrum for the process and to use this to identify the pigments involved. An **action spectrum** is a graph showing the effectiveness of different wavelengths (VIBGYOR) of light in stimulating the process of photosynthesis, where the response could be measured in terms of oxygen produced at different wavelengths of light. An **absorption spectrum** is a graph representing the relative absorbance of different wavelengths of light by a pigment. An action spectrum for photosynthesis is shown in Fig. 11.2 together with an absorption spectrum for the combined photosynthetic pigments. Note the close similarity, which indicates that the pigments, chlorophyll-a in particular, are responsible for absorption of light used in photosynthesis.

All wavelengths of light are not equally effective in photosynthesis i.e. the rate of photosynthesis is more in some and less in others.

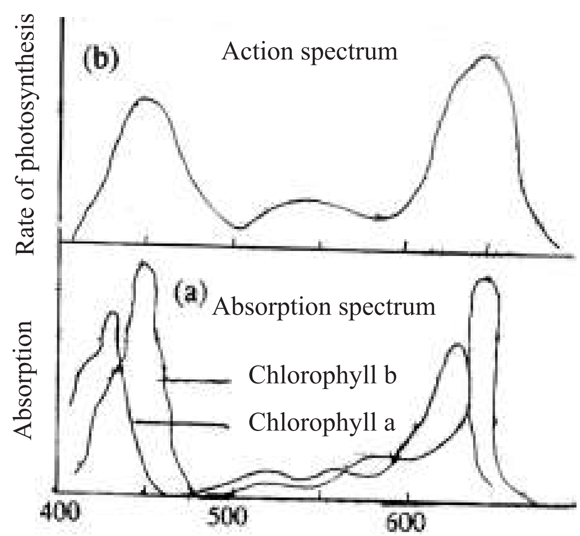


Fig. 11.2 Absorption Spectra of electromagnetic radiation B. Action Spectrum

Photosynthesis occurs maximum in blue and red region of spectra. Photosynthesis is very little in green and yellow light, because these rays are reflected back from the leaf.

INTEXT QUESTIONS 11.1

1. (i) Define photosynthesis

   ....

(ii) Give the overall general chemical equation of photosynthesis.

....

2. (i) List the two categories of photosynthetic pigments.

....

(ii) Which pigments are known as accessory pigments?

....

3. (i) What does chlorophyll do to the light falling on it?

....

(ii) Which pigment system absorbs maximally the red wavelength of light?

....

4. Answer the following

(i) In which colour of light, rate of photosynthesis is minimum and in which colour of light it is maximum?

....

(ii) Name the type of energy that is used in the process of photosynthesis. In which form does this energy get stored in plant body?

....

5. Which molecule is the source of evolution of oxygen in photosyntheisis— CO_2 or H_2O?

....

11.4 PHOTOCHEMICAL AND BIOSYNTHETIC PHASE

- The entire process of photosynthesis takes place inside the chloroplast. The structure of chloroplast is such that the light dependent (**light reaction**) and light independent (**Dark reaction**) reactions take place at different sites in the same organelle.
- The thylakoids have the pigments and other necessary components to absorb light and transfer electrons to carry out the light reaction or Electron Transport Chain (ETC). In ETC upon absorption of light, the electrons from PSII and PSI are excited to a higher energy level i.e. the electrons acquire excitation energy. As the electrons gain this energy, they are accepted by the electron acceptor which in turn is reduced, leaving the reaction centres of PSII and PSI i.e. P_{680} and P_{700} molecules in an oxidised state. This represents the conversion of light energy into chemical energy. The electrons then travel downhill in energy terms, from one electron acceptor to another in a series of oxidation-reduction reaction. This electron flow is 'coupled' to the formation of ATP. In addition, NADP is reduced to $NADPH_2$. The product of light reaction is called the reducing power or assimilatory power (ATP and $NADPH_2$) which move out of the thylakoid into the stroma of the chloroplast.
- In the stroma, the second step called as **dark reaction or biosynthetic pathway** occurs, where CO_2 is reduced by the reducing power generated in the first step and carbohydrates are produced.

Let us study these two steps in some more detail in the next part of the lesson.

11.4.1 Electron transport chain in photosynthesis

After receiving light PSII absorbs light energy and passes it on to its reaction centre, P_{680}. When P_{680} absorbs light, it is excited and its electrons are transferred to an electron acceptor molecule (Primary electron acceptor i.e. pheophytin) and it itself comes to the ground state. However by losing an electron P_{680} is oxidised and in turn it splits water molecule to release O_2. This light dependent spliting of water is called **photolysis**. With the breakdown of water electrons are generated, which are then passed on to the electron deficient P_{680} (which had transferred its electrons earlier). Thus the oxidised P_{680} regains its lost electrons from water molecules.

The reduced primary acceptor now donates electrons to the down stream components of the electron transport chain. The electrons are finally passed onto the reaction centre P_{700} or PSI. During this process, energy is released and stored in the form of ATP.

Similarly, PSI also gets excited when it absorbs light and P_{700} (Reaction centre of PSI) gets oxidised as it transfers its electrons to another primary acceptor molecule. While the oxidised P_{700} draws its electrons from PSII, the reduced primary acceptors molecule of PSI transfers its electrons via other electron carrier to NADP (Nicotinamide Adenine Dinucleotide Phosphate) to produce $NADPH_2$ a strong reducing agent. Thus we see that there is a continuous flow of electrons from the H_2O molecules to PSII to PSI, and finally to the NADP molecule which is reduced to $NADPH_2$. $NADPH_2$ is then utilised in reduction of CO_2 to carbohydrates in the biosynthetic pathway.

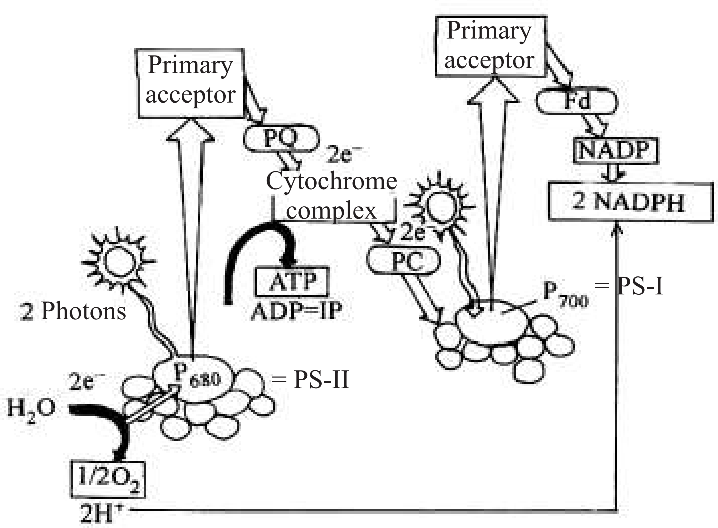


Fig. 11.3 Non-cyclic (z-scheme) photophosphorylation PQ = Plastoquinine, PC-Plastocyanin Fd = Ferredoxin

- Reduction of CO_2 to carbohydrate also requires ATP, which too are generated via electron transport chain. As the energy rich electrons pass down the electron transport system, it releases energy which is sufficient to bind inorganic phosphate (Pi) with ADP to form ATP. This process is called photophosphorylation. Since this takes place in presence of light it is called **Photo-phosphorylation.** It occurs in chloroplast in two ways:

(a) Non-cyclic photophosphorylation where electrons flow from water molecule to PSII and then to PSI and ultimately reduce NADP to $NADPH_2$. Since the electron flow is unidirectional and the electrons released from one molecule do not return to the same molecule, it is called non-cyclic photosphorylation (Fig. 11.3).

(b) Cyclic photophosphorylation occurs in photosynthetic bacteria which lack PS-II, and it involves PSI only. During this process electrons from PSI are not passed on to NADP. Instead the same electrons are returned to the oxidised P_{700} molecule. During this downhill movement of electrons ATP formation takes place. Thus this is termed as cyclic photophosphorylation (Fig. 11.4).

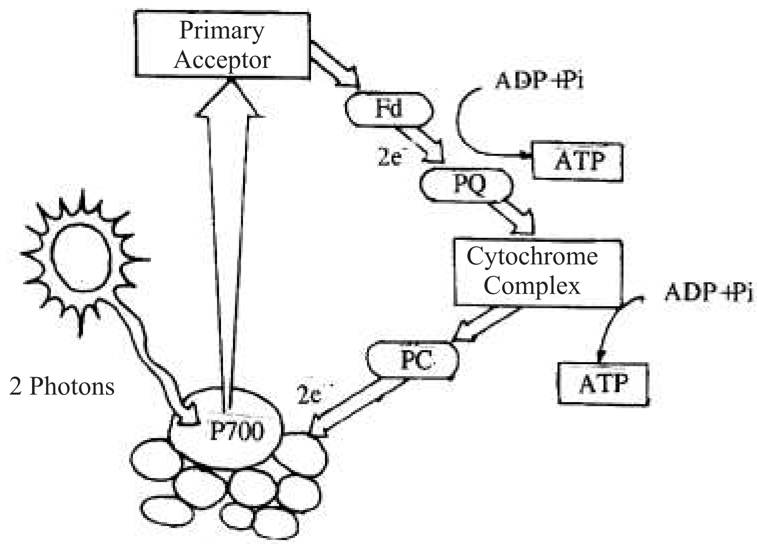


Fig. 11.4 Cyclic photophosphorylation

Table 11.2 Differences between cyclic and non-cyclic photophosphorylation

Cyclic photophosphorylation	Non-cyclic photophosphorylation
1. Only PSI is functional.	1. Both PSI and PSII are functional.
2. Electron comes from the chlorophyll P_{700} molecule and returns to the same chlorophyll P_{700}	2. Water is the primary source of the electrons and H^+. It gets photolysed through the process called **Photolysis;** NADP is the final acceptor of the electrons and H^+ ions.
4. Oxygen is not evolved because there is no photolysis of water	4. Oxygen is evolved as a bye product.
5. This process is found mainly in photosynthetic eubacteria e.g. purple sulphur bacteria.	5. This mainly takes place in all green plants, and cyanobacteria except photosynthetic eubacteria.

In higher photosynthetic plants, extra ATP can be made via cyclic photophosphorylation if cyclic and non-cyclic photophosphorylaiton occur side by side. The efficiency of energy conversion in the light reactions of photosynthesis is high and estimated at about 39%.

11.5 BIOSYNTHETIC PATHWAY (DARK REACTION)

- Both $NADPH_2$ and ATP produced during light reaction are essential requirements for synthesis of carbohydrates.
- These series of reactions which catalyse the reduction of CO_2 to carbohydrates (also called fixation of CO_2) take place in the **stroma** of the chloroplast.
- These reactions are independent of light i.e. light is not necessary but can continue in light as well if products of the light reaciton are available. Thus it is also called **dark reaction**.
- The carbon fixation reactions produce sugar in the leaves of the plant from where it is exported to other tissues of the plant as source of both organic molecule and energy for growth and metabolism.
- There are **two** major pathways by which CO_2 fixation (Dark reaction) takes place.

11.5.1 C_3 cycle (also called Calvin cycle after the name of its discoverer, Melvin Calvin)

In this cycle, initially the atmospheric CO_2 is accepted by a 5-carbon sugar ribulose bisphosphate (RuBP) resulting in the generation of two molecules of 3-carbon compound, 3-phosphoglyceric acid (PGA). This 3-carbon molecule is the first stable product of this pathway and hence the name C_3 cycle is given. Formation of PGA is called **carboxylation**. This reaction is catalysed by an enzyme called **ribulose bisphosphate carboxylase/oxygenase or Rubisco.** This enzyme is probably the most abundant protein on earth.

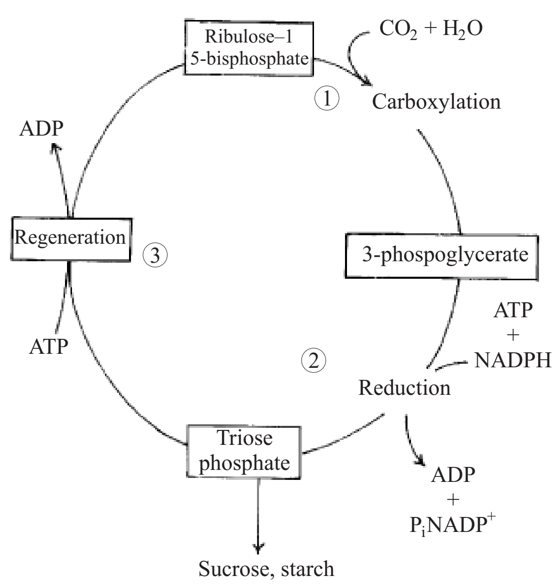


Fig. 11.5 The Calvin cycle

Notes

- In the next step, PGA is reduced to 3-carbon carbohydrate called **triose phosphate** using $NADPH_2$ and ATP (from light reaction). Much of these molecules are then diverted from the C_3 cycle and used for synthesis of other carbohydrates such as glucose and sucrose.
- To complete the cycle, the initial 5-carbon acceptor molecule, RuBP is regenerated from the triose phosphates using ATP molecule thus the C_3 cycle continues to regenerate the CO_2-acceptor (RuBP).

11.5.2 C_4 Cycle (or Hatch Slack Cycle)

- The C_4 cycle seems to be an adaptation for plants growing under dry hot environment. Such plants can photosynthesise even in the conditions of very low CO_2 concentration and under partial closure of stomata.
- Such plants can thus grow at low water content, high temperature and high light intensity. Sugarcane, and maize are some examples.
- Photorespiration (oxidation of RuBP in presence of O_2) is absent in these plants. So the photosynthetic rate is high. (For detail of photorespiration refer to lesson-12 Plant Respiration Section No. 12.5)
- The leaves of C_4 plants show presence of dimorphic chloroplasts, called **Kranz anatomy**.
  - (a) In these plants, the vascular bundles have a sheath of large parenchyma cells around them in the form of a wreath, thus the name Kranz anatomy (Kranz : wreath)
  - (b) Leaves possess two types of chloroplasts (dimorphic chloroplasts)
  - (c) Chloroplasts in the mesophyll cells are smaller and have well developed grana (granal chloroplasts) but do not accumulate starch.
  - (d) Chloroplasts in the bundle sheath cells are larger and lack grana (**agranal chloroplasts**) but contain numerous starch grains. (See Fig. 11.6).

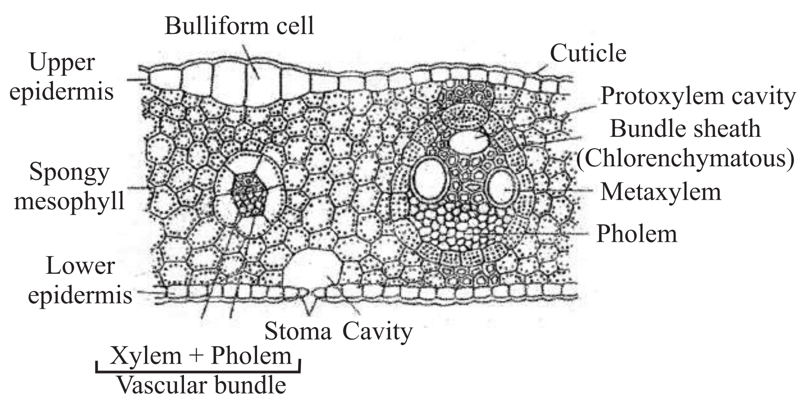


Fig. 11.6 Transverse section of maize leaf showing Kranz' anatomy

- In C_4 plants, the initial acceptor of CO_2 is **phosphoenol pyruvic acid or PEP**, a 3-carbon compound. It combines with CO_2 in presence of an enzyme **Phosphoenol pyruvate carboxylase (PEP carboxylase)** and forms a C_4 acid, oxaloacetic acid (OAA). This fixation of CO_2 occurs in the cytosol of the mesophyll cells of the leaf. OAA is the first stable product of this cycle which is 4 carbon compound and hence the name C_4 pathway is given.

- OAA then travels from mesophyll cells to the chloroplasts of bundle sheath cell where it releases the fixed CO_2. C_3 cycle operates within these cells and this CO_2 immediately combines with RuBP in C_3 cycle producing sugars. (See Fig. 11.7).

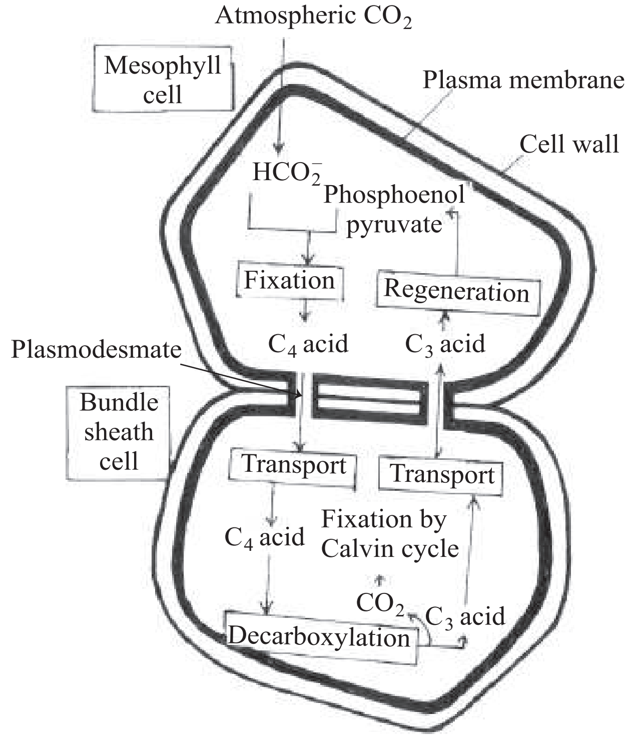


Fig. 11.7 The C4 photosynthetic carbon cycle

- Thus in C_4 pathway of dark reaction, there are two carboxylase enzymes that take part. PEP carboxylase (PEPCo) in the mesophyll cells and RUBP carboxylase (Rubisco) in the bundle sheath cells.

- The differences between C_3 and C_4 plants are tabulated below.

Table 11.3 Difference between C_3 and C_4 Plants

	C_3 Plants	C_4 Plants
Carbon dioxide fixation	Occurs once	Occurs twice, first in mesophyll cells, then in bundle sheath cells.
Carbon dioxide acceptor	Only one acceptor, RuBP which occurs in all green cells of the plant	In Mesophyll cells, PEP (Phosphoenol Pyruvic acid), 3-C, compound is CO_2 acceptor, but in the bundle sheath cells-RuBP, 5C, compound, is the CO_2^- acceptor
Carbon dioxide fixing enzymes	RuBP carboxylase, which is not efficient when CO_2 conc is low	PEP caboxylase which is very efficient, even if CO_2 conc. is low RuBP carboxylase, works efficiently because carbon dioxide concentration is high.
First product of photosynthesis	The first stable product is 3-C compound phosphoglyceric acid	The first product is 4-C compound oxaloacetic acid

Concentration of CO_2	Higher CO_2 conc. promotes photosynth]esis	Photosynthetic efficiency is high even if CO_2 conc. is low
Leaf anatomy	Only one type of chloroplast Kranz' anatomy is absent	Two types of chloroplasts (dimorphic) or Kranz' anatomy, i.e., two types of cells. each with its own type of chloroplasts are present.
Photorespiration	Occurs; excess of oxygen is an inhibitor of photosynthesis	Photorespiration is absent. The photo synthetic efficiency is further increased
Efficiency	Less efficient plotosynthesis than C_4 plants. Yields usually much lower.	More efficient photosynthesis as compared to that of the C_3 plants. Yields usually much higher.

INTEXT QUESTIONS 11.2

1. What is the role of NADP?

   ....

2. Why is dark reaction called so?

   ....

3. What is the role of the enzymes (i) rubisco and (ii) PEPCo and where are they present?

   ....

4. Explain Kranz anatomy.

   ....

5. Differentiate between the chloroplasts present in the mesophyll cells and in the bundle sheath cells of the leaf of a C_4 plant.

   ....

6. Why are C_4 plants more efficient than C_3 plants?

   ....

7. Name the two sets of reactions in photosynthesis in which light energy is required.

   ....

11.6 FACTORS AFFECTING RATE OF PHOTOSYNTHESIS

11.6.1 Factors affecting Photosynthesis

Factors affecting photosynthesis can be divided into two broad categories, the internal and external (environmental) factors.

(i) Internal Factors

1. **Chlorophyll :** The amount of chlorophyll present has a direct relationship with the rate of photosynthesis because this pigment is directly involved in trapping light energy responsible for the light reactions.
2. **Leaf age and anatomy :** Newly expanding leaves show gradual increase in rate of photosynthesis and the maximum is reached when the leaves achieve full size. Chloroplast functions decline as the leaves age. Rate of photosynthesis is influenced by variation in (i) number, structure and distribution of stomata, (ii) size and distribution of intercellular spaces (iii) relative proportion of palisade and spongy tissues and (iv) thickness of cuticle.
3. **Demand for photosynthate :** Rapidly growing plants show increased rate of photosynthesis in comparison to mature plants. When demand for photosynthesis is lowered due to poor meristematic activity, the photosynthetic rate declines.

(ii) External Factors

The major external factors which affect the rate of photosynthesis are temperature, light, carbondioxide, water, and mineral elements.

Concept of limiting factors : When a process is affected by various factors, the rate of the process depends upon the pace of the slowest factor. Let us consider three factors like light, carbon dioxide and temperature. It is seen that when all three factors are optimum, the rate of photosynthesis is maximum. However, of the three factors even if one of the factors becomes suboptimal and the other factors remain optimal, the rate of the photosynthetic process declines substantially. This is known as law of limiting factors shown by Blackman in 1905. It is defined as when a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest factor which is known as the **limiting factor**.

Light : The rate of photosynthesis increases with increase of intensity of light within physiological limits or rate of photosynthesis is directly proportional to light intensity. Except on a cloudy day and at nights, light is never a limiting factor in photosynthesis in nature.

At a certain light intensity the amount of CO_2 used in photosynthesis and the amount of CO_2 produced in respiration are the same. This point of light intensity is known as **compensation point**.

Wavelength of light absorbed by photosynthetic pigments affects rate of photosynthesis. Red light and to some extent blue light has an enhancing influence on photosynthesis (See action spectrum).

The proportion of the total incident sunlight on earth, absorbed by green plants is generally a limiting factor. As per the estimates of the total incident light reaching the green plants, only about 1-2% is actually absorbed, because 70% is transmitted, and 28-29% is reflected back into the atmosphere.

Temperature : Very high and very low temperature affect the rate of photosynthesis adversely. Rate of photosynthesis will rise with temperature from 5°-37°C beyond which there is a rapid fall, as the enzymes involved in the process of the dark reaction are denatured at high temperature. Between 5°-35°C, with every 10°C rise in temperature rate of photosynthesis doubles or Q_{10} is 2 (Q = quotient), or slightly less than two.

Carbon dioxide : Since carbon dioxide being one of the raw materials for photosynthesis, its concentration affects the rate of photosynthesis markedly. Because of its very low concentration (0.03%) in the atmosphere, it acts as limiting factor in natural photosynthesis. At optimum temperature and light intensity, if carbon dioxide supply is increased the rate of photosynthesis increases markedly until CO_2 conc. is as high as 3.0%. Thus, CO_2 conc. in the atmosphere is always a limiting factor for photosynthesis.

Water : Water has an indirect effect on the rate of photosynthesis. Loss of water in the soil is immediately felt by the leaves, which get wilted and their stomata close down thus hampering the absorption of CO_2 from the atmosphere. This causes decline in photosynthesis.

Oxygen : Concentration of oxygen as an external factor, is never a limiting factor for photosynthesis because it is a by-product of photosynthesis, and it easily diffuses into the atmosphere from the photosynthesizng organ, **the leaf**. However, excesss of O_2 surrounding a green plant, reduces photosynthetic rate by promoting the rate of aerobic respiraiton.

Mineral elements : Some mineral elements like magnesium, copper, manganese and chloride ions, which are components of photosynthetic enzymes, and magnesium as a component of chlorophylls are important, and their deficiency would affect the rate of photosynthesis indirectly by affecting the synthesis of photosynthetic enzymes and chlorophyll, respectively.

11.7 CHEMOSYNTHESIS

Chemosynthesis

When plants utilise light energy to reduce carbon dioxide to carbohydrates, they are called photosynthetic autotrophs. There are some bacteria which can utilise chemical energy released during biological oxidation of certain inorganic substances to reduce carbon dioxide to carbohydrate. These bacteria are called **chemosynthetic autotrophs.**

This is found in many colourless bacteria and because they use chemical energy to reduce carbon dioxide, this process of carbohydrate synthesis is known as **chemosynthesis**.

Chemosynthesis may be defined as "the method of carbon assimilation when the reduction of CO_2 is carried out in darkness, utilising the energy obtained from oxidation of inorganic substances, such as H_2S and NH_3.

The common chemosynthetic forms are :

(i) Nitrifying bacteria. *Nitrosomonas* and *Nitrobactor* oxidise NH_3 to NO_2

(ii) Sulphur bacteria

(iii) Iron bacteria

(iv) Hydrogen and methane producing bacteria

Differences between photosynthesis and chemosynthesis

Chemosynthesis	Photosynthesis
1. It occurs only in colourless anaerobic bacteria	1. This process occurs in all green plants including green bacteria.
2. During this process CO_2 is reduced to carbohydrates without light and chlorophyll.	2. CO_2 and H_2O are converted into carbohydrates in the presence of light and chlorophyll.
3. Here chemical energy released during oxidation of inorganic substances is used up to synthesise carbohydrates.	3. Light energy is converted into chemical energy and stored in the form of carbohydrates.
4. No pigment molecule is involved and oxygen is not evolved.	4. Several pigments are involved and oxygen is evolved as a by-product.
5. No photophosphorylation takes place.	5. Photophosphorytion takes place i.e. ATP is produced.

11.8 CHEMIOSMOTIC SYNTHESIS

This is a process in which energy stored as a hydrogen ion gradient across a membrane is used to synthesise ATP from ADP and Pi. The enzyme which uses the energy is ATP synthase and the energy or power source is the difference in the concentration of H^+ ions on opposite sides of the membrane. The membrane is the inner membrane of the mitochondrion or the chloroplast. The word 'osmosis' in Greek means 'push' and here the flow of H^+ ions across the membrane provides the energy or push to ATP synthase enzyme which then catalyses the synthesis of ATP.

Chloroplasts use chemiosmosis to generate ATP during photosynthesis. The prokaryotes lack the organelles mitochondria and chloroplast to generate H^+ gradients across plasma membranes and cannot use it for ATP synthesis. Peter Mitchell won the Nobel prize in 1978 for proposing the chemiosmotic model for syntheis of ATP.

INTEXT QUESTIONS 11.3

1. List the internal factors that influence the rate of photosynthesis?

   ....

2. State the principle of limiting factor.

   ....

3. Give an example of chemosynthetic bacteria.

   ....

4. Why are prokaryotes not able to produce ATP by chemiosmosis?

   ....

WHAT YOU HAVE LEARNT

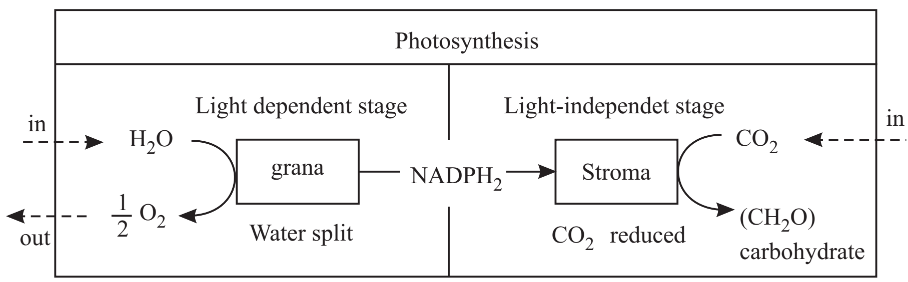
- Green plants are capable of synthesizing carbohydrates from CO_2 and H_2O in the presence of light, by the process of photosynthesis.
- During photosynthesis 'light energy', which is captured by the photosynthetic pigments (chlorophyll, carotenoids and xanthophylls) present in the chloroplasts, is converted into chemical energy.
- Photosynthesis in general is expressed by the following equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{Light}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

- Photosynthesis comprises two sets of reactions:
- Light reactions: which take place in grana or thylakoids of chloroplasts only in the presence of light.
- Dark reactions: Which occur in the stroma of chloroplast and are independent of light, if products of light reaction are provided.
- Light energy is used for splitting of water, and production of ATP and $NADPH_2$ and actual reduction of CO_2 takes place in the dark reaction.
- Light reaction occurs with the help of two functional units, photosystem-I and photosystem-II.
- During light reaction phosphorylation of ADP to ATP may occur in two ways, cyclic and non-cyclic.
- During dark reactions CO_2 is accepted by Ribulose biphosphate (RuBP) and the first stable product. 3-PGA (3 phosphoglyceric acid) is formed, which by further cyclic reactions (Calvin Cycle) leads to the formation of carbohydrates as well as in regeneration of RuBP.

- In C_4 plants like maize, jawar, bajra, the primary acceptor of CO_2 is in mesophyll cells and the first detectable product of dark reaction is oxaloacetic acid (OAA), whereas in the bundle sheath cells CO_2 fixation occurs through. Calvin cycle.
- Occurrence of dimorphic chloroplasts in C_4 plants is known as "Kranz anatomy" and is characterized by the presence of a sheath of parenchyma cells around a vascular bundle (bundle sheath). Cells of this sheath have larger chloroplasts which lack grana and are filled with starch grains. In contrast mesophyll cells contain chloroplasts which are smaller but have well developed grana.
- Rate of photosynthesis is influenced by (i) environmental factors such as light, temperature, carbon dioxide concentration and water, and (ii) internal factors which include age of leaf, chlorophyll content and leaf anatomy.

A SUMMARY OF PHOTOSYNTHESIS



Light-dependent stage	Light independent stage
• occurs in the thylakoid membranes of the grana	• occurs in the stroma
• largely a photochemical change, requiring light energy	• a series of biochemical changes, each reaction catalysed by an enzyme
• light energy is converted to chemical energy in the form of ATP and $NADPH_2$; water is split into hydrogen and oxygen; hydrogen is combined in $NADPH_2$; oxygen gas is released as a byproduct	• carbon dioxide is converted to compounds such as carbohydrates (with the help of chemical energy of ATP and $NADPH_2$); the reactions of the light-independent stage are known as the Calvin cycle and C_4-pathway
• chlorophylls are grouped together in units of about 300 molecules (known as photosystems); two types exist, photosystems I and II	• carbon dioxide is combined with ribulose bisphophate (the acceptor substance) and the product splits instantly into two molecules of glycerate 3-phosphate (GP, the first product of photosynthesis) in C_3-plants
• light energy absorbed by the photo-systems causes electrons from chlorophyll to be raised to a high energy level and to pass to $NADPH_2$; ATP is generated; water is split and provides the electrons	• CO_2 is reduced with the help of RuBP and Rubisco to a three-carbon sugar, triose phosphate; then, in a series of reactions, the acceptor molecule is regenerated and sugars, starch and other substances are formed from

Notes

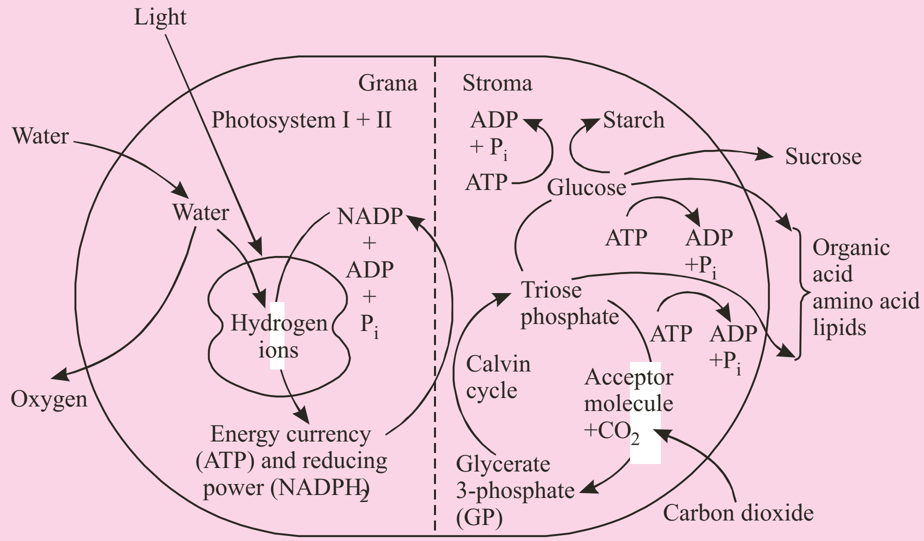
to the photosystem and the hydrogen for $NADPH_2$ production:

$$2H_2O + 2NADP \xrightarrow[\text{Chlorophyll}]{\text{Light}} O_2 + 2NADPH_2$$

$$ADP + P_i \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{ATP (considerable, but variable amount)}$$

triose phosphate:

$$3ATP + CO_2 + 2NADPH_2 \longrightarrow (CH_2O) + H_2O + 3ADP + 3P_i + 2NADP$$



TERMINAL EXERCISES

1. Describe briefly the process of photosynthesis.
2. Write short notes on (i) Ultrastructure of chloroplast and (ii) Pigments involved in photosynthesis.
3. What are accessory pigments? Why they are called so?
4. Mention path of electrons in the light reaction of photosynthesis.
5. What do you understand by photophosphorylation.
6. Discuss photolysis of water and its significance.
7. Describe the reactions occurring during dark reaction of photosynthesis.
8. Differentiate between C_3 and C_4 plants.
9. Differentiate between PSI and PSII.
10. What are the products of light reactions. What is the fate of these products?

11. Why is cyclic photophosphorylation called so?

12. What is Kranz anatomy?

13. Name the two carboxylase enzymes in C_4 cycle.

14. What are chemosynthetic autotrophs?

15. How does CO_2 concentration affect the rate of photosynthesis?

16. What is the effect of excess of oxyygen on the rate of photosynthesis?

17. Whether light absorbed by green plants, on global basis is limiting factor for photosynthesis or not! Explain

ANSWERS TO INTEXT QUESTIONS

11.1 1. (i) It is the process by which green plants produce food (carbohydrates) from simple substances like CO_2 and water in presence of sun light and chlorophyll.

(ii) $6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$

2. (i) Chlorophylls and carotenoids.

(ii) Carotenoids and chlorophyll b

3. (i) Absorb it and then convert it into chemical energy.

(ii) Chlorophyll a and b

4. (i) Minimum in green and yellow light and maximum in blue and red light.

(ii) light energy; chemical energy

5. From photolysis of water in PSII

11.2 1. NADP acts as an electron acceptor and H^+ acceptor and finally, it gets reduced to $NADPH_2$.

2. It is called dark reaction because it can occur independent of light i.e. can occur both in light and in dark.

3. (i) Rubisco is a part of C_3 cycle and combines with CO_2 to produce a C_3 compound called PGA.

(ii) PEPCo is a part of C_4 path way and combines with CO_2 to form a C_4 compound called OAA.

Rubisco is present in the mesophyll cells of C_3 plants and in the bundle sheath cells of C_4 plants.

PEPCo is found only in mesophyll cells of C_4 plants.

4. See text
5. See text
6. C_4 plants have no photorespiration and thus there is no loss of additional carbon dioxide, due to breakdown of RuBP to Glycolate and CO_2.
7. (i) Photolysis of water

11.3

1. leaf age, chlorophyll content, leaf anatomy (size, internal structure, stomatal distribution)
2. See text
3. *Nitrosomonass* and *Nitrobacter*.
4. Because they are not able to maintain H^+ gradient across a membrane in the absence of membrane bound organelles in their cytoplasm.

12

RESPIRATION IN PLANTS

Two most important prerequisites of life are continuous supply of materials for growth of body and energy for carrying out various life processes. All systems, from a single cell to ecosystem, require energy to work. As you have already studied, light energy is converted into chemical energy by plants during photosynthesis and this energy is then stored in the bonds of complex molecules such as glucose, and starch. It is these complex molecules which are given the name ‘food’.

However, the energy in the food has to be made available to the cells in a usable form. This is the role of respiration. Respiration is the process by which fats and protein’s the energy stored in organic molecules is released by oxidation. This energy is thus made available to the living cells in the form of ATP (Adenosine Tri-Phosphate). The O_2 required for respiration is obtained from the atmosphere. ATP is the energy currency of the cell. This lesson covers various aspects of respiration in plants.

OBJECTIVES

After completing this lesson, you will be able to :

- *define respiration, fermentation, photorespiration and Respiratory Quotient;*
- *list the basic events of anaerobic respiration and write the chemical equation representing it;*
- *state the role of fermentation in industry;*
- *compare aerobic and anaerobic respiration;*
- *draw the flow-chart to show the basic steps in Kreb’s Cycle;*
- *explain how energy is actually released and stored in the form of ATP in the cell;*
- *account for 38 ATP molecules that are released during aerobic respiration;*
- *list the factors that influence the rate of respiration and appreciate the usefulness of RQ value of different food items.*
- *to understand the Pentose Phosphate Pathway (PPP) which is the special feature of the microbes (bacteria and funagi) as well as the cells of the highly active tissues of the animals.*

12.1 RESPIRATION

Respiration is the stepwise oxidation of complex organic molecules and release of energy as ATP for various cellular metabolic activities. It involves exchange of gases between the organism and the external environment. The green as well as non-green plants obtain oxygen from their environment and return carbon dioxide and water vapour into it. This mere exchange of gases is known as **external respiration** or breathing in case of animals. It is a physical process.

The biochemical process, which occurs within cells and oxidises food to obtain energy, is known as **cellular respiration**. Various enzymes (biocatalysts) catalyze this process. The process by which cells obtain energy from complex food molecules depends upon whether or not oxygen is present in their environment and utilised. Respiration is termed **aerobic** when oxygen is utilized and **anaerobic** when oxygen is not utilized. In anaerobic respiration, organic molecules are incompletely broken down in the **cytosol** of the cell and only a small fraction of energy is captured as ATP for use by the cell. In aerobic respiration the reactions of anaerobic respiration are followed by an oxygen requiring process that releases much larger quantity of energy in the form of ATP. This occurs in the **mitochondria** of the eukaryotes and in the folded plasma membrane (mesosome) of the prokaryotes.

It is important for you to note that several common processes occur in both, anaerobic and aerobic respiration, such as,

- Oxidation reaction to release chemical energy from complex food.
- Use of coenzyme as carriers of hydrogen to remove the hydrogen from the organic molecule leading to reduction of the coenzyme and oxidation of the substrate. Most of the hydrogen carriers are NAD (nicotinamide adenine dinucleotide) and FAD (flavin adenine dinucleotide).These are later reoxidised, releasing energy for ATP synthesis
- Use of high-energy phosphate compounds like ATP for energy transfer.

The basic differences between the two forms of respiration are given in the Table 12.1.

Table 12.1 Differences between aerobic and anaerobic respiration.

Aerobic (Aero = Air)	Anaerobic (Anaero = No Air)
1. Takes place in the presece of oxygen.	1. Takes place in the complete absence of oxygen.
2. Leads to complete oxidation of organic substrate.	2. Incomplete oxidation of organic substrate takes place.
3. It is most common in higher organisms (both plants and animals).	3. Takes place in lower organisms such as bacteria, fungi, and in higher animals under limiting conditions of oxygen (e.g. in muscles when oxygen present is insufficient).

4. $C_6H_{12}O_6 \longrightarrow 6CO_2 + 6H_2O + 6O_2$ $+38$ ATP	4. $C_6H_{12}O_6 \longrightarrow$ 2Ethyl alcohol + $2CO_2$ +2 ATP (as in yeast) OR $C_6H_{12}O_6 \longrightarrow$ 2 Lactic acid + 2 ATP (as in muscles)
5. Takes place in the cytoplasm, and mitochondria in eukaryotes and plasma membrane in prokaryotes.	5. Takes place in the cytoplasm.

Coenzyme is a complex non-protein molecule which is temporarily bound to an enzyme and acts as a link between metabolic pathways, (series of biochemical reactions).

INTEXT QUESTIONS 12.1

1. How do plant and other organisms obtain energy for various activites such as growth?

   ....

2. Name the energy-rich molecule formed during respiration from food.

   ....

3. Give two differences between aerobic and anaerobic respiration.

   ....

12.2 EXTERNAL RESPIRATION/GASEOUS EXCHANGE

- In plants, the atmospheric air moves in and out by simple diffusion that takes place through,
  (a) the general body surface of the plant (stems, roots, fruits and seeds);
  (b) lenticels (openings in the bark of the tree trunk (Fig. 12.1);
  (c) stomata present in the leaves and young, green parts of the stems.

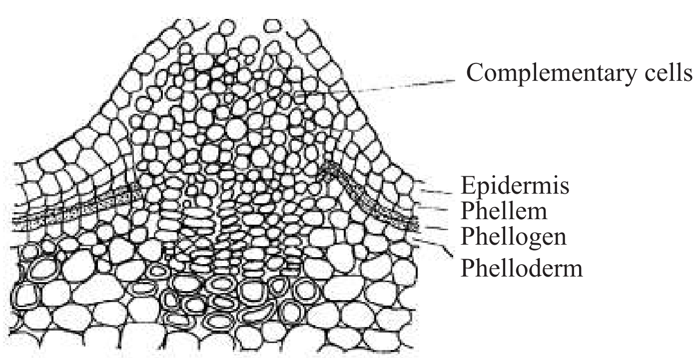


Fig. 12.1 Lenticels on the bark of a tree

- Plants do not need O_2 carrier (in contrast to animals) where O_2 is carried by blood). This is because O_2 requirement is less in plants than in animals since the plants have a large surface area (leaves) to absorb the required amount of O_2 through diffusion.
- From the atmosphere, gases enter the intercellular spaces inside the plants. As O_2 is utilized, more of it diffuses into the plant. Since CO_2 is being continuously formed, its concentration in tissue spaces becomes higher than in the surrounding air. As a result, it diffuses out of the plant, specially when it is not being used for photosynthesis.
- Can you explain as to why during the day, plants give out O_2 instead of taking it up for respiration?

In plants, O_2 released during photosynthesis in day time is made available for respiration. However, the rate of photosynthesis is higher than that of respiratin. Thus, plants give out excess O_2 in the daytime. However, these release only CO_2 at night as photosynthesis stops in the absence of sunlight. Animals give out CO_2 at all times.

INTEXT QUESTIONS 12.2

1. Name the surfaces that help plants in taking up oxygen from the atmosphere.

   ....

2. Name the process by which oxygen is taken up by the plants from the atmosphere.

   ....

3. Name the gases given out by plants during daytime and night.

   ....

4. Why do plants not have any special respiratory organs like animals? Give two reasons.

   ....

12.3 CELLULAR RESPRIATION

Oxygen that is absorbed in the body, is used to oxidize the nutrients, viz., glucose, amino acids and fatty acids completely producing CO_2, water and energy. It occurs within the cells and tissues. Observe Fig. 12.2 and identify the steps of cellular (aerobic and anaerobic) respiration. Note that the first stage in all these pathways is **glycolysis**.

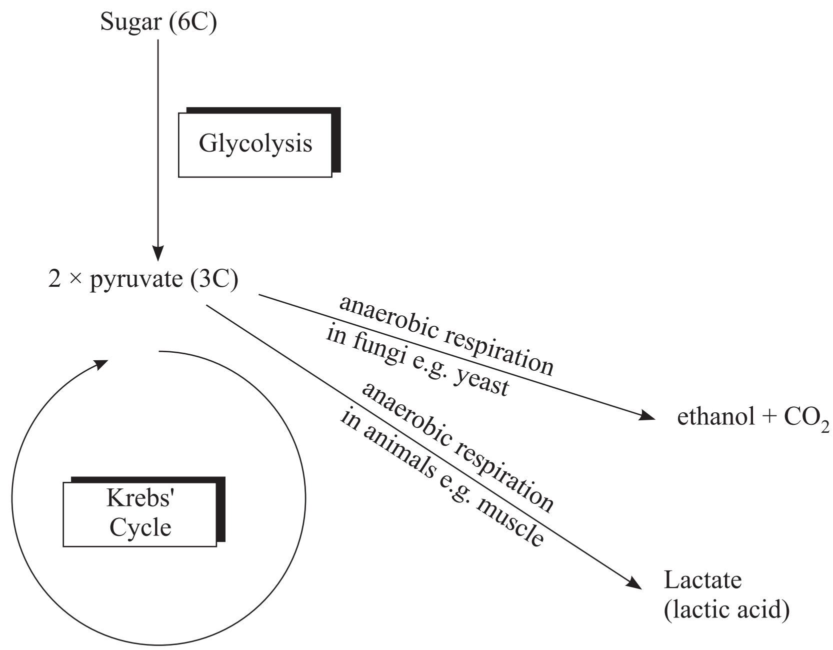


Fig. 12.2 Pathways in cellular respiration

12.3.1 Glycolysis (Also known as-Embden-Meyerhof-Parnas Pathway)

Whether or not the oxygen is available in the cells, the breakdown of glucose is initially always anaerobic. It is common to both aerobic and anaerobic respirations.

It involves oxidising **glucose** (6-carbon compound) to two molecules of **pyruvic acid** through a series of enzymatically controlled reactions occurring in the cytosol. Initial substrate is glucose (either from photosynthesis as in plants or from carbohydrate digestion as in animals).

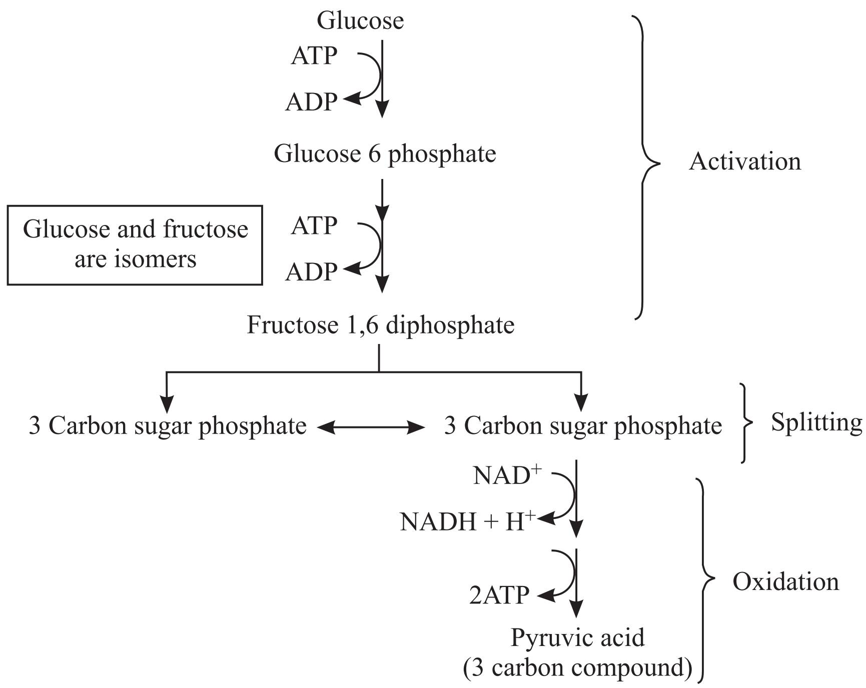
Glycolysis may be subdivided into **3 major phases:**

1. Phosphorylation of glucose to fructose 1,6 diphosphate. This is activation of glucose and 2ATPs are used.
2. Splitting of this compound into two 3- carbon sugar phosphates, which are interconvertible. Note that this is the origin of the term **glycolysis** meaning splitting of glucose.
3. Oxidation by dehydrogenation. Each 3-C sugar phosphate is oxidized by removal of hydrogen, making a reduced NAD that is NADH and production of 2ATPs.

This group of reactions is believed to be one of the first energy capturing reactions which evolved about three billion years ago in ancient bacteria and today it occurs in virtually all cells of all forms of life.

$$ATP \longrightarrow ADP + Pi + 30.6 \text{ kJ}$$

The balanced equation is:



- Glucose + 4ADP + 4Pi + 2NAD $\longrightarrow$ 2Pyruvic acid + 4ATP + 2NADH
- Two molecules of ATP were used up in the initial steps of glycolysis. Thus, the net gain of ATP during glycolysis is 4 – 2 = 2 ATP. Also, 2NADH + H^+ are produced.
- Thus, we see that only a small amount of energy is released at the end of glycolsis.

12.3.2 Fermentation

Further oxidation of Pyruvic acid requires O_2 (as you will study soon). It then enters mitochondria for aerobic respiration.

Under anaerobic conditions (or insufficient supply of O_2) microbes, plants and animals carry out fermentation.

Fermentation involves **reduction** of pyruvic acid to **ethyl alcohol** and **CO_2** (as in yeast) or to **lactic acid** (as in muscle cells of animals) and oxidation of NADH to NAD^+. Thus, NAD is regenerated which can be used in glycolytic pathway and production of 2 ATPs can continue under anaerobic conditions. (Refer to the figure 12.3). Note that there is no further release of ATP during fermentation.

> Although you are more familiar with the term fermentation in the context of alcoholic fermentation it is now being used for the anaerobic pathway after the production of pyruvic acid, in glycolysis in cytosol.

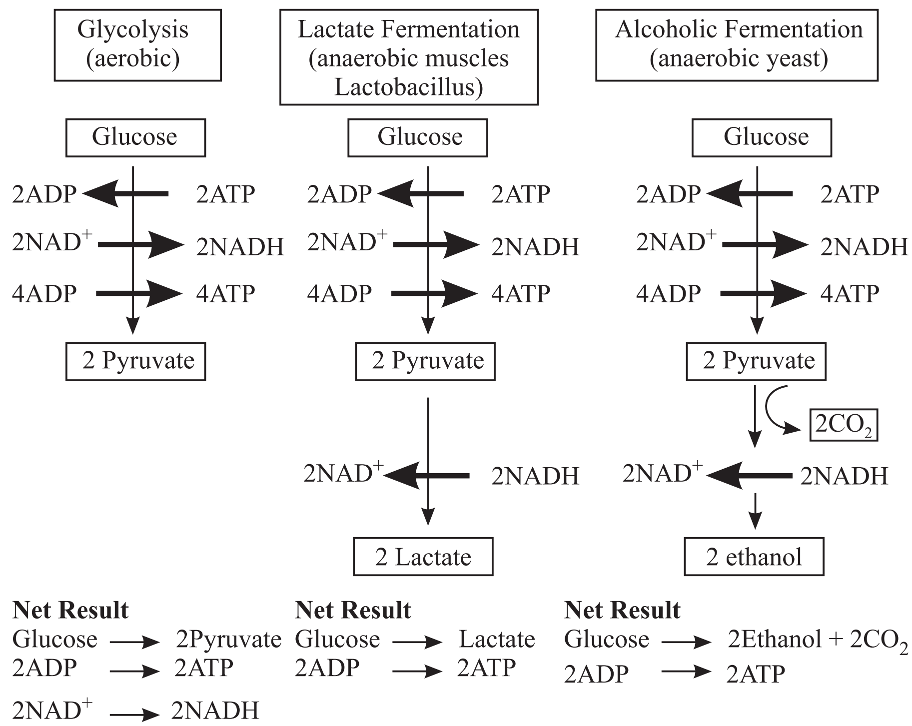


Fig. 12.3 Pathways of anaerobic respiration

Significance of fermentation

Fermentation has a number of industrial applications. It is made use of on a large scale in certain industries. Micro-organisms like the different strains of bacteria and yeast are cultured in very large numbers and used for various purposes.

1. In bakeries for preparing bread, cakes and biscuits.
2. In breweries for preparing wine and other alcoholic drinks.
3. In producing vinegar and in the tanning and curing of leather.
4. Ethanol is used to make gasohol, a fuel that is used for cars in Brazil.
5. In everyday life, fermentation is used while making *idli*, *dosa, bhatura* and *dhokla*. The kneaded flour or *maida* left for some hours in warm environment becomes somewhat spongy (leavening). This is because of fermentation by the bacteria that begin to grow in it. As carbon dioxide escapes, it causes leavening. Fermentation products give a typical flavour and taste to these items.

> Do you know why muscles pain during prolonged exercise? This is due to accumulation of lactic acid under anaerobic condition.

12.3.3 Fate of pyruvic acid in aerobic respiration

- You have already learnt how glucose is converted into 2 molecules of pyruvic acid in the cytoplasm of a cell during glycolysis.

- In the presence of oxygen, pyruvic acid enters the mitochondria and is decarboxylated (removal of CO_2) and dehydrogenated (removal of H) to acetyl CoA. **Acetyl CoA** is thus the connecting link between glycolysis and the next series of reactions that yield more energy in the form of ATP. Acetyl CoA can also be generated from fats and proteins.

Krebs' Cycle or the citric acid cycle

- Acetyl CoA is the molecule entering the Krebs' Cycle taking place in the matrix of the mitochondria.
- Details of this cycle were worked out by Sir Hans Krebs in the 1930s. It is also known as tricarboxylic acid cycle or TCA cycle.
- Steps of the Krebs' Cycle are as follows, (*See* Fig. 12.4)

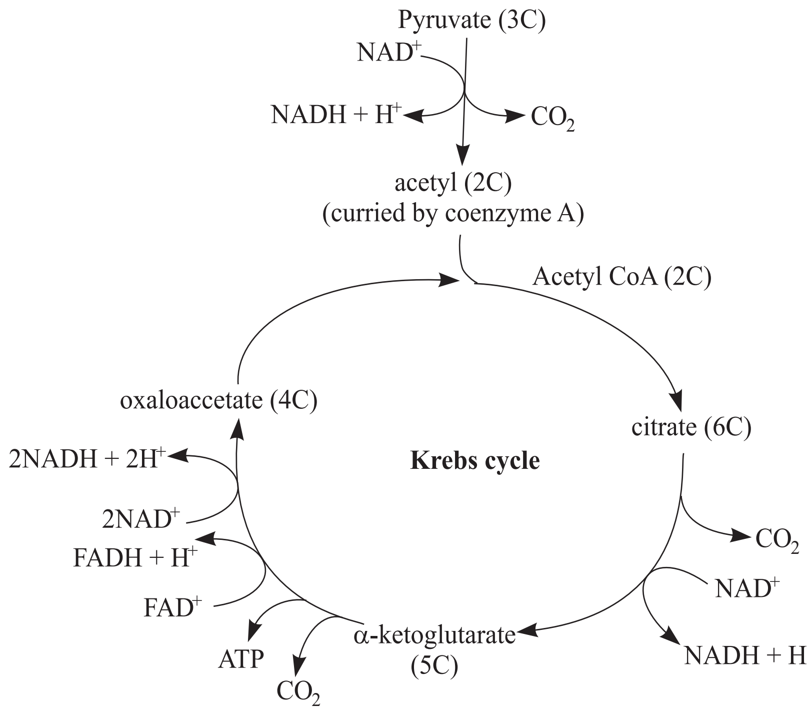


Fig. 12.4 Kreb's Cycle (simplified)

Summary of this phase in respiration is

$$2\text{Pyruvic acid} + 8NAD + 2FAD + 2ADP \longrightarrow 6CO_2 + 8NADH + 2FADH_2 + 2ATP$$

> H-carrier NAD and FAD are derived from vitamin B complex and are known as coenzymes

- Acetyl group (2 carbon) enters the cycle by combining with **oxaloacetate** (4 carbon), to form **citrate** (6 carbon). This initiates citric acid cycle.
- As acetyl group passes round the cycle, the 2 carbon atoms are lost in CO_2 in two decarboxylation reactions, and hydrogen is added to hydrogen carriers in four dehydrogenation reactions, resulting in a total of 3 $NADH_2$ and 1 $FADH_2$ molecules.

- One molecule of ATP is also made directly for every turn of the cycle. (Remember that two acetyl groups were made from one glucose molecule. As such two turns of the cycle occur per glucose molecule used). Oxaloacetate is regenerated at the end of the cycle ready to accept another acetyl group.
- Thus, at the end of the Citric Acid Cycle, there are a total of 10NADH and $2FADH_2$ (2NADH from glycolysis).
- Note that all the hydrogen atoms from the original glucose are now on hydrogen carriers, NAD and FAD.

These hydrogen carriers enter the next phase known as the respiratory chain or Electron-Transport-Chain (E.T.C.) for further release of energy.

The Respiratory Chain or Electron Transport Chain (E.T.C.) or Oxidaive-Phosphorylation

- The hydrogen carriers now move to the inner membrane of the mitochondrion. This membrane has folds called *cristae*, which increase its surface area.
- The hydrogen ions carried to the cristae undergo stepwise oxidation using molecular oxygen and energy is released in a series of small steps. Some of this energy is used to make ATP from ADP and inorganic Phosphate (P_i). This is called *oxidative phosphorylation*.
- During these reactions, the hydrogen is split into H^+ and electrons (e^{-1}), which are accepted by a series of hydrogen or electron carriers ending with oxygen. This series of carriers constitute the **respiratory chain** (Fig. 12.5).

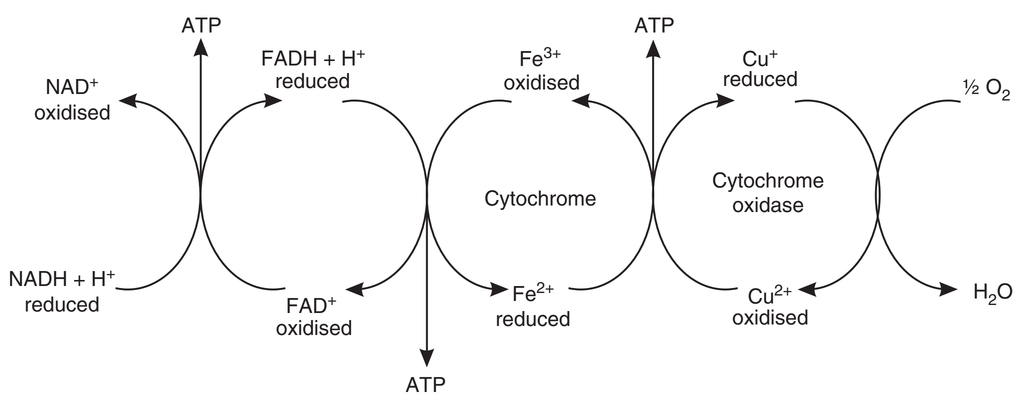


Fig 12.5 Respiratory Chain (Oxidative Phosphorylation)

- Hydrogen or electrons at a higher energy level are passed from one carrier to the next, moving downhill in energy terms, until they reach oxygen, the final acceptor of electrons which as a result is reduced to water.
- At each transfer level, some energy is released as heat and in some of the transfers this is used for the formation of ATP.
- The final step involves cytochrome oxidase enzyme, which hands over the electrons to the H^+ before being accepted by oxygen to form water.
- For each $NADH_2$ that enters the respiratory chain, 3 ATP can be made but for each $FADH_2$, only 2 ATP can be made. Can you guess why? This is owing to the facts that $FADH_2$ enters the respiratory chain at a lower energy level in the chain of reactions.

Substances like carbon monoxide and H_2S act as poisons since they block the H-transfer system and stop ATP generation.

Overall budget for aerobic respiration of one glucose molecule

See table no: 12.2

	CO_2	ATP	$NADH+H^+$	$FADH_2$
Glucolysis	-	2	2	-
Pyruvate-> Acetyl coA	2	-	2	-
Krebs cycle	4	2	6	2
Total	$6CO_2$	4ATP	10 $NADH+H^+$ 10×3=30 ATP	2 $FADH_2$ 2×2=4 ATP

Total No. of ATP mols = 38

* Remember that two turns of the Krebs' Cycle take place per glucose molecule as at the end of glycolysis two pyruvic acid molecules are formed each of which separately enters the Krebs' Cycle.

* According to some biologists, the total numbr of ATP molecules produced in cell respiration after oxidatrion of one glucose molecule is 36 and not 38 because two $NADH_2$ molecules produced in glycolysis in cytoplasm, are theoretically oxidised through electron-transport system in mitochondrion. In the mitochondrion, on the other hand, the matrix is already having higher concentration of $NADH_2$ molecules. Thus, two $NADH_2$ molecules produced in glycolysis, have to enter the mitochondrion against the Concetration Gradient, for oxidation, and for this process, two ATP-molecules would be consumed. For this reason, the net amount of ATP molecules per glucose oxidation by aerobic respiration, should be 36. However, since bacteria do not have mitochondria; the number of ATP molecules produced per glucose molecule oxidised by prokaryotes,

should be considered as 38.

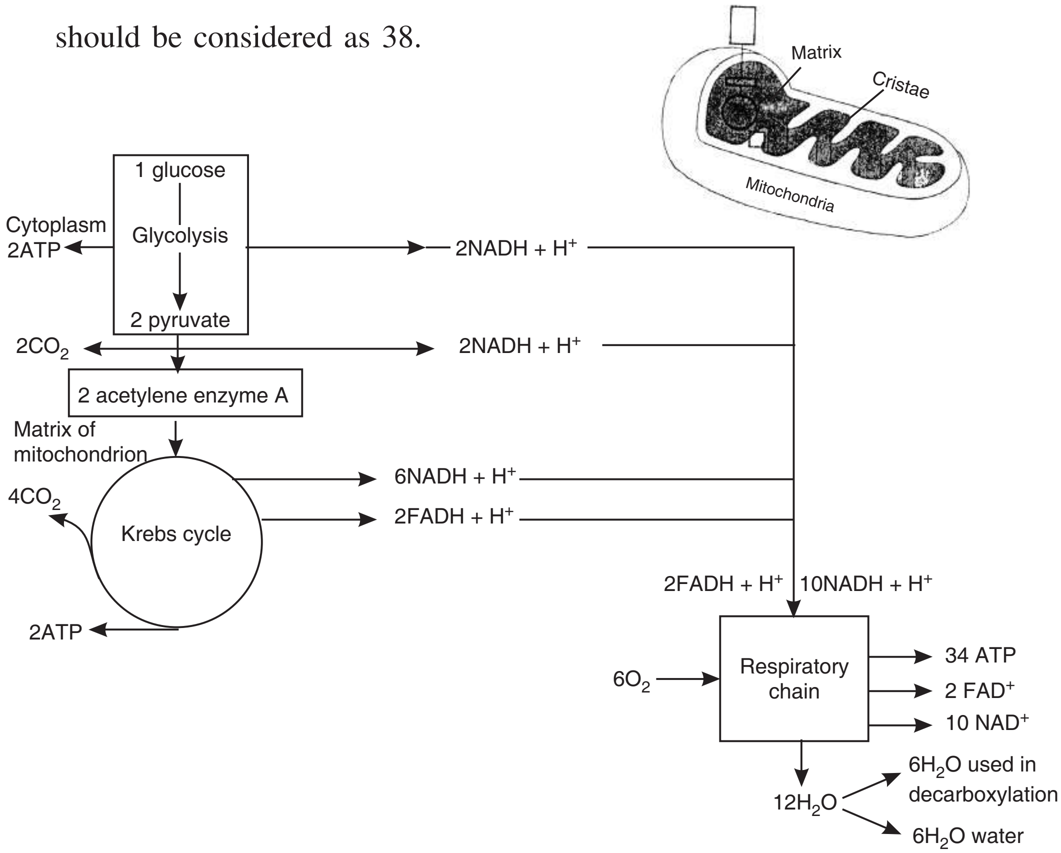


Fig 12.6 Summary of Aerobic respiration.

12.3.4. Significance of Krebs' Cycle and Acetyl CoA

1. It is the major pathway to release reduced coenzymes and energy, in a controlled manner.
2. It is the common pathway for oxidative breakdown of glucose, (carbohydrates), fatty acids and amino acids. The fatty acids undergo β oxidation to produce acetyl CoA and amino acids from proteins enter Krebs' Cycle after deamination (removal of $-NH_2$ group) of amino acids.
3. Krebs' Cycle provides series of intermediate compounds needed for the synthesis of other biomolecules like amino acids, nucleotides, chlorophyll, and fats.

12.3.5 Amphibolic Pathway

Respiration is necessary for the survival of all living beings. In respiration, oxygen is utilised and carbon dioxide given out. The green plants carry out photosynthesis during which CO_2 and H_2O are utilised in the presence of sunlight to synthesize starch and energy. As such, photosynthesis is the building up or anabolic pathway whereas respiration is a breaking down or catabolic process in which glucose is oxidised to yield CO_2, H_2O and energy. The two pathways occurring together constitute the amphibolic pathway (amphi = two).

The light intensity at which photosynthesis just compensates for respiration is called **Compensation Point**. In other words, in a green plant at the compensation point, amount of CO_2 consumed during photosynthesis is equal to the amount of CO_2 generated through respiration.

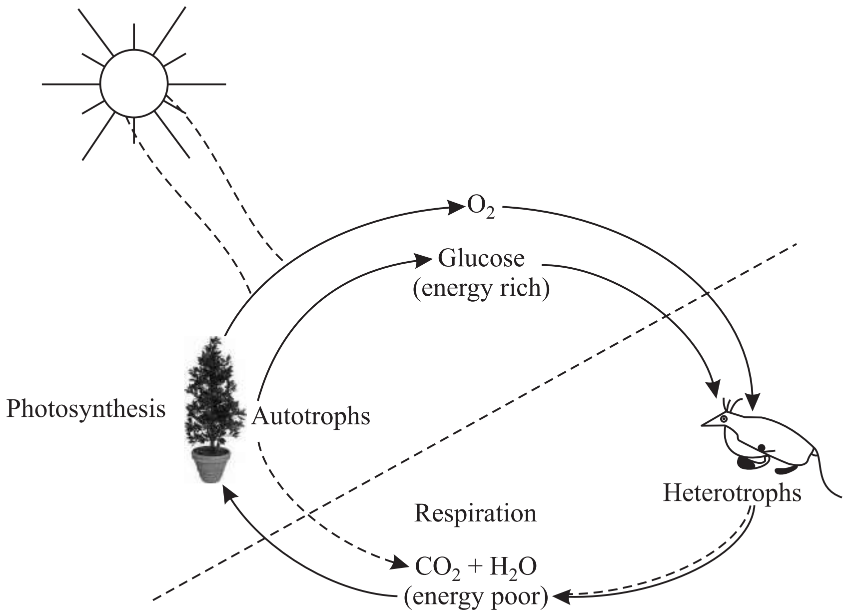


Fig. 12.7 Anaerobic respiration in germinating seeds

INTEXT QUESTIONS 12.3

1. Why is pyruvic acid converted into alcohol or lactic acid during fermentation?

   ....

2. Why is there less release of energy during anaerobic respiration?

   ....

3. List the three phases of aerobic respiration of glucose. Where in the cell do these reactions take place?

   ....

4. What is the role of O_2 in aerobic respiration?

   ....

5. Name the substrate and products of Krebs' Cycle.

   ....

6. How do fatty acids enter Krebs' Cycle?

   ....

7. When the amount of CO_2 uptake during photosysthesis is equal to the amount of CO_2 generated through respiration, it is called ....
8. What is amphibolic pathway?

   ....

12.4 RATE OF RESPIRATION AND FACTORS AFFECTING IT

The rate of respiration can be measured by the amount of CO_2 released per unit time. As expected, it varies in different organs and with age.

In general the factors which affect respiration include **internal factors** such as minerals, structure of respiratory tissue or organ, the activity of the respiratory enzymes and the type of substrate; and **external factors** such as oxygen, water, and temperature.

(a) **Type of substrate**-Respiratory substrate may be carbohydrate, protein or fats. The kind of substrate being oxidized can be determined by measuring the **Respiratory Quotient** of the respiratory tissue or oxygen. What is respiratory quotient or R.Q?

$$R.Q = \frac{\text{Volume of } CO_2 \text{ evolved}}{\text{Volume of } O_2 \text{ consumed}}$$

For carbohydrates, $CO_2/O_2 = 1$ as in the stem and roots.

For protein, $CO_2/O_2 < 1$ as in protein-rich seeds like pulses.

For fat and oils $CO_2/O_2 > 1$ as in the oil-containing seeds e.g. mustard.

As for fats RQ > 1 since more energy is released per mol of fat than per mol of glucose.

(b) **Temperature -** The temperature between 30-35°C is most suitable for respiration. Can you guess why? This is because the enzymes can work best in this range. Respiration is reduced beyond 50°C and also at very low temperatures (0-10°C).

(c) **Oxygen**-the rate of respiration increases with rise in oxygen concentration. As O_2 concentration increases from zero, the rate of respiration increases. However, beyond a limit the rate of increase falls.

(d) **Carbon dioxide**–rate of respiration decreases if CO_2 is allowed to accumulate surrounding the respiratory tissue.

(e) **Water**–respiration is very slow if the water content of the protoplasm is low as in dry, matured seeds. Dormant seeds show very low rate of respiration. It water is supplied to dry seeds, respiration starts immediately.

INTEXT QUESTIONS 12.4

1. What is the R.Q. for carbohydrates and fats?

   ....

2. What is the effect of high concentration of O_2 on respiration?

....

3. What is the ideal temperature for the process of respiration ?

....

4. Define R.Q.

....

5. What is the limiting factor of respiration in dry seeds?

....

12.5 PHOTORESPIRATION

- Your have aready studied that during dark reaction of photosynthesis, the enzyme RUBISCO catalyses the carboxylation of RUBP :

$$\text{RUBP} + CO_2 \xrightarrow{\text{RUBISCO}} \text{2PGA (Phosphoglyceraldehyde)} \longrightarrow \text{Calvin Cycle}$$

- This enzyme also has very high affinity for O_2. It can therefore, catalyze the reaction of O_2 with RUBP (oxygenation).
- The respiration that is initiated in chloroplast and occurs in the presence of light and high concentration of O_2 (and low CO_2) is called photorespiration :

$$\text{RUBP} + O_2 \xrightarrow{\text{RUBISCO}} \underset{\substack{\downarrow \\ \text{Calvin Cycle}}}{\text{2PGA}} + \text{1 Phosphoglycolate}$$

Thereafter, the phosphoglycolate undergoes series of reactions in **mitochondria and peroxisomes.** 2 molecules of phosphoglycolate ultimately produce 1 molecule of PGA and 1 molecule of CO_2. Note that there is no ATP production here, unlike respiration.

- This occurs because RUBISCO anzyme has the same active site for both CO_2 and O_2.
- Oxygenation of RUBP in presence of oxygen leads to a loss of about 25% carbon fixed by plants during the dark reaction.
- Use: Protects the plants from photo-oxidative damage by utilising part of the solar energy which would otherwise damage the plant pigments.

Notes

INTEXT QUESTIONS 12.5

1. Name the products that are formed when RUBP combines with O_2. Name the enzyme that is responsible for this reaction.

   ....

2. Give one point of difference between respiration and photorespiration.?

   ....

3. State the conditions under which photorespiration occurs?

   ....

12.6. PENTOSE PHOSPHATE PATHWAY OR HMP-PATHWAY

In microbes (bacteria and some fungi) used for Industrial production of commercial products such as antibiotics and in highly metabolically active tissues of animals, most efficient respiratory pathway has been discovered. It is called **PPP or Pentose Phosphate Pathway or Hexose-Monophosphate Shunt Pathway** or **Direct Oxidation of Glucose-pathway**. The site of this respiratory pathway is cytosol and it does not require ETC (electron transport chain) or the mitochondrion.

It this pathway, when a molecule of glucose enters the respiratory process, it is phosphorylated to Glucose-6-Phosphate by consumption of one ATP-molecule. This Glucose-6-P molecule, meets a group of 5 glucose-6-P molecules in the cytoplasm, which in the presence of dehydrogenase and 6 NADP get oxidized to 6 Phosphoglucomutase molecules, producing 6 $NADPH_2$ molecules. In the next reaction catalyzed by dehydrogenase and decarboxylase, six-phosphogluconate molecules, get oxidised to six molecules of pentose sugar, Ribulose-5P; producing $6CO_2$ (that diffuse in air) and 6 more NADP get reduced to 6 $NADPH_2$. Thus, in this respiratory pathway a glucose molecule is broken down to 6 CO_2 + $12H_2$ (as part of 12 $NADPH_2$), side by side producing 6 molecules of pentose sugar (Ribulose-5 phosphate) which is utilized for regeneration of 5 molecules of Glucose-6-P through a long chain of intermediate compounds produced in Calvin Cycle of photosynthesis to restart another cycle of glucose-oxidation.

You would observe that in this pathway if 12 $NADPH_2$ molecules produced within two steps of glucose-oxidation, are allowed to enter oxidative phosphorylation (ETC), 36 ATP molecules would be produced. If we deduct one ATP, consumed in first step of conversion of Glucose to Glucose-6P, a net amount of 35ATP molecules would be available as respiratory energy produced by complete oxidation of one glucose molecule within two chemical reactions to $12H_2$ and $6CO_2\uparrow$

PPP is so-called because after complete oxidation of one glucose molecule to $6CO_2$ + $12NADPH_2$; a side product is a pentose phosphate sugar i.e., ribulose-5-Phosphate. If glucose molecules keep entering this pathway, a large number of pentose sugars would be formed. This sugar, on conversion to ribose-5-P, would act as raw material for RNA synthesis. If ribose-5-P loses one O-atom, it would change to deoxyribose-5P, that can act as raw material for DNA-synthesis. However, in general, 6 molecules of ribulose-5P, through large number of intermediate compounds (such as erythrose, sedoheptulose, and hexoses), regenerate 5 molecules of Glucose-6-P, responsible for new cycle of Pentose Phosphate Pathway.

PPP is also called HMP-pathway because the raw material for glucose oxidation is Glucose-6-P which is a hexose sugar produced after consuming only one ATP in contrast to Glycolytic pathway, where two ATP-molecules are consumed during the respiratory-oxidation of Glucose under aerobic condition.

ACTIVITY I

To demonstrate anaerobic respiration in germinating seeds

Take eight or ten water-soaked pea seeds with the seed coats removed and push them into the mouth of a test tube filled with mercury and invert it in a beaker of mercury. The pea seeds float on the top and are completely surrounded by mercury. After about two days there is a fall in the level of the mercury because of gas liberation. If potassium hydroxide (KOH) is introduced into the test tube then it is found that KOH floats up through the mercury and on coming in contact with the gas, makes the level of mercury to rise up again. Now can you say why does this happen? KOH absorbs the carbon dioxide gas liberated by the seeds. Therefore this experiment demonstrates the anaerobic respiration (See Fig. 12.8) wherein, CO_2 is process of evolved due to anaerobic respiration of seeds soaked in water.

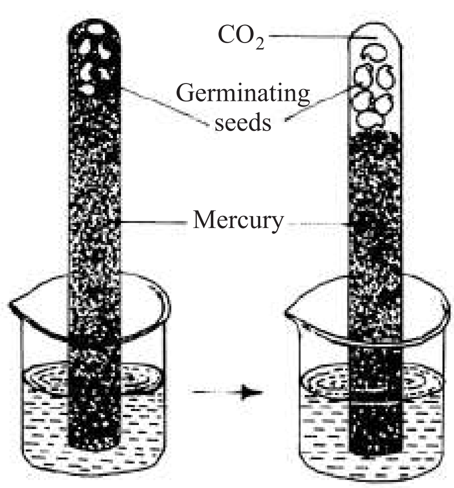


Fig. 12.8 Anaerobic respiration in germinating seeds

ACTIVITY II

Anaerobic respiration in yeast

Procedure : Take a pinch of dry baker's yeast (in water) or few ml of yeast suspension used in a bakery. Add this to 10 ml of 10% glucose solution in test tube A. Cover the surface of the liquid in the tube with oil to prevent contact with air. Close the test-tube tightly with a cork. Take a double bent glass delivery tube with one end small and other end long (See Fig. 12.9).

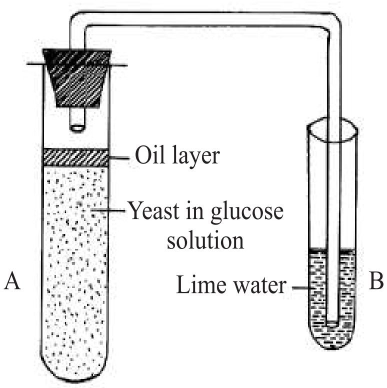


Fig. 12.9 Anaerobic respiration in yeast.

Insert the short end of the glass tube through the rubber-cork stopper so that it remains exposed to the air inside the tube A. Insert the other end of the tube into the limewater containing test tube B, as shown in the figure.

Place test tube A in warm water 37-38°C in a beaker. Observe that lime water gradually turns milky indicating evolution of CO_2 from yeast preparation. Also note that the level of the limewater in the delivery tube does not rise, showing that there is no fall in volume of gas in test tube A and therefore no utilization of O_2 by yeast. Keep the experimental set up for one day. Open the stopper of tube A and smell. Do you notice the smell of alcohol? Can you name the alcohol and write the equation for the alcoholic fermentation

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + 2ATP$$

ACTIVITY I

You can use similar set-up as in activity II to demonstrate aerobic respiration in yeast. Make the following changes :

1. Replace the test tube A with a large conical flask so that it has sufficient space left above the glucose solution with yeast.
2. The surface of the solution should not be covered with oil to permit easy contact with air.

3. Observe that lime water turns milky in this experiment too, indicating evolution of CO_2. Also note that the level of H_2O in the delivery tube B also rises indicating a fall in gas volume in tube A. How do you explain this? Oxygen is utilized by the yeast, and you will not smell alcohol after the reaction in the test tube A

Note that the yeast grows both in aerobic and anaerobic conditions but better under aerobic conditions. The secret of brewing is to regulate the conditions very strictly.

WHAT YOU HAVE LEARNT

- All living organisms require energy. Oxidation of food molecules provides this energy.
- Respiration involves (i) external respiration or gaseous exchange, and (ii) cellular respiration.
- Anaerobic respiration is the process of incomplete oxidation and produces only 2 molecules of ATP whereas the aerobic respiration is a process of complete oxidatin with production of 38 molecules of ATP, per molecule of glucose-oxidised.
- Aerobic respiration occurs in three main steps viz. Glycolsis; Krebs' Cycle; and electron trasport chains (or oxidative phosphorylation).
- Steps of glycolysis are common between aerobic and anaerobic respiration.
- Glycolysis occurs in cytoplasm and Krebs' Cycle and ETC in mitochondria.
- Alcoholic fermentation has many industrial applications.
- Young parts of the plants show higher rate of respiration.
- Factors like type of substrate, temperature, oxygen and amount of available water influence the rate of respiration.
- RQ value is important in identifying the kind of substrate used in respiration.
- Photorespiration occurs in plants during intense light and low level of carbon dioxide. There is no net gain of ATP. It protects the chlorophyll pigments from photo-oxidation, when light intensity is very high.

TERMINAL EXERCISES

1. Define respiration
2. What is the role of O_2 in electron transport chain (ETC)?
3. How many molecules of ATP are released when a molecule of glucose is oxidised to
   (a) CO_2 and H_2O?
   (b) Ethyl alcohol and CO_2?

4. Write the equation for aerobic respiration.
5. Name the end products of electron transport chains.
6. Respiration is a continuous process in green plants. Then why is it that they give out O_2 and not CO_2 during the day?
7. What is the site for
   (a) Glycolysis,
   (b) Krebs Cycle,
   (c) ATP generation by oxidative phosphorylation?
8. What is the fate of pyruvic acid in the (a) presence, and (b) absence of oxygen? Write the equations representing the processes, that take place in (a) & (b).
9. What is the significance of stepwise oxidation of organic molecules instead of one step reaction?
10. What is the significance of photorespiration?
11. List the substrates that enter and the products produced in
    (a) Glycolysis
    (b) Krebs Cycle
12. How is yeast useful in industry? Give any three examples.
13. How does exchange of respiratory gases take place in plants
14. Define RQ. What is its significance?
15. Mention the significance of TCA cycle.
16. Why does fermentation yield less energy than aerobic respiration?
17. List any 2 important contributions of PPP in a cell.
18. What are the three major phases of glycolysis?
19. What is the importance of Krebs' Cycle?
20. Differentiate between aerobic and anaerobic respiration
21. Why is photorespiration a wasteful reaction?
22. What is respiratory chain or ETC? What is its significance?
23. Discuss the site of Pentose Phosphate Pathway in a cell.

ANSWERS TO INTEXT QUESTIONS

12.1 1. The green Plants convert solar energy to chemical energy and store it in the form of complex organic molecules. During respiration, they are oxidised and large amount of energy is released. This is stored as ATP. Plants use this ATP for metabolic activities.

2. In the form of ATP

3. Please see text.

12.2 1. Gaseous exchange takes place through the general body surface of the plants; through the stomata; and the lenticels.

2. Diffusion

3. Oxygen; carbon dioxide

4. (a) They have a large surface area to allow exchange of gases from and (b) their requirement of oxygen is much less.

12.3 1. In the presence of O_2, it is completely broken down to simple forms such as CO_2 and H_2O.

$$2\text{Pyruvic acid} + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 30ATP$$

(8ATP are obtained from glycolysis)

In the absence of O_2 they carry out alcoholic fermentation.

$$2\text{Pyruvic acid} \longrightarrow 2\text{Ethyl alcohol} + 2CO_2$$

2. This is becausse organic molecules are only partially oxidised in anaerobic respiration and much of the energy remains in the end products such as alcohol or lactic acid.

3. Glycolysis-in cytosol

Krebs' Cycle-matrix of mitochondria

E.T.C.-inner membrane of mitochondria

4. O_2 acts as the terminal acceptor of electrons and H_2, removed from the glucose molecule and gets reduced to H_2O.

5. Substrate- Acetyl CoA

Product-2 CO_2, 3 $NADH_2$, 1 $FADH_2$, 1 ATP

6. Fatty Acid undergoes β oxidation and produces acetyl CoA. This can enter the Kreb's Cycle

12.4 1. R.Q. is 1

2. Rate of respiration increases up to a point and beyond this point its rate of increase falls.

3. 30-35°C

4. It is the ratio of the volume of CO_2 evolved to the volume of O_2 consumed in respiration. It gives us an idea of the kind of substrate used for respiration.

5. Water for hydration of respiratory enzymes.

12.5 1. Products are1 P.G.A. and 1 Phosphoglycolate

2.

Respiration	Photorespiration
1. Occurs in cytoplasm and mitochondria	1. It involves 3 organelles chloroplast, mitochondria peroxisome
2. Substrate is glucose	2. Substrate is RUBP
3. ATP, CO_2 and H_2O are given out as products	3. The products are only CO_2 and P.G.A. and no ATP is generated
4. Takes place in C_3 as well as C_4-plants	4. Takes place in green plants (C_3-plants)
5. Occurs at both day and night	5. Takes place under high O_2 and low CO_2 and high temperature. Therefore occurs only during the day.
6. Makes energy available for metabolic activities.	6. It is a wasteful reaction. Its only use is that it prevents photo-oxidative damage of photosynthetic pigments in the green-C_3-plants. (any one)

3. (a) Light
   (b) High concentration of O_2
   (c) Low concentration of CO_2

13

NUTRITION AND DIGESTION

Plants manufacture their own food by photosynthesis, but animals including humans have to take in ready made food. Most part of such food consists of complex organic molecules (carbohydrates, proteins and fats) which have to be broken down into simpler forms before they can be absorbed into the body. Such breaking down of the food and subsequent absorption of food constituents occurs inside the digestive tract (alimentary canal). The digestive tract together with the associated glands constitute the digestive system.

OBJECTIVES

After studying this lesson, you will be able to :

- *define the term nutrition and mention types of nutrition;*
- *draw a labelled diagram of the alimentary canal of cockroach and of humans;*
- *describe the steps involved in the nutrition of humans viz., ingestion, digestion, absorption, assimilation and egestion;*
- *differentiate between intracellular and intercellular digestion;*
- *tabulate the organs of digestion, the enzymes they secrete, the substrates acted upon by enzymes and the end products formed.*
- *explain the process of food absorption in certain regions of digestive tract;*
- *explain briefly the role of hormones in digestion.*
- *list some digestive disorders and mention their cause, symptoms and remedies.*

13.1 NUTRITION AND DIGESTION

Our food contains a number of organic and inorganic constituents to meet the requirements of our body. These food constituents must be digested to be utilized by our body. The process by which organisms obtain and utilize food for their growth, development and maintenance is called **nutrition** and the chemical constituents present in the food are called **nutrients**. On the other hand, **digestion** is the breaking down of complex constituents of food by enzymes into simpler soluble forms that can be absorbed and utilised by the cells of the body.

In this lesson you will study the various modes of nutrition, types of digestion, the process of digestion of food, and its absorption and assimilation in humans. The nutritional role of food constituents will be discussed in lesson 27.

Types of nutrition

There are mainly two types of nutrition **autotrophic nutrition** and **heterotrophic nutrition**.

Nutrition

- Autotrophic nutrition
  (Auto : self, trophos : food)
  Green plants and certain bacteria manufacture their own food (organic substances) from inorganic substances (CO_2 and H_2O) using energy from sunlight.
- Heterotrophic nutrition
  (Hetero : different, trophos : food)
  Food (organic and inorganic substances) obtained by feeding on other organisms.
  - Holozoic
    Organisms engulf the food into the body, digest it and absorb the soluble products of digestion, eg., humans.
  - Saprotrophic
    Ogranisms secrete digestive enzymes on to dead organic material and absorb the products of digestion, eg., certain bacteria and fungi.
  - Parasitic
    Food is derived from other living organisms by living on or inside their body eg., certain bacteria,roundworm, tapeworm, *Cuscuta*, etc.

There are Five Major Steps in Animal Nutrition (Holozoic nutrition)

The food we take contains highly complex nutrients like **protein, carbohydrates** and **fats**. These substances cannot be utilized as such by our body. These have to be broken down into simpler and smaller molecules before they can enter into the cells. Proteins must be broken down into amino acids, carbohydrates into glucose, fats into fatty acids and glycerol. Amino acids, glucose, fatty acids and glycerol are simpler substances, and can be directly utilised by our body. This breakdown of complex food constituents and their absorption is accomplished by the **digestive system**. The processes involved in nutrition are :

(i) **Ingestion :** Taking in food, chewing or sucking it and swallowing.

(ii) **Digestion :** Conversion of complex food into simpler absorbable form.

(iii) **Absorption :** Absorbing digested food from the gut to reach the body tissues.

(iv) **Assimilation :** Utilization of digested food nutrients by the body tissues.

(v) **Egestion :** Removal of undigested and unabsorbed food from the body.

13.2 TWO TYPES OF DIGESTION (Intracellular and extracellular)

Generally two types of digestion are seen in heterotrophs :

(a) Intracellular (b) Extracellular

13.2.1 Intracellular Digestion (Intra = inside)

All the five steps of nutrition occur inside the cell itself, as in *Amoeba*, *Paramecium* and other unicellular animals.

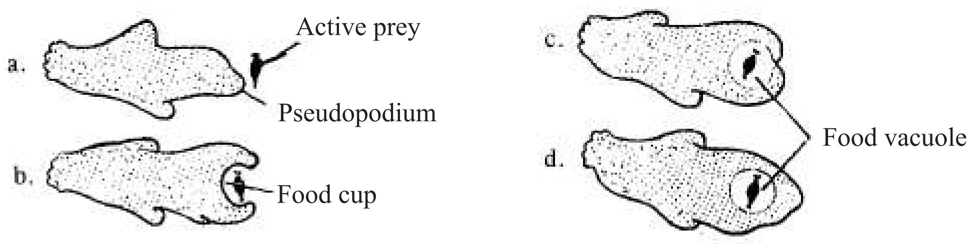


Fig. 13.1 Intracellular digestion in Amoeba

- Food particles such as minute bacteria are enclosed (caught) by pseudopodia (pseudo = false, podia = feet) to form a *food vacuole (Ingestion).*
- Enzymes from cytoplasm are secreted into the food vacuole to break down complex food. *(Digestion)*
- Digested food is absorbed into the cytoplasm. *(Absorption)*
- The absorbed food is used up wherever required in the cell. *(Assimilation)*
- The undigested unabsorbed food is expelled, when the food vacuole comes near the cell surface and bursts open. *(Egestion)*

Food vacuoles are temporary structures and every time the Amoeba feeds, a new food vacuole is produced. All free-living *unicellular* animals carry out intracellular digestion, as mentioined above.

13.2.2 Extracellular digestion (extra = outside)

Digestion occurs outside the cell. All animals (excluding sponges) carry out extracellular digestion. They have either a cavity, a tube, or a food canal which receives the ingested food. Digestive enzymes are poured over the food, and the products of digestion are absorbed back into the cells. The undigested, unabsorbed food is thrown out of the digestive cavity. For example, Fig.13.2 shows digestive organs of cockroach where extracellular digestion occurs.

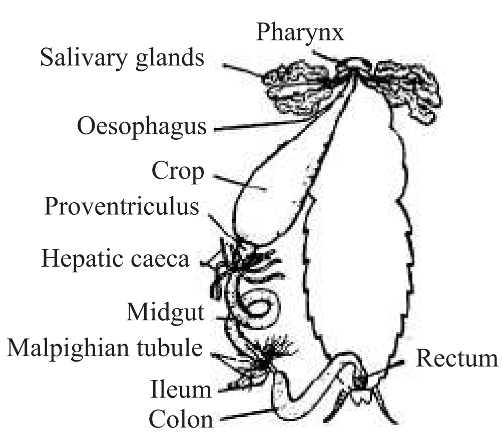


Fig. 13.2 Digestive organs of a cockroach for extracellular digestion.

13.2.3 Joint Intracellular and Extracellular digestion

In Hydra and other Cnidarians, the food (tiny prey) is caught by the tentacles and ingested through the mouth into the single large digestive cavity, called gastro-vascular cavity (Fig. 13.3). Enzymes are secreted from the cells bordering this cavity and poured on the food for **extracellular digestion**. Small particles of the partially digested food are engulfed into the vacuoles of the digestive cells lining gastrovascular canal for intracellular digestion. Any undigested and unabsorbed food is finally thrown out of the mouth.

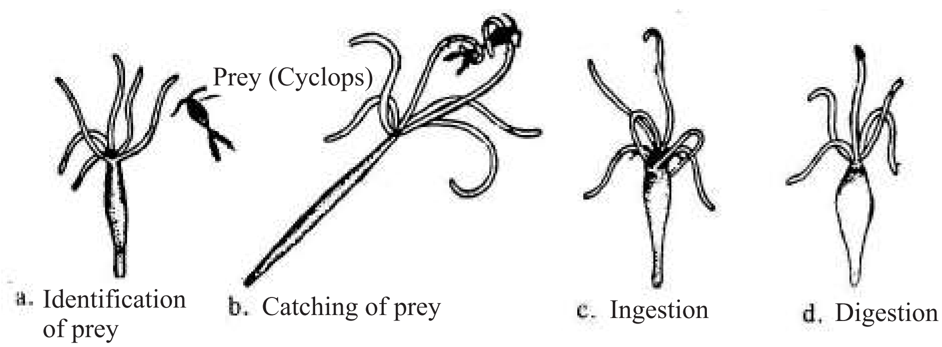


Fig. 13.3 Hydra catching its prey

INTEXT QUESTIONS 13.1

1. List the five major steps in animal nutrition

   (i) ....

   (ii) ....

   (iii) ....

   (iv) ....

2. What is intracellular digestion? Give example of an organism showing intracellular digestion.

   ....

13.5 THE HUMAN DIGESTIVE SYSTEM

The digestive system in humans consists of an alimentary canal and associated digestive glands. The human alimentary canal (aliment: nourish) is a continuous muscular digestive tube that runs through the body. It is open at two ends with the openings, which are **mouth** at anterior end and **anus** at posterior end. It digests the food, breaks it down into smaller substances, and absorbs the digested food. The alimentary canal has the following parts (Fig. 13.4).

1. **Mouth** and associated organs (teeth, tongue)
2. **Pharynx (or throat) :** A cavity at the back of the mouth. It is a common passage for the inhaled air and the swallowed food.
3. **Oesophagus :** A narrow tube arising from pharynx, continuing through the thorax and ending in the stomach.
4. **Stomach :** An elastic bag with highly muscular walls, located below the diaphragm.

5. **Small intestine :** Longest part of alimentary canal, a tube about 7 meters long and about 2.5 cm wide. Much coiled and folded, it is contained in the abdomen. Its three subdivisions are:
   (i) **Duodenum–**Short upper part, next to stomach
   (ii) **Jejunum–**Slightly longer part, about 2 meters long.
   (iii) **Ileum–**Longest, about 4 meters long, coiled and twisted.

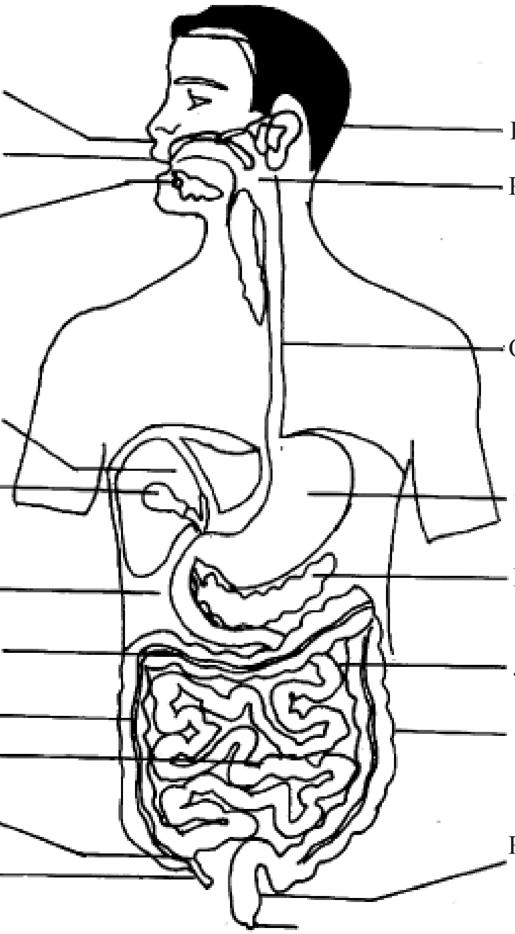


Fig. 13.4 Human Alimentary canal and the associated glands.

6. **Large Intestine :** About 1.5 meters long and has three parts.
   (i) **Caecum–**Small blind pouch at the junction of small and large intestine. A narrow worm-shaped tube (vermiform appendix) projects from the caecum.
   (ii) **Colon :** A little over 1 meter long, it has three parts termed ascending, transverse and descending limbs of the colon.
   (iii) **Rectum :** Last part, about 15 cm. long. It has two parts, the rectum proper and anal canal. Anus is the external opening surrounded by circular muscles (sphincters).

The vermiform appendix is a vestigial (functionless) organ in humans, but is large and functional in herbivorous mammals.

(a) Digestive Glands (Sources of digestive enzymes)

There are two sources of digestive enzymes :

1. The glandular cells of the lining of stomach and intestine, which directly pour their secretion into the lumen of the gut or the alimentary canal.
2. Special glands such as the **salivary glands**, the **liver** and the **pancreas** which pour their secretions into the gut through their ducts.

Our mouth is always moist, even on a hot summer day. How does this happen? This happens because there is a watery fluid called saliva which is secreted by salivary glands into the mouth cavity. It is this saliva, that keeps the mouth moist all the time.

(b) Salivary Glands

There are three pairs of Salivary glands in our mouth cavity (Fig. 13.4).

1. **Parotid glands** located in front of and below each ear, produces watery saliva rich in amylase (Starch digesting enzyme)

2. **Submaxillary glands** close to inner side of lower jaw, produce water and mucus.

3. **Sublingual glands** below the tongue, produce water and mucus.

These glands continuously pour saliva into the mouth cavity. Do you know that the amount of saliva secreted is about 1000 to 1200 ml per day.

(c) Functions of Saliva

1. It cleans the mouth cavity and tends to destroy germs with its lysozymes that cause teeth decay.
2. It moistens and lubricates food which helps in swallowing.
3. It acts as solvent, dissolving some food particles to stimulate taste buds of the tongue.
4. Saliva helps in the digestion of food as it contains an enzyme salivary amylase which digests starch converting it into sucrose. That is why starch when chewed leaves a sweet taste in the mouth.

(d) Liver

Liver is the largest gland, located in the upper right side of the abdomen below the diaphragm. It secretes bile, which gets collected in gall bladder and is finally poured into the duodenum through the common bile duct (Fig. 13.4). Besides secreting bile, which helps in digestion, the liver has numerous other functions.

(e) Pancreas

Pancreas is a reddish brown gland located in the bend of the duodenum. Its digestive secretion (pancreatic juice) is poured into the duodenum by the pancreatic duct. (Pancreas also produces certain hormones, which will be taken up in details in lesson no 16)

INTEXT QUESTIONS 13.2

1. Match the characteristics in column A with the parts of digestive system given in column B

Column A	Column B
Characteristics	Part
(1) Common passage for air breathed in and the food swallowed.	(a) Small intestine
(2) Elastic bag like structure	(b) Pancreas
(3) Has three limbs-ascending, transverse and descending	(c) Duodenum
(4) Longest part of the food canal	(d) Pharynx
(5) Receives bile and pancreatic juice	(e) Appendix
(6) Narrow worm-shaped projection	(f) Stomach
(7) Largest gland in body	(g) Colon
(8) Gland located in the bend of duodenum	(h) Liver

2. Name the **three** salivary glands and mention their location in the mouth cavity.

....

13.6 THE DIGESTIVE PROCESS

Digestion involves two kinds of processes :

(a) ***Mechanical process*** which includes cutting and, grinding thus breaking the food into small particles; swallowing the food and then pushing the food along the food canal. **Smaller particles expose greater surface area for action by enzymes.**

(b) ***Chemical process*** which includes the enzymatic breakdown of complex food constituents (nutrients) into simpler absorbable form.

Digestion involves hydrolysis, i.e. spliting by addition of water (H^+ and OH^- ions) to a molecule resulting in its break down into two or more simpler molecules. The enzymes act only as catalysts to accelerate the reaction.

For example $\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{Sucrase}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(fructose)}}{C_6H_{12}O_6}$

(a) Mechanical Process in Digestion

- The lips hold the food within the mouth and help in sucking it in and sipping liquids.
- The teeth cut, tear and grind the food.

- The tongue manipulates food while chewing, mixes saliva in it, rolls it into a ball termed as **bolus** and helps in swallowing.
- The oesophagus conducts the food (bolus) down into the stomach by a wave of contraction of the circular muscles in the wall of alimentary canal (Fig. 13.5). This wave of contraction is called **peristalsis**.

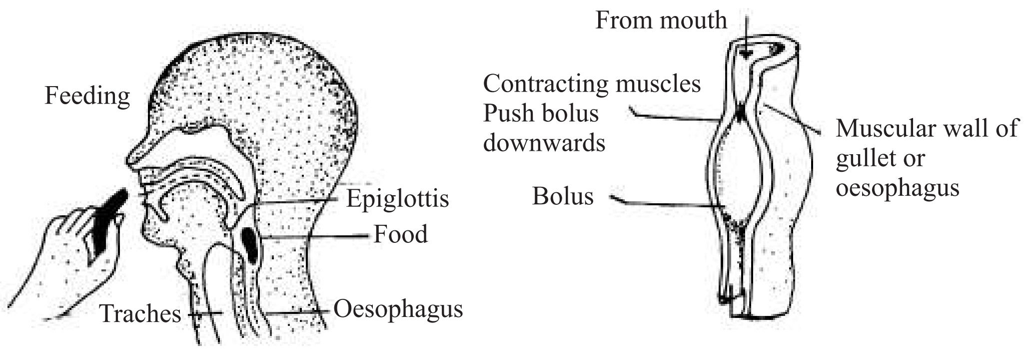


Fig. 13.5 **A**-During swallowing, the epiglottis closes the opening of the trachea, leading to momentary stoppage of breathing, and the food is pushed down the oesophagus, **B**-Peristalsis is a wave of contraction of muscles of alimentary canal which pushes food down through the alimentary canal.

- The stomach churns the food mixing it with gastric juice and thus produces a creamy **chyme** (partially digested food).
- The peristaltic movements keep pushing the food from stomach to the intestine and finally pushing it into the rectum.

(b) Chemical Processes in Digestion

1. In Mouth

Saliva contains only a single enzyme Amylase (old name Ptyalin) which acts on starch in two ways :

(i) Raw *uncooked* starch $\xrightarrow{\text{Amylase}}$ Dextrins
(soluble, partially hydrolysed starch)

(ii) Cooked starch $\xrightarrow{\text{Amylase}}$ Maltose (a sweet-tasting disaccharide)

2. In Oesophagus

Food as bolus moves through obsophagus into the stomach by peristalsis. Salivary amylase continues digesting starch.

3. In Stomach

Initial digestion of starch by salivary amylase continues till the contents of stomach become acidic by presence of HCl. The gastric juice produced from the lining of the stomach is a colourless highly acidic liquid (pH 1-2). It contains *Water* (98%), some salts, ***hydrochloric acid*** (0.5%), the lubricant mucin and two enzymes ***pepsin*** and ***lipase***.

Hydrochloric acid is secreted by ***Oxyntic (parietal)*** cells of the stomach wall. It performs the following function :

(i) kills bacteria entering along with food,
(ii) loosens fibrous material in food,
(iii) activates the inactive pepsinogen to its active form pepsin,
(iv) maintains acidic medium for action by pepsin,
(v) curdles milk so that it does not flow out and stays for action by pepsin.

Pepsin is secreted in its inactive form or the proenzyme called pepsinogen secreted from the chief cells of the stomach wall. In the presence of HCl it turns into the active pepsin which acts on proteins and breaks them down into proteoses and peptones.

$$\text{Protein} \xrightarrow{\text{Pepsin}} \text{Proteoses and peptones}$$

4. Small Intestine

In the small intestine the food which is partially digested in the stomach, and called **chyme** is acted upon by three main digestive juices.

(i) Bile juice from the liver
(ii) Pancreatic juice from the pancreas
(iii) Intestinal juice secreted from special cells in the intestinal epithelium at the base of intestinal villi. (Fig. 13.6)

The bile juice and pancreatic juice are poured into the duodenum by their respective ducts which join together to form a common hepato pancreatic duct. The intestinal juice directly mixes with the food.

(i) Bile Juice

Bile is a yellowish, green, alkaline liquid (pH about 8). It consists of (i) *water* (98%), (ii) *sodium carbonate* in large quantity which neutralizes the acid of the **chyme** (semi digested food) received from stomach; makes it alkaline, and (iii) *bile salts* (sodium glycocholate and sodium taurocholate) which emulsify fats.

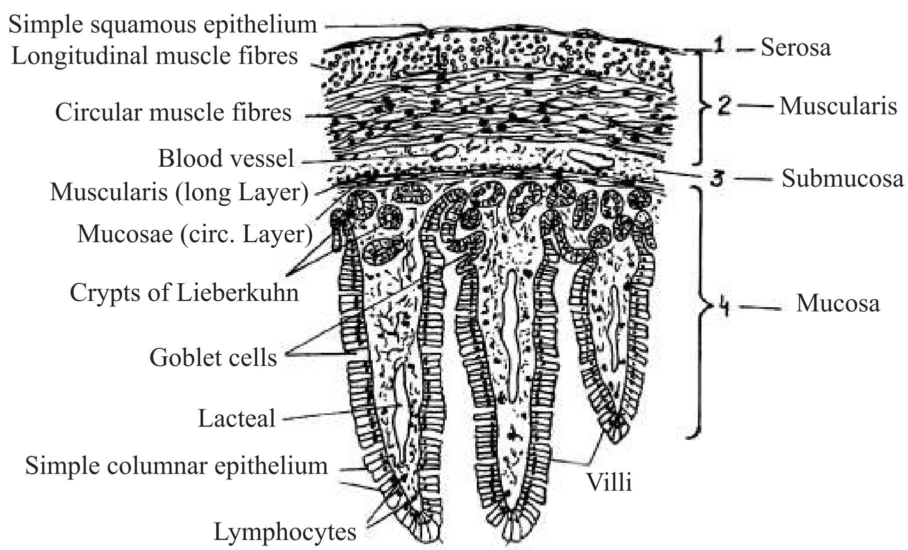


Fig. 13.6 Portion of intestinal wall showing villi and the associated structures.

Emulsification is the breaking up of large lipid (fat) droplets into small droplets, which provides greater surface for enzyme action.

The yellowish green colour of the bile is due to the pigments ***biliverdin*** and ***bilirubin*** produced by the breakdown of the dead and worn out RBCs (Red Blood corpuscles). These pigments are excreted in faeces (solid or semi-solid waste and undigested food) that is thrown out through the anus.

Bile has no digestive enzymes. It simply emulsifies fats.

(ii) Pancreatic Juice

The pancreatic juice contains *six* major categories of enzymes, which act in an **alkaline medium**.

(a) **Amylase –** completes conversion of starch (polysaccharide) into maltose (disaccharide).

(b) **Lipase –** also called *steapsin*, acts on emulsified fats to produce *fatty acids* and *glycerol*.

(c) **Nucleases –** digest nucleic acids, i.e. DNA and RNA content of the food.

(d) **Trypsinogen –** the inactive precursor (proenzyme) of trypsin. It is activated into *trypsin* by the enzyme *enterokinase* secreted by the lining of duodenum. Trypsin acts on remaining proteins (not digested by pepsin) and the proteoses and peptones to produce *peptides* and *amino acids*.

(e) **Chymotrypsin –** acts on milk protein casein to produce *paracasein* (curd), and also converts other proteins into *peptides*.

(f) **Carboxypeptidases –** act on peptides to produce small *peptides* and *amino acids*.

(iii) Intestinal Juice or Succus Entericus

It contains the following categories of enzymes :

(i) **Glycosidases** (including maltase, sucrase and lactase). These hydrolyse the disaccharide maltose (malt sugar), sucrose (cane sugar) and lactose (milk sugar) into the simpler absorbable monosaccharides (glucose, fructose and galactose).

$$\text{Disaccharides}\left\{\begin{array}{l}1.\ \text{Maltose}\xrightarrow{\text{Maltase}}\text{gluscose}+\text{glucose}\\ 2.\ \text{Sucrose}\xrightarrow{\text{Sucrase}}\text{gluscose}+\text{Fructose}\\ 3.\ \text{Lactose}\xrightarrow{\text{Lactase}}\text{gluscose}+\text{galactose}\end{array}\right\}\text{Monosaccharides}$$

(ii) **Lipase** completes the digestion of any lipid (fat) not digested by pancreatic juice.

(ii) **Peptidases** (aminopeptidase and dipeptidase) act on peptides and dipeptides to produce smaller peptides and amino acids.

(iii) **Nucleases** breakdown nucleotides into phosphate, sugar and different nitrogenous bases.

Summary of digestion in various parts of human alimentary canal is shown in table 13.1

Table 13.1 : Various digestive enzymes secreted and their role in the digestion of food in humans

Site of Secretion	Digestive juice	Enzyme	Mode of action
Mouth	Saliva	Salivary amylase (ptyalin)	Converts starch into maltose
Stomach	Gastric juice	Pepsin	Converts proteins into peptones and proteoses
Duodenum	Bile juice	No Enzyme	Emulsification of fats
	Pancreatic juice	Trypsin	Converts peptones and small peptides into amino acids.
Small intestine	Intestinal juice	Erepsin	Converts peptones and small peptides into amino acids.
		Sucrase	Converts sucrose into glucose and frutose.
		Maltase	Converts maltose into glucose
		Lactase	Converts lactose into glucose and galactose.
		Lipase	Converts fats into fatty acids and glycerols.

INTEXT QUESTIONS 13.3

1. How is grinding of food in the mouth helpful in digestion?

   ....

2. Name the source gland for following enzymes.

   (i) amylase ....

   (ii) pepsin ....

   (iii) lipase ....

3. List at least **four** enzymes that contribute towards digesting proteins.

   (i) …………… (ii) ...………… (iii) ………… (iii) ……..…....

13.7 ABSORPTION OF NUTRIENTS

Some absorption occurs in the mouth itself, some in the stomach but most absorption occurs in the intestine. The summary of absorption of nutrients is given below.

1. In Mouth

Minute quantities of water, water-soluble vitamins and simple sugars like glucose (as in honey) are absorbed in the mouth.

2. In Stomach

Water, glucose, ethanol (alcohol), certain minerals, vitamins and certain drugs may be absorbed into the cells lining the stomach. This absorption occurs by osmosis, diffusion (down the concentration gradient) and active transport (against concentration gradient).

3. Small Intestine

Most absorption of digested food occurs in small intestine. For this, the small intestine is adapted in many ways :

(i) It is very long and therefore provides more surface area for absorption.

(ii) Many folds in its wall called *villi* (singular, *villus*) further increase the surface area of absorption. (Fig. 13.6).

(iii) Single cell epithelial lining further reduces the distance between the food and underlying blood vessels.

(iv) The epithelial cells have **microvilli** which are projections of plasma membrane to further increase the absorptive surface.

(v) It is narrow for slow movement of nutrients allowing absorption.

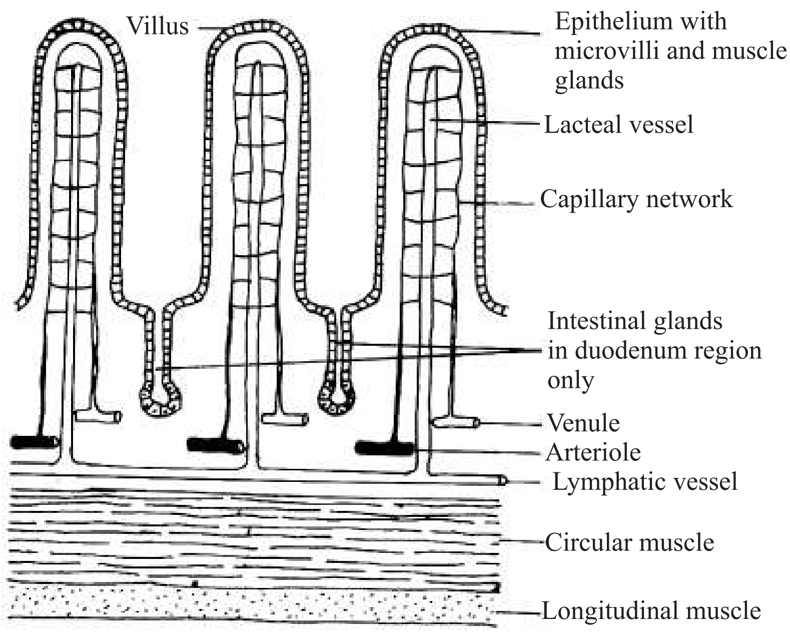


Fig. 13.7 Magnified details of Microscopic structure of a part of the wall of small intestine.

- Products absorbed *into the blood capillaries* of the villi are amino acids and monosaccharides (glucose, fructose, galactose).

- Products absorbed into the lacteals (lymph vessels) of the villi are fatty acids and glycerol.
- Nutrients absorbed into the blood is carried by veins into the liver, and the nutrients absorbed by the **lacteals** (small lymph vessels) enters the lymphatic system.

4. Large Inestine

Most of the water present in the food is absorbed in the *colon* by diffusion. Some mineral ions are absorbed by the colon through active transport.

13.8 ASSIMILATION

The final conversion of the absorbed nutrients into the living substance, i.e. their utilization by the cells is called **assimilation**.

After absorption from the food canal the digested food is assimilated by the body in the following ways.

(i) Fatty acids and glycerol are again converted into fats, that may be used or stored in adipose tissue.

(ii) Simple sugars (monosaccharides) which are in excess are converted into complex polysaccharides like glycogen in liver.

(iii) Amino acids are utilized in the synthesis of proteins for building up the body tissues and enzymes.

(iv) Excess amino acids are deaminated (removal of nitrogenous part) to produce simple sugar. (*Amino acids* cannot be stored).

13.9 EGESTION (DEFAECATION)

The undigested part (plant fibers) and the unabsorbed digested substances pass into the *rectum*. Such food remnants are temporarily stored in rectum. More water is absorbed and the remnants become semisolid to form *faeces*.

A special reflex called defaecation reflex causes emptying of the rectum and the faeces are passed out via the anus by the relaxation of *sphincter* muscle (A ring shaped muscle which contracts and relaxes to close and open the anus or anal opening.

INTEXT QUESTIONS 13.4

1. In which part of the alimentary canal does maximum absorption of water occur?

   ....

2. List any three ways in which the intestine increases the surface area for absorption?

   (i) ....

   (ii) ....

   (iii) ....

3. Which end products of digestion are absorbed by
   (i) blood capillaries of intestinal villi? ....
   (ii) Lacteals? ....

13.10 NEURAL AND HORMONAL CONTROL OF DIGESTIVE SYSTEM

Do digestive juices flow into the alimentary canal all the time? If it were so, it would mean terrible wastage of enzymes when there is no food in the alimentary canal. So, everything must be so timed that there is neither wastage, nor shortage. How is it possible? Let us see how this happens.

Think of the following situations:

1. When we see or smell good food or even think or talk about it, our mouth begins to "water" (salivation). This happens through stimulation by nerves coming from the brain. The secretion of thicker saliva is stimulated by chewing action (even if you chew wax instead of food, you will salivate).
2. On reaching the stomach, the presence of food stimulates the stomach lining to secrete gastric juice. Secondly, the mechanical stimulation of stomach wall produces a hormone, **gastrin** which again stimulates the secretion of gastric juice.
3. As the food enters duodenum, the duodenal epithelium secretes four hormones- **Secretin, Pancreozymin, Cholecystokinin, and Enterogastrone**.
   (i) **Secretin** stimulates the flow of pancreatic juice, which is rich in bicarbonates (to neutralize acid).
   (ii) **Pancreozymin** helps in the flow of pancreatic enzymes.
   (iii) **Cholecystokinin** stimulates flow of bile from gall bladder.
   (iv) **Enterogastrone** stops secretion of gastric juice, because stomach becomes empty as food now passes from stomach to duodenum.

Several nerves (from sympathetic and parasympathetic nervous system) stimulate and control the gut to accelerate or slow down the movements of alimentary canal as termed peristalsis.

INTEXT QUESTIONS 13.5

1. Mention the source of secretion and the effect of the following:
   (i) Gastrin ....
   (ii) Enterogastrone ....

13.11 ROLE OF LIVER IN METABOLISM

Liver is the largest gland associated with the alimentary canal. It is reddish brown in colour and is located on the upper side of the abdomen just below the diaphragm. Its numerous functions can be grouped under five major categories :

Blood related functions :

(i) Produces *red blood cells* in the embryo. (In adults, RBCs are produced in bone marrow).

(ii) Produces *prothrombin* and *fibrinogen* required for blood clotting.

(iii) Produces *heparin* which prevents unnecessary coagulation of blood.

(iv) Destroys dead and worn out red blood cells.

(v) Removes toxic and metallic poisons from the blood (protective function).

Storage functions :

(i) Storage of iron and some other metallic ions.

(ii) Storage of vitamins A, D and B_{12}.

(iii) Converts extra blood glucose into glycogen and stores it.

Metabolic functions

(i) **Regulation of blood** sugar level by retaining excess *glucose* received as product of carbohydrate digestion from the intestines, and storing it as insoluble *glycogen* to release it again as soluble glucose when the blood sugar level falls.

(ii) **Breaking down of excess amino acids.** Amino acids are the end products of protein digestion. Liver breaks down excess amino acids into urea and sugar. Urea is excreted out in urine and sugar is stored for use.

(iii) **Synthesizes fatty acids** from carbohydrates, which can be used or stored as fat.

INTEXT QUESTIONS 13.6

1. Name any three substances related to the blood, produced by liver.

   (i) …………...... (ii) …………...... (iii) …………......

2. List any three substances which the liver stores.

   (i) …………...... (ii) …………...... (iii) …………......

3. What happens to excess amino acids absorbed from gut ?

   ....

13.12 SOME DIGESTIVE DISORDERS (VOMITING, DIARRHOEA, CONSTIPATION, INDIGESTION AND JAUNDICE)

13.12.1 Vomiting

Vomiting is the forcible voluntary or involuntary emptying (throwing up) of stomach contents through the mouth. Vomiting is not a disease but a symptom of many conditions such as motion sickness, emotional stress, overeating, reaction to certain smells and odours, food poisoning, and infections. The most common cause of vomiting is **gastroenteritis**. This is an infection of the gut usually caused by virus or bacteria. Prolonged and excessive vomiting can dehydrate the body and may alter the electrolyte balance. Repeated or excessive vomiting may cause injury to the oesophagus or may corrode the oesophageal mucosa (inner lining of oesophagus). In such a case, fresh blood may be seen in the vomit. However, in most cases vomiting does not last for more than one or two days and is not very serious.

A person who is vomiting should be given lot of fluids. ORS (**Oral Rehydration Solution**) may be given frequently. ORS is a special powder which contains sugar and salts in specific amounts. This powder can be converted into a liquid form by following the instructions written on the packet. Person who is vomiting should sip this fluid at regular intervals. A home made sugar solution with a pinch of salt can substitute for ORS.

Vomiting should not be taken very lightly. Persistent vomiting can sometime be due to a severe infection. A doctor must definitely be consulted if vomiting continues for more than a day.

13.12.2 Diarrhoea

Passing loose stool or liquid stool three or more times in a day is termed Diarrhoea. It is usually a symptom of gastrointestinal infection which can be caused by bacteria, virus or a parasitic protozoan. It begins as an irritation in the colon wall, then peristalsis increases and absorption of water by the colon becomes very slow.

Infection is spread through contaminated food or by drinking contaminated water or from person to person because of poor hygiene. *Rotavirus* and *Escherichia coli* (colon bacteria) are two most common causative agents of diarrhoea in developing countries. Severe diarrhoea leads to fluid and electrolyte imbalance particularly in children and people who are malnourished and have impaired immunity.

The most serious threat posed by diarrhoea is **dehydration**. Water and electrolytes (sodium, chloride, potassium and bicarbonate) are lost through liquid stools, vomiting, sweat, urine and with breathing. If these are not replaced then the person suffers from dehydration and if proper treatment is not given then the person may even die because of severe dehydration and fluid loss.

A person suffering from diarrhoea should be given ORS at regular intervals and doctor should be consulted if diarrhoea persists for more than a day or two.

In order to prevent diarrhoea one should always observe good personal hygiene and prevent food from contamination. Some of the precautions for preventing diarrhoea are:

- washing hands with soap before taking food
- fruits and vegetables thoroughly washed with water before eating or cooking
- keeping food covered and unexposed to flies or dust and dirt
- drinking safe and clean uncontaminated water

13.12.3 Constipation

Constipation is a term which is used when bowel movement becomes difficult or less frequent. The faeces become excessively dry and hard. This happens when the undigested food passes slowly through the colon and large amount of water is absorbed in the large intestine. It is basically a disorder of the bowel function caused mainly due to inadequate fibre in the diet, irregular diet, inadequate activity or exercise, and stress or due to resisting the urge to have a bowel movement. Medicines (especially strong pain killers, antidepressants), or hypothyroidism may also be a cause of constipation. One can easily prevent constipation by eating a well balanced diet with plenty of fibre, drinking lot of water/fluids, regular exercises and passing stool whenever one feels the urge.

13.12.4 Indigestion

Indigestion, also called **dyspepsia** is another name for an upset stomach. Indigestion is a feeling of discomfort in the upper abdomen during or immediately after eating (commonly called stomach ache). There is a recurrent pain and burning sensation in the upper abdomen. Indigestion may be triggered by overeating, eating spicy, greasy or fatty foods, emotional stress, consuming too much of high fibre foods, caffeine or tobacco and smoking or drinking too much of alcohol. Frequent consumption of medicines like antibiotics and pain killers, stomach or intestinal ulcers, and gastritis (inflammation of stomach lining and gall stones) are some other causes of indigestion.

Indigestion is common in all age groups and is not a sign of serious health problem unless there are other accompanying symptoms like an unexplained weight loss or severe abdominal pain. It can easily be prevented by life style changes. Some of these are:

- Cutting down on fatty foods, tea, coffee, alcohol
- Not eating too much food or too quickly
- Eating at least two or three hours before going to bed
- Reducing stress
- Giving up smoking

13.12.5 Jaundice

In jaundice, there is a yellow discoloration of the skin and the eyes due to a high level of bilirubin (bile pigment) in the blood. This happens when not much of it gets excreted. The high levels of bilirubin may be because of inflammation or other abnormalities of the liver cells, or blockage of the bile ducts. Sometimes jaundice is caused by the breakdown of a large number of red blood cells, which can occur in newborn babies. Jaundice is usually the first sign, and sometimes the only sign, of liver disease. Jaundice may also be caused by viral infection transmitted through infected water.

Jaundice is related to the function of the liver so it is necessary to keep the liver healthy by eating a balanced diet and doing regular exercises.

INTEXT QUESTIONS 13.7

1. (a) A doctor advises a person to sip ORS at regular intervals because he/she was suffering from diarrheoa. What is this ORS?

   ....

   (b) Name any one causative agent of diarrhoea in developing countires.

   ....

   (c) During the rainy season there is a rise in diarrhoea cases. What piece of advice will you give to your younger brother/sister to prevent oneself from getting diarrhoea?

   ....

2. A little girl/boy had a problem in passing stool. The faeces were dry and hard. The doctor said that this was because the child was not taking adequate amount of fibres in the diet and was not taking proper diet at proper time. What is this child suffering from?

   ....

3. What is dyspepsia? What are its symptoms?

   ....

4. Which organ of the body is involved in jaundice and how can you make out that a person is suffering from jaundice.

   ....

WHAT YOU HAVE LEARNT

- Digestion is the breakdown of complex food, and nutrition include taking in and utilization of food.
- All animals are heterotrophic or phagotrophic or holozoic (ingesting bulk food) while the green plants are autotrophic (or holophytic)
- Animal nutrition involves five steps-ingestion, digestion, absorption, assimilation and egestion (defecation).

- Digestion can be either intracellular or extracellular.
- The human alimentary canal consists of mouth, pharynx, oesophagus, stomach, small intestine, large intestine and anus.
- The digestive enzymes poured into the gut, are secreted from two kinds of sources; gut epithelium of stomach and intestine, and special glands (salivary glands, liver and pancreas).
- Starch is digested in the mouth by salivary amylase, and in the duodenum by pancreatic amylase. Other carbohydrates like maltose, sucrose and lactose are digested by the respective enzymes in the intestine.
- Fats are emulsified by bile, and are hydrolysed by lipases in stomach and intestine.
- Proteins are digested by pepsin in the stomach and by trypsin in the intestine and the peptidases break them into amino acids.
- Absorption of digested food mainly occurs in the small intestine – simple sugars and amino acids are absorbed into the blood capillaries of the intestinal villi and the fatty acids and glycerol into lacteals.
- Most water from the digested food is absorbed in colon and rectum.
- Defaeaction is the expulsion of semi-solid faeces.
- Several hormones regulate the secretion of digestive juices from different parts, at the right time and in right quantity.
- Besides playing an important digestive role, the liver has numerous other functions in connection with blood and general metabolism.
- Common digestive disorders are vomiting, diarrhoea, constipation, indigestion and jaundice
- Intake of ORS or oral Rehydration solution is a must when suffering from digestive disorders like vomiting and diarshoea in order to prevent dehydration.

TERMINAL EXERCISES

1. Explain the term "autotrophs". How are animals different from plants with regard to their mode of nutrition?
2. Enlist at least ten organs of the alimentary canal of man.
3. Define the term "digestion". List the digestive processes occurring in the small intestine.
4. How does digestion of carbohydrates and proteins take place in humans?
5. Explain the role of the following in the digestive process in humans :

   (a) Gastrin (b) Hydrochloric acid (c) Secretin
6. Write short notes on

   (a) absorption of the digested food (b) assimilation

   (c) defaecation (d) role of liver in metabolism.

7. Name the enzymes concerned with the digestion of various carbohydrates, the region of the gut where they act and their products in the table given below:

	Carbohydrate	Enzyme	Region of gut	Product
1.	Starch	....	....	....
2.	Dextrin	....	....	....
3.	Maltose	....	....	....
4.	Sucrose	....	....	....
5.	Lactose	....	....	....

8. Bile has no digestive enzyme yet it plays a key role in digestion. What is its role?
9. Draw a well labelled diagram of alimentary canal in humans.
10. List common digestive disorders. Add a note on ORS.

ANSWERS TO INTEXT QUESTIONS

13.1 1. Ingestion, digestion, absorption, assimilation, egestion

2. All the five steps of digestion occur inside the cell itself. Paramecium, Amoeba etc.

13.2 1. 1. d, 2. f, 3. g, 4. a, 5. c, 6. e, 7. h, 8. b

2. Parotid – in front of and below ear

   Submaxillary – inner side of lower jaw.

   Sublingual – below the tongue

13.3 1. Smaller particles provide larger surface area for digestive action.

2. (i) Salivary glands (ii) Stomach (iii) Pancreas

3. 1. Pepsin 2. Trypsin, 3. Chymotrypsin, 4. Carboxypeptidase.

13.4 1. Colon/large intestine.

2. (i) very long (ii) villi (iii) microvilli

3. (i) Amino acids and simple sugars, (ii) fatty acids and glycerol.

13.5 1. (i) Gastrin-stomach, stimulates secretion of gastric juice

   (ii) Enterogastrone-Duodenum, stops secretion of gastric juice.

13.6 1. Fibrinogen, prothrombin, heparin

2. Sugar/glycogen, iron, vitamin A/D/B_{12}

3. Broken down to produce sugar and urea, sugar is used and urea is excreted.

13.7 1. (a) Oral Rehydration Solution which is drinking water containing a pinch of sugar and salt. Its consumption prevents dehydration.

(b) Rota virus / E.coli

(c) Wash hands with soap and water before eating/wash raw vegetables well before cooking or consuming / cover food so that flies cannot sit on it / consume clear uncontaminated water.

2. Constipation

3. Indigestion or upset stomach. Symptoms–Stomach pain

4. Lever; urine and eyes look yellow.

14

RESPIRATION AND ELIMINATION OF NITROGENOUS WASTES

Every living organism needs energy to perform various life activities, and the process of respiration fulfils this energy requirement. You have already learnt in the lesson on food and nutrition that animals take in high energy organic molecules in the form of food. During respiration, this food is broken down in the presence of oxygen and energy is released during respiration. Respiration also produces carbon dioxide, a toxic substance which is eliminated from the body. Thus, uptake of oxygen and removal of carbon dioxide is an essential requirement of all animals.

At the same time numerous other toxic wastes such as ammonia, and urea are also produced in the tissues during various cellular activities. Such toxic wastes need to be removed from the body. In this lesson you will learn about removal of nitrogenous wastes and maintenance of water and salt balance in the body.

OBJECTIVES

After completing this lesson you will be able to :

- *define respiration, breathing, inspiration, expiration and vital capacity;*
- *describe briefly the gaseous exchange in earthworm and cockroach;*
- *describe the parts of respiratory system in the human body and mention their functions;*
- *draw a labeled diagram of human respiratory system;*
- *differentiate between breathing and respiration; and inspiration and expiration;*
- *describe the mechanism of breathing and its regulation;*
- *describe the exchange of respiratory gases in the lungs and their transport to and from tissues;*

- *name some common ailments of respiratory system and suggest their prevention;*
- *define excretion and mention its importance;*
- *explain the terms such as ammonotelism, ureotelism and uricotelism;*
- *list the organs of excretion in cockroach;*
- *list the parts of human excretory system and mention their functions;*
- *explain ultrafiltration and describe how urine is formed in humans;*
- *draw the microscopic structure of the human kidney;*
- *list the normal and abnormal components of urine;*
- *explain the mechanism of osmoregulation and its regulation by ADH;*
- *explain the role renin-angiotensin system in regulating blood volume and blood pressure.*
- *explain the role of dialysis and kidney transplantation in case of kidney failure;*
- *explain the role of liver in excretion.*

14.1 RESPIRATION

Respiration is the stepwise oxidation of glucose (and other nutrients) which results in the release of energy that is stored in the cytosol in the form of ATP (adenosine triphosphate). Whenever energy is required by our body, ATP is broken down and large amount of energy is released.

Respiration is completed in following steps :

Step-1 Gaseous exchange

It involves exchange of gases between the cell and its surrounding medium. The cells obtain oxygen from the environment and return carbon dioxide and water vapour to it. In most higher animals this exchange of gases takes place in two phases :

(a) exchange of gases between the animal body and its external environment, also called **ventilation** or **breathing.**

(b) transport of gases O_2 and CO_2 between the respiratory surface and the cells.

Oxygen obtained from the atmosphere is used up in the second step i.e. during **cellular respiration**, which occurs inside the cell.

Step 2 Cellular Respiration

It is a complex and elaborate process which occurs in the cytoplasm and the mitochondria. It involves :

(i) the uptake of oxygen by tissues,

(ii) stepwise oxidation of glucose molecules and other nutrients, and

(iii) release of carbon dioxide and energy.

Thus ultimate goal of respiratory system is to provide oxygen to the tissues for oxidation of food and removal of carbon dioxide from them.

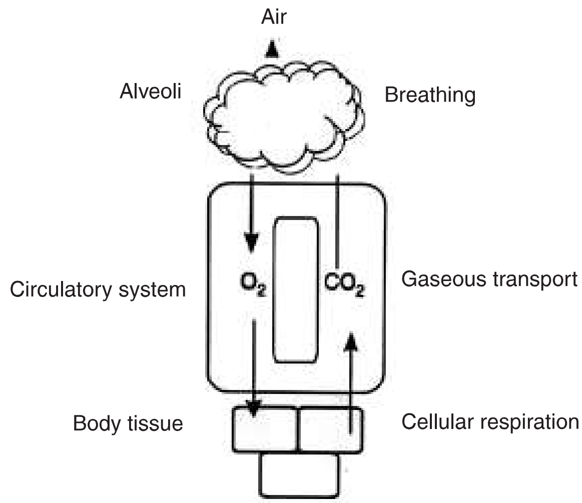


Fig. 14.1 General features of respiration

14.1.1. Respiratory Exchange in Different Animals

- All animals exchange gases with their surroundings by the mechanism of diffusion.
- A gas diffuses across a membrane from outside where its concentration (partial pressure) is higher than inside where its concentration is lower.
- Thus oxygen is taken up and carbon dioxide is released from the respiratory surface.
- For efficient gas exchange the respiratory surface should be large, moist, highly vascular, thin and easily permeable to oxygen and carbon dioxide.
- To fulfill this requirement complex respiratory systems have evolved in the animal world. You will study a few of them in this lesson.

14.1.2 Gas exchange through the general body surface in earthworm – cutaneous respiration

- Earthworm has no respiratory organs. The entire skin on the body of earthworm functions as the respiratory surface.
- The skin of earthworm is thin, moist and has a rich supply of blood capillaries. Thus, it is very suitable for respiration.
- The body surface is covered with a moist film consisting of secretions of mucous glands, coelomic fluids and excretory wastes.
- The capillaries on the skin take up O_2 dissolved in the water (in the moisture) on the surface of skin and release CO_2 into the atmosphere.
- Earthworms have a closed circulatory system which means that blood flows within blood vessels. The respiratory pigment haemoglobin remains dissolved in blood plasma and not in any cell. In human beings and other vertebrates, Haemoglobin is inside RBC
- There is regular rhythmic contraction of blood vessels which helps in the circulation of blood and hence in the transport of dissolved gases in the body.

Even frogs show cutaneous respiration (respiration through skin) across their moist skin, particularly during hibernation when they become inactive during the winter to avoid cold. However, frogs are mainly lung breathing animals.

14.1.3 Tracheal System in Cockroach

You must have noticed that the insects keep expanding and contracting their abdomen. This is to allow gaseous exchange.

- Like majority of insects, cockroach respires by means of internal tubes called **tracheae**.
- These tubes branch out extensively inside the body and carry air directly to the tissues from the atmosphere.
- In cockroach, respiration does not involve blood as shown in the flow chart given below and therefore it is very fast and very efficient. Tracheae open up to the exterior by paired slit like apertures called **spiracles**. Spiracles are found on the sides in the thorax and abdomen.
- The fine branches of tracheal trunks called **tracheoles** finally penetrate the cells of the body and allow diffusion of respiratory gases directly into and from the cells.
- The ends of the tracheoles are thin and filled with fluid in which respiratory gases dissolve. The inflow and outflow of air is affected by alternate contraction and expansion of the abdomen.

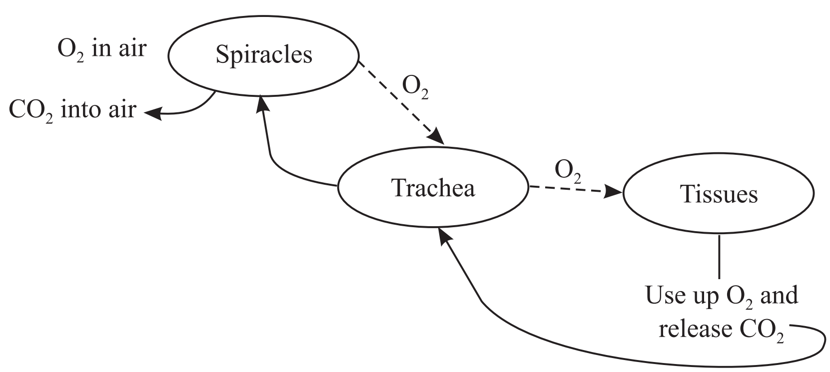


Fig. 14.2 Tracheal system in a cockroach

14.1.4 Respiratory system in humans (pulmonary respiration)

- Humans have a well developed respiratory system suitable for meeting the higher requirement of oxygen in their bodies.
- The respiratory system consists of nostrils, nasal cavity, pharynx, larynx, trachea, and bronchi.
- The two bronchi branch extensively into bronchioles, terminal bronchioles and ultimately end in the air sacs called alveoli. The bronchioles, their branches and air sacs are enclosed in a double membrane called pleural membrane to form the lungs. The lungs are the main respiratory organs.

- Air passes through nostrils into bronchi, to bronchioles and into air sacs which are thin walled sacs with a single layer of cells and heavily covered with blood capillaries. O_2 from alveoli passes into capillaries and CO_2 from other capillaries diffuses into alveoli for being removed. Alveoli are the organs where the actual gaseous exchange occurs.
- The double layer pleural membrane covers the lungs for its protection. It contains pleural fluid, which makes the movement of the lungs easy.
- Each lung consists of a tree like system of branched bronchial tubes.
- The finest of them terminate into millions of tiny sac like structures called alveoli.
- Alveolar membrane is very thin, moist and richly supplied with blood capillaries.
- The walls of both the capillaries and alveoli consist of a single layer of flattened epithelial cells.

Refer to the following table 14.1 to get an idea of the structure and functions of different parts of the human respiratory system.

Table 14.1 Respiratory organs of human body

Organ	Structure	Function
Nostril	Opening of Nose	Filtration of unwanted particles.
Nasal Cavity	Covered with mucous membrane and cilia	Traps dust, bacteria; warms and moistens the air in the pharynx.
Pharynx (Throat)	Muscular Tube	The common passage for both respiratory gases and food moving into digestive passage, separated by epiglottis Epiglottis is a flap like structure that closes the tracheal opening (opening of the wind pipe) called glottis when food is swallowed.
Larynx /Voice Box)	A small cartilaginous organ with vocal cords : lined by ciliated epithelium	Connects pharynx to the trachea; helps in sound production.
Trachea (Wind pipe)	Supported by C-shaped cartilaginous rings to prevent it from collapsing. Trachea divides into two bronchi and enters the two lungs	Passage for air upto bronchi.
Bronchus (Plural : Bronchi)	Elastic, ciliated and covered with mucous epithelium	Enters the lungs and divides to form secondary bronchi, tertiary bronchioles and ultimately terminal bronchioles. Together they form the bronchial tree.

Bronchioles	Small terminal branches of bronchus leading to alveoli	Convey air into alveoli.
Alveoli (Air sacs)	Supplied with blood capillaries, thin moist	Exchange of Gases.

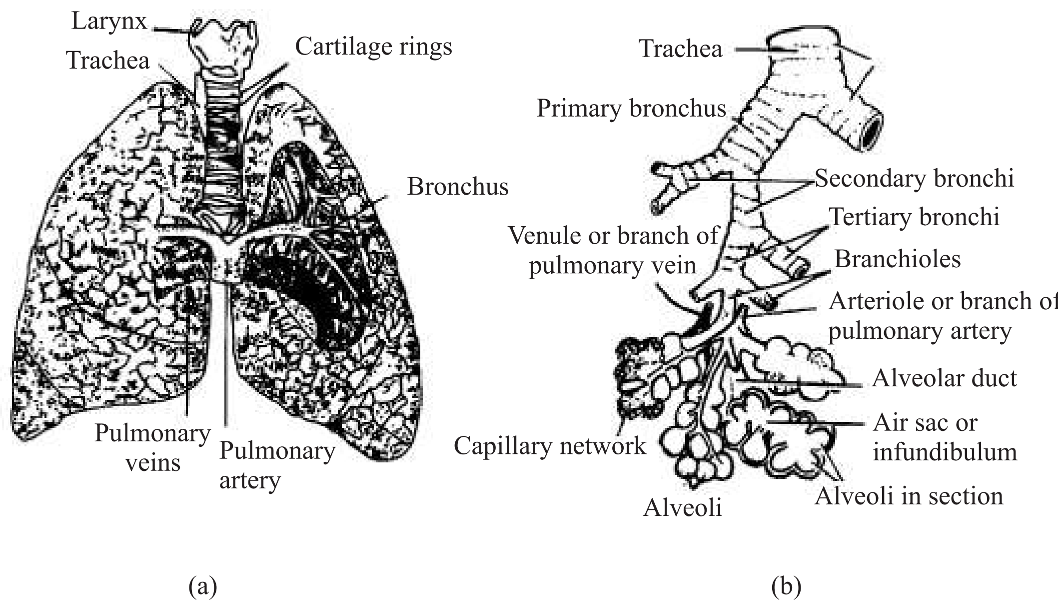


Fig. 14.3 (a) Human lungs (b) branching of bronchi upto terminal alveoli

Table 14.2 : Differences between breathing and respiration

Breathing	Respiration
1. Physical process	1. Bio-chemical process involving enzymes
2. Takes place only in reptiles, birds and mammals	2. Occurs in all organisms
3. It is a rhythmic process	3. It is a continuous process
4. It is an extracellular process	4. It is an intracellular process
5. It involves gaseous exchange between the animal and its external environment	5. It involves enzymatic breakdown of glucose in the presence or absence of Oxygen to release energy

INTEXT QUESTIONS 14.1

1. Define respiration

    ....

2. Name the two gases that are exchanged during respiration.

    ....

3. What is cutaneous respiration? Name one animal that undertakes cutaneous respiration.

   ....

4. What is the colour of the blood of the earthworm? Name the pigment responsible for the colour.

   ....

5. How is oxygen transported to the cells in the cockroach?

   ....

6. Name the group of animals in which blood is not involved in gaseous exchange.

   ....

7. How does trachea communicate with the exterior in cockroach?

   ....

8. Trace the path of air from the nostrils to the lungs in the human body.

   ....

9. Name the part of the respiratory system where air is filtered, moistened and warmed in humans

   ....

10. What is the function of the epiglottis in humans?

   ....

14.2 MECHANISM OF PULMONARY RESPIRATION

The main purpose of respiratory system is to provide oxygen to the tissues and to remove carbon dioxide from them. This entire process is achieved through the following steps:

(i) Breathing or pulmonary ventilation leading to exchange of oxygen and carbon dioxide between the atmospheric air and the lungs.

(ii) Exchange of gases at the alveolar surface.

(iii) Transport and exchange of gases in the tissues.

(iv) Cellular respiration.

14.2.1 Breathing or pulmonary ventilation

It is a mechanical process of taking in atmospheric air into the lungs and giving out carbon dioxide. Breathing is an involuntary process but under special conditions it can become voluntary also. It consists of two steps during which lungs are contracted and expanded alternately.

1. Inspiration or taking air in, and
2. Expiration or forcing air out (refer to Fig. 14.4).

1. **Inspiration (The intake of air) :** A muscular dome shaped diaphragm is present at the base of the lungs. On contraction it becomes flattened and lowered. The lower surface of lungs is pulled downwards and the volume of lungs increases.

External intercostal muscles present between the ribs contract, the rib cage moves outwards and upwards. These contractions together increase the volume of the chest cavity, lower the air pressure within the lungs and the atmospheric air rushes in filling the lungs with fresh air. Thus, inspiration is an active phase of breathing.

2. **Expiration (releasing air) :** This step involves the relaxation of external intercostal muscles and contraction of internal intercostal muscles. As a result the rib cage lowers and moves inwards. The diaphragm also relaxes and rises again into its original dome shaped condition. The abdominal organs press up against the diaphragm. This change decreases the volume of the chest cavity, thus, increasing the air pressure within the lungs and the air, which is laden with CO_2 and is forced out.

Forced breathing. It is possible that during forced breathing both inspiration and expiration are active processes because some more intercostal muscles and the abdominal muscles are brought into action for deeper breathing movements

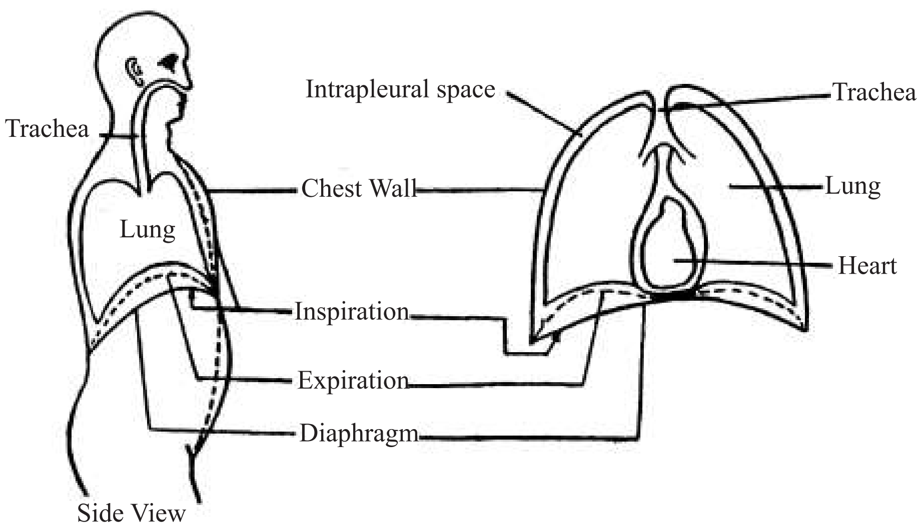


Fig. 14.4 Breathing movements

14.2.2 Exchange of gases at the alveolar surface

- Blood is the medium for the transport of oxygen from the lungs to the different tissues and carbon dioxide from tissues to the lungs.
- The deoxygenated blood is brought to the lungs by pulmonary artery which divides into fine capillaries that surround alveoli.
- Both alveoli and capillaries are made up of thin walled single layer of epithelial cells and therefore allow gaseous exchange easily.
- There is more oxygen in alveolar air and more carbon dioxide in the capillaries. Due to the pressure difference of oxygen and carbon dioxide between the alveoli and blood capillaries, the oxygen diffuses from alveolar air into the blood

capillaries. At the same time carbon dioxide diffuses from blood capillaries into the alveolar air.

- Oxygenated blood is taken from the lungs to the heart by pulmonary vein.

Volumes exchanged

Following table 14.3 shows the air volumes exchanged during breathing in a normal adult human being.

Table 14.3 : Air volume exchanged during breathing

Tidal volume (TV)	Volume of air inhaled and exhaled without any noticeable effort (normal breathing).	500mL
Vital capacity (VC)	Volume of air that can be maximally breathed out after a maximum inspiration (VC = IRV+TV+ERV).	3400-4800mL
Inspiratory reserve volume (IRV)	Volume of air that can be taken in by forced inspiration over and above the normal inspiration.	2000-3000 mL
Expiratory reserve volume (ERV)	Volume of air that can be expelled by forced expiration over and above the normal expiration.	1000 mL
Residual volume (RV)	Volume of air that cannot be forced out even on forced expiration. This is the air that remains in the lungs and in the air passage.	1000-1500mL
Total lung capacity	Sum of all lung volumes (maximum air that remains in the lungs after a maximum inhalation).	5500-6000mL

> Vital capacity may be highly reduced in smokers and people suffering from tuberculosis. Athletes and singers on the other hand have higher vital capacity.

14.2.3 Transport of oxygen by blood from lungs to tissues

Efficient transport of oxygen is by a complex blood protein called haemoglobin. This iron rich protein is packed in Red Blood Corpuscles (R.B.Cs) giving blood a red colour. About 97 percent of the total oxygen is transported from lungs to the tissues in combination with haemoglobin. Only 3% of oxygen is transported in dissolved form by plasma. Oxygenation of blood takes place in lungs. Four molecules of oxygen form a reversible bond with haemoglobin forming the compound oxyhaemoglobin.

$$\underset{\text{(Haemoglobin)}}{Hb + 4O_2} \underset{\text{Active Tissue}}{\overset{\text{Lung alveoli}}{\rightleftharpoons}} \underset{\text{(Oxyhaemoglobin)}}{Hb(4O_2)}$$

When the oxygenated blood reaches the tissue surface there is high concentration of CO_2 in the tissues, oxygen having been used up and low concentration of O_2. As a result the bonds holding oxygen and haemoglobin in Hb $(4O_2)$ becomes unstable and blood releases oxygen and takes up CO_2.

14.2.4 Transport of carbon dioxide (from tissues to lungs)

Blood transports carbon dioxide with comparative ease because of its high solubility. Active tissues constantly produce CO_2. This CO_2 is transported to the lungs in three ways:

(i) CO_2 is physically dissolved in blood plasma (only 5-7% of the total CO_2 is transported).

(ii) CO_2 directly combines with haemoglobin of RBCs to form carbaminohaemoglobin (about 21-23% only).

(iii) As bicarbonate it is dissolved in plasma but produced in RBCs catalysed by the enzyme carbonic anhydrase and then diffuses into plasma (largest fraction of CO_2, about 75% to 80%) to be transported in this manner.

$$CO_2 + H_2O \underset{\text{Carbonic anhydrase}}{\overset{\text{Enzyme}}{\rightleftharpoons}} \underset{\text{(Carbonic acid)}}{H_2CO_3}$$

$$\underset{\text{Carbonic acid}}{H_2CO_3} \longrightarrow \underset{\text{(Bicarbonate ion)}}{HCO_3^- + H^+}$$

Bicarbonate is extremely soluble and dissolves in blood plasma. It again passes into RBC and breaks into CO_2 and H_2O in the alveoli. Inside the lungs the CO_2 is transported to lungs from tissues in the three ways mentioned above and is released into the alveolar air and finally breathed out (Fig. 14.5).

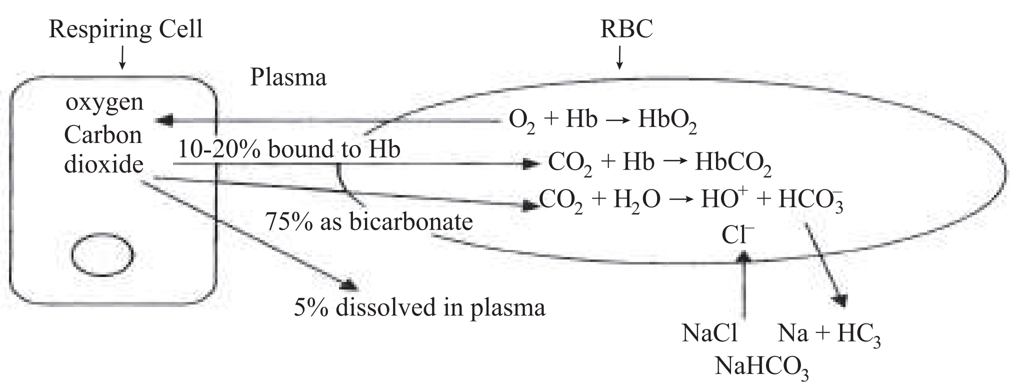


Fig. 14.5 Transport of carbon dioxide in the blood.

14.2.5 Regulation of respiration

Count the number of times you breathe during normal resting condition and when climbing up the stairs. How is the change in the breathing rate brought about? You will now study about regulation of respiration.

The regulation of respiration is under nervous control. There are three groups of neurons called respiratory centres present in the medulla oblongata and pons the brain. These are:

(a) **Dorsal respiratory group** – generates basic respiratory rhythm. It stimulates the external intercostal muscles, the diaphragm contracts and inspiration occurs. When the stimulation ceases, these muscles relax and expiration takes place.

(b) **Ventral respiratory group** sends signals under enhanced respiratory needs. It controls both inspiration and expiration.

(c) **Pneumotaxis center** in the pons controls switch off point of inspiration and thereby smoothens the transition between inspiration and expiration.

Increase in blood carbon dioxide and hydrogen ions increase the rate of respiration.

> If we try to hold our breath, we are not able to hold it for long time. This is because the respiratory centres of the medulla automatically reinstate breathing when the concentration of CO_2 in blood reaches a critical level.

14.2.6 Cellular respiration

Oxygen taken in the blood is utilised in all the living cells during cellular respiration. It is a complex process that is completed in the mitochondria. During cellular respiration, glucose is oxidized to release energy. Energy released is stored in ATP (Adenosine Triphosphate) molecules and is readily available for cell use. The process can be summed up as follows:

$$C_6H_{12}O_6 + 6CO_2 \xrightarrow[\text{Cell Respiration}]{\text{Mitochondria}} 6CO_2 + H_2O + ATP \text{ (e}$$

Respiration that takes place in the presence of O_2 is called **aerobic respiration**. It is more efficient as 38 molecules of ATP are released on the oxidation of one glucose molecule.

Absence of oxygen for sometime may lead to **anaerobic respiration**. It is inefficient as only 2 molecules of ATP are produced from one glucose molecule (Refer lesson 12 for details).

Respiration
Breakdown of glucose to release energy

Aerobic (Respiration when O_2 is available)
↓
Glucose
↓
2 Pyruvic acid
↓ ← O_2
$6CO_2 + 6H_2O + 38ATP$

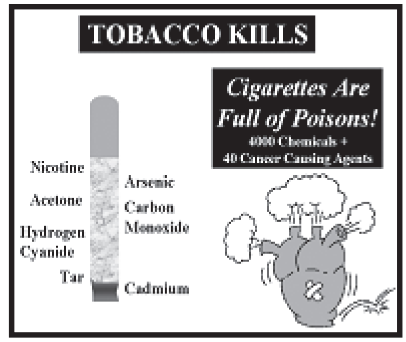
Anaerobic (respiration in the absence of O_2)
↓
Glucose
↓
2 Pyruvic acid → 2 Lactic acid + 2ATP
↓
$2CO_2$ + Alcohol + 2ATP

14.3 Common respiratory disorders and their prevention

Disease	Cause	Symptoms	Prevention
Bronchial asthma	It is an allergic disease caused due to certain foreign substance in the air.	Causes difficulty in breathing and coughing because excess mucous secretion may narrow down (clog) the bronchioles.	Avoiding exposure to the foreign substance is the best preventive measure.
Bronchitis	Inflammation of bronchi caused by infection. It can also be caused by smoking and by exposure to air pollution.	Regular coughing with greenish blue sputum	Avoiding exposure to smoke and dust prevents bronchitis.
Pneumonia	Acute inflammation caused by diplococcus infection in the alveoli of the lung.	It causes fever, pain and severe cough. Most of the air space is occupied by fluid and dead W.B.C.	Avoid crowded places where infection is prevalent.
Tuberculosis	It is a bacterial infection that spreads through droplets of infected persons	It can affect many other organs but pulmonary T.B. is most common. Weight loss and cough are common symptoms. It is accompanied by low fever. In extreme cases blood may come out while coughing.	BCG vaccine can prevent T.B. Well – ventilated dwellings and protein rich diet is also essential for T.B. patients.
Occupational lung hazards	Caused due to exposure to harmful substance like silica, asbestos, dust etc. present in the environment where a person works.	It is expressed after exposure of 10-15 years or more. It causes fibrosis of the lungs.	Such diseases can be prevented by minimizing the exposure to such substances by using protective masks and clothing. Regular health check – up is necessary.

The suffix 'itis' means inflammation of an organ. Bronchitis, pharyngitis or tonsillitis affects different respiratory tissues. Can you tell the specific organ affected?

Some Basic Facts



Why is cigarette smoking harmful?

Cigarette smoking is harmful because it leads to:

- diminished or extinguished sense of smell and taste
- smoker's cough
- gastric ulcers
- chronic bronchitis
- increase in heart rate and blood pressure
- premature and more abundant face wrinkles
- heart disease
- stroke
- cancer of the mouth, larynx, pharynx, oesophagus, lungs, pancreas, cervix, uterus, and bladder

14.2.7 Emphysema

Emphysema is a respiratory disorder caused by excessive cigarette smoking and chronic bronchitis. Either the bronchioles or the alveolar sacs get distended abnormally in Emphysema resulting in loss of elasticity of these parts. Gradually due to continuous distention, lung increases in size and air remains in lungs even after expiration.

Emphysema can be prevented by giving up smoking before damage is done to alveoli. Cure is difficult as elasticity is lost irreversibly.

INTEXT QUESTIONS 14.2

1. What is breathing?

   ....

2. What is the position of the diaphragm at the time of expiration?

   ....

3. What is the capacity of tidal volume?

   ....

4. What is the maximum number of oxygen molecules with which haemoglobin can combine?

   ....

5. Name the blood vessel that takes oxygenated blood from the lungs to the heart.

   ....

6. What are the three forms in which carbon dioxide is transported by the blood?

   ....

7. Name the vaccine used for prevention of TB.

   ....

8. What is an occupational hazard.

   ....

9. What is the difference between bronchitis and asthma?

   ....

10. The alveoli of a heavy smoker were damaged, their surface area was reduced and elasticity was lost. What is the technical term for this condition.

   ....

14.3 EXCRETION

All animals possess some mechanism of getting rid of the waste substances produced in their body during metabolic activities. These waste substances include CO_2, water, urea, uric acid and ammonia. Such substances can be harmful if retained in the body.

Besides metabolic wastes, excess salt (eg. NaCl taken in food), H_2O and even excess of some vitamins needs to be eliminated. Certain medicines (antibiotics) too are removed from the blood in the urine. **Removal of all harmful, unwanted products (specially nitrogenous wastes) from the body is called excretion**. Excretory system is primarily associated with removal of nitrogenous wastes.

Urea is the main nitrogenous waste in our body. It is formed by the breakdown of surplus amino acids and nucleic acids in the liver. Blood transports urea to the kidneys for filtration and removal in the form of urine.

14.3.1 Modes of removal of nitrogenous wastes

Depending upon the nitrogenous wastes excreted, animals can be classified as **ammonotelic, ureotelic** and **uricotelic**. Table 14.4 gives categories of animals on the basis of nitrogenous waste produced.

Table 14.4 Categories of animals on the basis of nitrogenous waste produced

Category	Product formed	Solubility in water	Examples
Ammonotelic	Ammonia (highly toxic)	Highly soluble, therefore needs plenty of water for its excretion.	Fresh water aquatic animals e.g. bony fish, *Amoeba*
Ureotelic	Urea (less toxic)	Less soluble, thus needs less water for excretion	Mammals like humans, dog etc, marine fishes and amphibians like frog and toad
Uricotelic	Uric acid (least toxic)	Insoluble solids or semi solid. Needs very little water just to flush out the uric acid	Birds, reptiles and insects.

Importance of excretion

(a) Excretion is necessary for the elimination of nitrogenous wastes formed during metabolism of proteins (amino acids) and nucleic acids.

(b) Elimination of excess salts like NaCl, vitamins, bile pigments (from the breakdown of old RBCs) and certain medicines and drugs, and

(c) Removal of excess of water or its retention in case of shortage of water. This is to maintain the required quantity of water (osmoregulation) in the body.

INTEXT QUESTIONS 14.3

1. Name the organ where urea is produced and the organ from where urea is excreted.

   ....

2. Which is the most toxic form of nitrogenous waste? Name an organism that excretes it.

   ....

14.3.2 Excretory organs in cockroach

- Cockroaches are adapted for terrestrial life and possess excretory organs called **Malpighian tubules** (Refer Fig. 14.6). They excrete uric acid, which is almost insoluble in water.
- The malpighian tubules are long, blind ended tubules attached to the alimentary canal at the junction of mid and hindgut.
- They lie in the abdomen and are bathed in haemolymph (blood of insects).

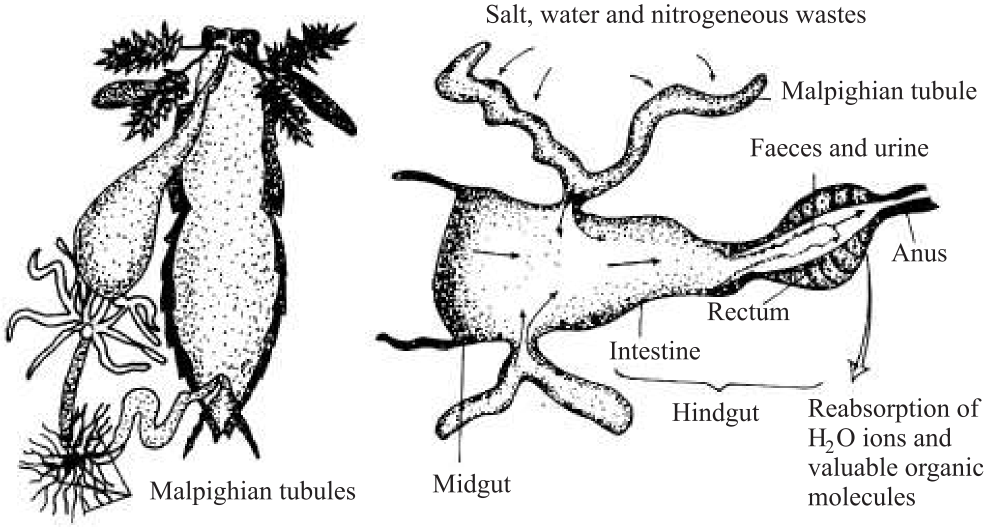


Fig. 14.6 Excretory organs of cockroach.

- The cells of tubules remove nitrogenous waste and certain salts from the haemolymph and then pump them into the lumen of the tubule.
- Fluid passes to the hindgut and in the process gets concentrated.
- This concentrated fluid then moves into the rectum and is excreted as concentrated urine along with faeces.
- Most of the salt and water is pumped back into the haemolymph by Malpighian tubules and in this way the nitrogenous wastes are eliminated as almost dry matter.

14.3.3 Excretary organs in humans

The human excretory system comprises of a pair of kidneys, a pair of ureters, a urinary bladder and urethra (Fig. 14.7)

- Kidneys are bean shaped organs located on either side of the vertebral column in the lower abdominal cavity.
- On the concave median margin of each kidney there is a notch called **hilum** which leads into funnel shaped space called **renal pelvis**.
- The renal pelvis is surrounded by an outer layer of tissue called **renal cortex** and an inner layer of tissue called the **renal medulla**.
- Kidneys filter metabolic wastes from the blood and excrete them as a liquid called urine. As kidneys form the urine, they also maintain the normal composition of blood, fluid and salt balance throughout the body tissues.
- Urine formed in the kidney is brought to the urinary bladder by two hollow muscular tubes called ureters.

- Urethra is the small tube that leads urine to the outside of the body.
- From urinary bladder urine is passed outside via urethra during urination voiding of urinary bladder is called micturition.

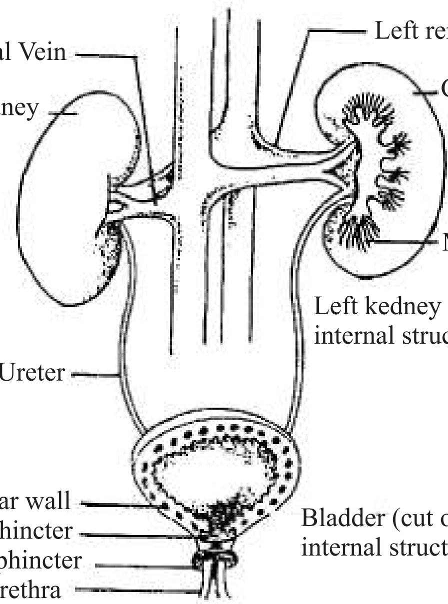


Fig. 14.7 Excretary organs of humans.

Structure of Kidney

Microscopic structure of kidney (Fig. 14.8)

- Kidney contains a large number of minute tubular structures called **nephrons** that are located partly in the renal cortex and partly in the renal medulla. They form urine and drain it ultimately into the pelvis of the kidney from where the ureters transport the urine to the urinary bladder.
- Nephrons are the structural and functional units of kidney associated with blood vessels and capillaries. There are about 1 million nephrons in each kidney which filter out about 180 litres of fluid per day most of which is reabsorbed. Each nephron can be divided into two regions (i) proximal nephron and (ii) loop of Henle. Further structural and functional components of a nephron are as follows:

  1. Renal corpuscle (is composed of cup-shaped Bowman's capsule and a tuft of capillaries (called glomerulus). Glomerulus receives the blood from a branch of renal artery.
  2. Proximal convoluted tubule (PCT)
  3. Descending limb of loop of Henle
  4. Ascending limb of loop of Henle

5. Distal convoluted tubule (DCT)
6. Collecting duct
7. Collecting ducts of all the nephrons join and ultimately form the renal pelvis from where the ureters arise.
8. Peritubular blood capillaries passing over the tubules join, and form the renal vein.

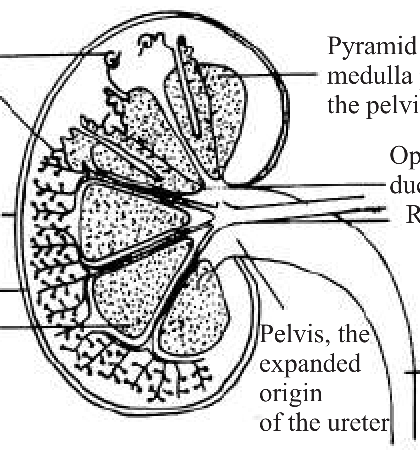


Fig. 14.8 Microscopic structure of human kidney

14.3.4 Formation of urine

Nephrons carry out excretory and osmoregulatory functions in the following steps-

1. Ultrafiltration
2. Selective reabsorption
3. Tubular secretion

1. Ultra-filtration

Each glomerular capillary receives blood flowing under high pressure through a branch of renal artery. There is continuous process of ultra filtration (filtration under pressure).

All small molecules like water, glucose, minerals, amino acids, urea and uric acid are filtered out of the blood plasma into the Bowman's capsule through the capillary walls. Proteins remain in the glomerular blood. Thus a protein free filtrate is collected in the lumen of the Bowman's capsule. The hydrostatic pressure of the circulating blood provides the pressure for filtration.

2. Selective reabsorption or tubular reabsorption

As the glomerular filtrate flows through the tubules several substances useful to the body such as glucose and animoacids and mineral ions needed to maintain the water and salt balance are reabsorbed through the walls of the renal tubule. The blood capillary passing over the nephrons absorb these substances.

(a) About 65%- 85% of filtrate is reabsorbed in Proximal Convoluted tubule (PCT). It includes water, glucose, amino acids, and salts.

(b) About 5% of water is reabsorbed in the descending limb.

(c) Ascending limb is impermeable to water; hence only salts are reabsorbed here.

(d) In Distal convoluted tubule (DCT) and collecting duct Na^+ is reabsorbed under the influence of the hormone **aldosterone** (secreted by adrenal cortex) . Water is absorbed under the influence of **ADH** (Anti diuretic Hormone) secreted by posterior pituitary.

3. Tubular Secretion

Cells of the renal tubule also directly serecte certain unwanted substances from the blood into the filtrate. These include uric acid, K^+ ions and ammonia. The filtrate is now known as urine.

Storage of Urine

The urine passes into urinary bladder via ureters and is stored there. The bladder can hold 400-500 cm^3 of urine. When about 200 cm^3 or more urine gets collected in urinary bladder, stretch receptors are stimulated leading to the desire to discharge urine.

14.3.5 Composition of urine (Table 14.5)

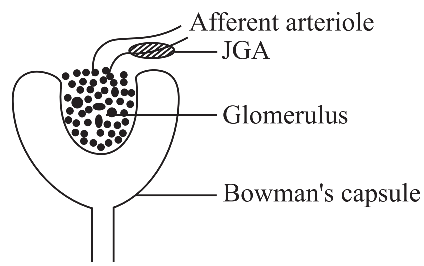
Table 14.5 Composition of urine

Normal components		Abnormal components	
Components	**Amount/Day**	**Component**	**Cause**
Water	1200-1500ml	Glucose	Diabetes mellitus
Urea	25-30 gms	Proteins	Kidney disease
Uric acid	0.7 gms	Acetones	Diabetes mellitus, starvation
Creatine	1.2 gms	Erythrocytes	Infection in urinary system
Ammonia	0.6 gms	Leucocytes	Large numbers indicate infection in urinary system
NaCl	10-15 gms	Uric acid crystals	Gout
KCl	2.5 gms		
Magnesium	0.2 gms		
Phosphate	1.7 gms		
Sulphate	2.0 gms		
Minute amounts of fatty acids, amino acids, pigments, mucin, enzymes, hormones, vitamins.			

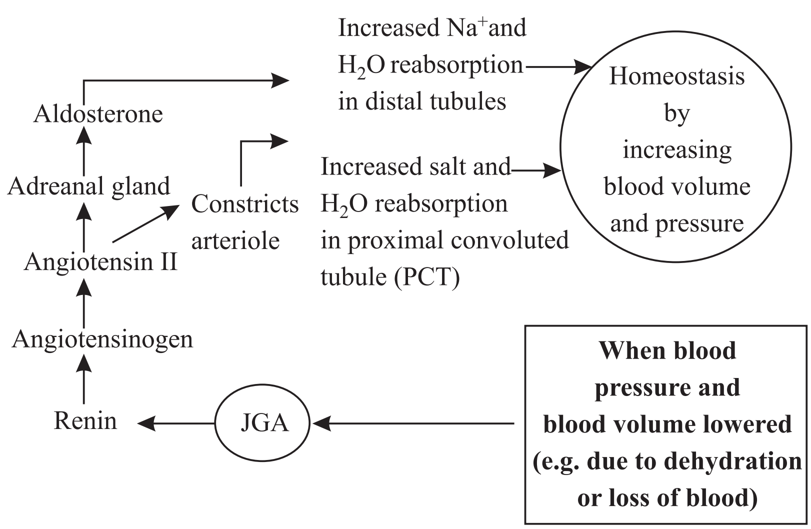
14.3.6 Renin-angiotensin and Atrial Natriuretic Factor

Renin-angiotensin is part of a feedback circuit which helps to regulate blood pressure and blood volume.

You know that nephron, the structural and functional unit of the human kidney has a cluster of capillaries called **glomerulus**. Recall its location from the Module 2, Unit 14 submit 14.3.3. Near the arteriole supplying the glomerulus lies a specialised tissue called **juxtaglomerular apparatus** (JGA)



When blood pressure or blood volume in the afferent arteriole drops, JGA secretes as enzyme called **renin.** Renin converts a plasma protein called **angiotensinogen** into **angiotensin II** which acts like a hormone, constricts the arteriole, which in turn elevates the blood pressure. Angiotensin II also stimulates the proximal convoluted tubules (PCT) of nephron (again, recall structure of nephron) to reabsorb more salt and water so that salt and water excreted in the urine are reduced. As a consequence, blood volume and blood pressure both increase. Angiotensin II also stimulates adrenal gland to release the hormone **Aldosterone** which makes distal tubules of nephron to reabsorb sodium and water. This also increases blood volume and blood pressure.



Renin angiotensin system for regulating blood volume and blood pressure

Antinatriuretic factor

Antinatriuretic factor is a powerful vasodilator and is a polypeptide hormone secreted by the cells of heart muscles (myocytes or muscle cells). It is released in the atria of the heart in response to the high blood pressure and is involved in the homeostatic control of water, sodium, potassium and fat in the body.

INTEXT QUESTIONS 14.4

1. In what form the cockroaches excrete their nitrogenous waste? What is its advantage for cockroach?

   ....

2. Where do Malpighian tubules of cockroach open?

   ....

3. List the parts of human excretory system and their functions.

   ....

4. Name the functional unit of kidney and its parts.

   ....

5. List the substances that are filtered out during ultrafiltration

   ....

6. What are the substances reabsorbed by the nephron?

   ....

7. What is the importance of tubular secretion?

   ....

8. Under which situation are the following present?

   (a) Glucose in the urine ....

   (b) Uric acid crystals ....

9. What is the normal volume of urine excreted per day?

   ....

10. What will happen if JGA (juxtaglomerular apparatus) stops secreting the enzyme renin?

    ....

11. Name a hormone, which is a polypeptide in nature and secreted by the heart muscles and is also a vasodilator.

    ....

14.4 OSMOREGULATION BY KIDNEY

Maintaining the solute concentration of the body fluids is called osmoregulation. Fine control of the precise amount of water and salt reabsorbed into blood is an important function of the distal convoluted tubules and collecting ducts. Depending on the need of the water in the body, kidneys excrete hypotonic (dilute) or hypertonic (concentrated) urine. Osmoregulation is controlled by the hormones ADH and aldosterone. Feedback circuits regulate their secretion.

(a) When the water content of the body is more, leading to low osmotic pressure, less ADH (anti diuretic hormone) is released. Hence the wall of the DCT and collecting tubules remain less permeable and as a result plenty of dilute urine (hypotonic urine) is excreted.

(b) When water content of the body is low, the posterior pituitary secretes more of ADH. The permeability of the tubules is increased. As a result more water is reabsorbed into the blood and reduced volume of concentrated urine is excreted (hypertonic urine). **Diuresis** means the production of increased amount of urine, so anti diuresis means reduction of urine volume and hence the name antidiuretic hormone or ADH.

(c) Urine is also concentrated by the counter current system of the descending and ascending limbs of Henle's loop. About 5% of the water from the filtrate is absorbed in this part.

(d) In response to low sodium ion concentration (or low blood pressure) another hormone, **aldosterone** is released by the adrenal cortex. It stimulates the kidney tubules to absorb sodium ions in exchange of potassium ions. This leads to reabsorption of water by osmosis. As a result of increased blood volume the blood pressure is increased. Similarly high sodium concentration will inhibit aldosterone release and as a result in would lead to lower sodium ion concentration in blood.

You will learn more about hormones in lesson 16.

14.5 HAEMODIALYSIS AND KIDNEY TRANSPLANTATION

Haemodialysis

1. The blood urea level rises abnormally (uraemia) in patients suffering from kidney failures. In such patients, an artificial kidney is used for removing excess urea from the blood by a process called **haemodialysis**. It is carried out in the following steps :
2. Blood is taken out from the artery of the patient and cooled to 0°C.
3. This blood is then passed through cellophane tubes of the artificial kidney. Cellphane is permeable to micro molecules such as urea, uric acid and mineral ions. It is not permeable to macromolecules such as plasma proteins.
4. Outside the cellophane tube is the dialyzing fluid, which has some solutes like those in blood plasma but no nitrogenous molecules like urea, and uric acid.
5. Hence the nitrogenous compounds from within the cellophane tubes flow into the dialyzing fluid by diffusion.
6. Blood coming out of the artificial kidney is warmed to the body temperature and returned to the vein of the patient.

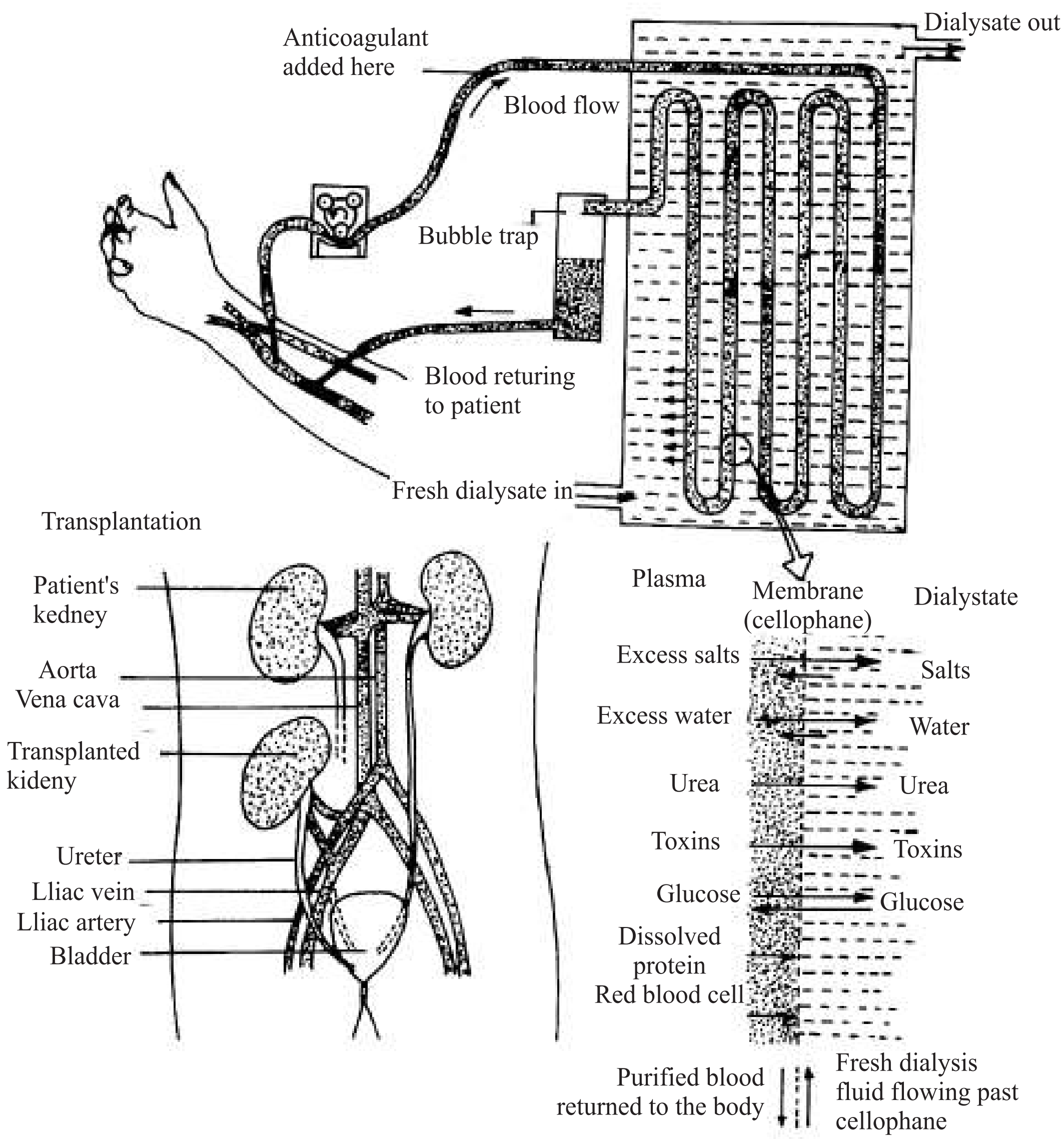


Fig. 14.9 Artificial kidney (haemodialysis)

Kidney transplantation

If kidney failure cannot be treated by other available means, kidney transplantation is advised.

- Donated kidney may come from a living person or a donor who has recently died.
- The genetic make up of the donor should be as close to the patient as possible, that is, if it is donated by a close relation, it reduces the chances of rejection.
- Drugs are, however, used to prevent rejection of the transplanted kidney by the body.

14.6 ROLE OF LIVER IN EXCRETION

- It excretes bile pigments, cholesterol, drugs and some vitamins.
- It excretes all the above mentioned substances in bile, which flows into the small intestine and from there these get removed with the faeces.
- Formation of urea and uric acid (from ammonia) also takes place in liver. These are removed from the body by the kidneys.

INTEXT QUESTIONS 14.5

1. Name the organ where urea is formed.

   ....

2. Why is cellophane used in haemodialysis?

   ....

3. What is the composition of dialyzing fluid?

   ....

4. From which type of blood vessel artery or vein, is the blood taken out for dialysis?

   ....

5. When is kidney transplantation advised?

   ....

6. How is bile pigment removed from our body?

   ....

WHAT YOU HAVE LEARNT

- Metabolic activities produce a number of waste products that need removal from the body.
- Breathing is a mechanical process of inhaling air (inspiration) and giving out of CO_2 rich air (expiration).
- Skin acts as the breathing organ for earthworm. It is thin, moist and richly supplied with blood capillaries.
- Cockroaches have air tubes called trachea for respiration. Air reaches directly to the tissues for gaseous exchange. Blood does not participate in gaseous transport.
- In humans, air passes through respiratory passage as follows-

  Nostrils→Pharynx→Trachea→Bronchi→Bronchioles→Alveoli in lungs

- Cellular respiration is a chemical process which takes place within the cell and is associated with release of energy.
- Haemoglobin is an iron containing pigment that can easily combine with oxygen and transport it to different parts of the body.
- Carbon dioxide in blood is transported in three ways: (a) dissolved in plasma, (b) as carbaminohaemoglobin, and (c) as bicarbonates
- Aerobic respiration takes place in the presence of oxygen. 38 molecules of ATP, carbon dioxide and water are released during this process.
- Anaerobic respiration takes place in the absence of oxygen. 2 molecules of ATP, carbon dioxide and alcohol or lactic acid are produced during this process.
- Excretion is the removal of nitrogenous wastes from the body.
- Human excretory system consists of a pair of kidneys, a pair of ureters, a urinary bladder and a urethra.
- Nephrons are the filtering units of kidney.
- Urine formation by nephrons has three steps : ultrafiltration, reabsorption and tubular secretion.
- Urine consists of water, urea, unwanted salts and some drugs.
- Depending upon the kind of excretory product, animals may be classified as ammonotelic ureotelic, or uricotelic.
- An artificial kidney or dialysis machine may be needed in case of kidney failure.
- Malpighian tubules in cockroach remove uric acid from the body cavity into the digestive tract for removal.
- Cigarette smoking is injurious to health and causes emphysema in which alveoli lose their elasticity.
- JGA or Jux taglomerular apparatus in the nephron helps to restore blood volume and blood pressure when it falls by secreting an enzyme renin.
- Heart secretes a hormone called antinatriuretic factor which helps in maintaining homeostasis, related to control of water, sodium, potassium and fat in the body.

TERMINAL EXERCISES

1. List the major steps that are involved with respiration in humans.
2. How is oxygen transported in earthworm?
3. Name the respiratory pigment in earthworm.
4. What is the role of carbonic anhydrase in the transport of carbon dioxide in our body?
5. Which part of our respiratory system is known as the voice box?
6. Where are respiratory centres situated in our brain?

7. Name one nitrogenous waste removed by the kidney.
8. Name the hormone the absence of which will result in excretion of hypotonic urine.
9. What is the role of cellophane in dialysis?
10. Why is inspiration said to be an active phase and expiration as passive phase?
11. Differentiate between
    (a) Breathing and respiration
    (b) Inspiration and expiration
12. List the special features of alveoli that enable easy gaseous exchange.
13. What is vital capacity, tidal volume and residual volume?
14. Give reasons for the following :
    (a) Exchange of gases at the alveolar surface continues even during expiration.
    (b) Trachea and bronchi do not collapse when air pressure decreases inside them.
15. Draw the excretory system of human and label the parts.
16. Draw the structure of a nephron and label the parts.
17. What is the cause and symptoms of pneumonia and TB?
18. What is the role of liver in excretion?
19. Explain how nitrogenous wastes are removed from the body of cockroach.
20. How does ultrafiltration and reabsorption occur in nephrons?
21. Explain how gaseous exchange takes place in the lungs.
22. How is oxygen transported from the lungs to the tissues and carbon dioxide from tissues to the lungs?
23. How is (a)Water balance, and (b) Salt balance maintained by kidney?
24. List the parts of human respiratory system in correct sequence and state their functions.
25. List three characteristics of our lungs which make them suitable as respiratory surface.

ANSWERS TO INTEXT QUESTIONS

14.1 1. Stepwise oxidation of glucose resulting in release of energy.

2. O_2, CO_2
3. Respiration by the skin; frog
4. Red, haemoglobin
5. Directly through tracheoles

6. Insects
7. Through spiracles
8. Nostrils → pharynx → bronchi → bronchioles → lungs
9. Nasal cavity
10. Prevent food from entering the trachea or food pipe

14.2
1. mechanism of taking in air and then giving it out
2. relaxed and dome shaped
3. 500 mL   4. 4 molecules   5. Pulmonary vein
6. (a) dissolved in plasma as carbon dioxide – 5%
   (b) as carboxy carbamino haemoglobin in RBC – 20%
   (c) as bicarbonate ions in RBC or plasma – 75%
7. Bacillus Calmette Guerin (BCG)
8. Silicosis or asbestosis
9. Bronchitis is an infection of the bronchi and antibiotics can cure it whereas bronchial asthma is an allergic reaction.
10. Emphysema

14.3
1. (a) Liver   (b) Kidney
2. Ammonia; amoeba and fresh water fishes

14.4
1. Uric acid; this is to prevent water loss as these animals need to conserve water
2. Malpighian tubules open at the junction of mid and hind gut
3. Kidney-filters nitrogenous wastes, excess of water and salt
   Ureters-transport urine to the bladder
   Urinary bladder-temporary storage of urine
   Urethra-drains urine outside the body
4. Nephron, consisting of renal corpuscles made up of Bowman's capsules and glomerulus, PCT, loop of Henle, DCT, collecting duct
5. Water, amino acid, glucose, urea, uric acid, minerals, vitamins.
6. Water, glucose, some salts, amino acid and small quantity of urea and uric acid.
7. Direct elimination of certain minerals can take place such as ammonia and potassium.
8. (a) Diabetes mellitus   (b) Gout
9. 1200 to 1500 mL
10. Blood Pressure will remain abnormally low.
11. Antinatriuretic factor.

14.5 1. Liver
2. Cellophane is impermeable to macromolecules like plasma proteins and blood corpuscles
3. It contains some minerals and solutes like those in plasma but no urea and uric acid is present.
4. Artery
5. When kidney failure cannot be treated.
6. Bile pigments are removed along with bile via the digestive tract.

15

CIRCULATION OF BODY FLUIDS

The body of almost all the animals, has some form of fluid circulating in the body. Such fluids constitute the distributing system (to supply substances) as well as collecting system (to pick up substances) from the various parts of the body (including the remotest cell). What are these fluids? How are these circulated and in what way do they function in our body? These and many more questions will be answered in this lesson.

OBJECTIVES

After studying this lesson, you will be able to :

- *explain the importance of the circulatory system in human body;*
- *differentiate between open and closed systems of circulation;*
- *list and draw the organs of circulatory system of cockroach;*
- *list and draw the organs of circulatory system in humans*
- *describe the histology, functions and composition of blood in humans*
- *compare the structure and functions of an artery, a vein and a capillary;*
- *explain the process of blood coagulation in humans*
- *name the blood groups and describe modalities of blood transfusion;*
- *explain blood pressure;*
- *describe lymphatic system and mention its components;*
- *define immunity and describe its different types;*
- *explain various immuno-deficiency disorders;*
- *name and describe some blood related disorders such as hypertension; atheroma and arteriosclerosis;*
- *explain the importance of ECG and role of pacemaker in treating heart beat related disorders.*

15.1 CIRCULATORY SYSTEM

Our body is made of cells. Cells need nutrients and oxygen to survive, and wastes need to be removed from them. Hormones are also needed to be transported from the endocrine glands which secrete them to their respective target cells. This work of transportation of nutrients, gases, wastes and other substances from one part of our body to the other part, is carried out by blood, and termed **circulation**.

> The organs responsible for the flow of blood and lymph through various parts of the body constitute the circulatory system

1. Functions of circulatory system

(i) Transport of nutrients to the tissues for their utilization

(ii) Transport of respiratory gases (O_2 and CO_2) to and from the cells.

(iii) Collection of metabolic wastes from different tissues and transporting them to excretory organs for their removal.

(iv) Transport of hormones from endocrine glands to target organs.

(v) Protection of body by destroying pathogens.

(vi) Uniform distribution of heat in the body.

2. Types of Circulatory System

Depending upon the mode of circulation, the circulatory system may be open or closed type.

(i) Open circulatory system

(a) Blood does not flow in closed vessels rather it flows through parts of the body cavity. It remains mixed with the body fluid.

(b) Sufficient high pressure for circulation is not maintained.

Organisms like prawns, and insects have open circulatory system.

(ii) Closed circulatory system

(a) Blood flows in well-defined tube-like vessels.

(b) Sufficient high pressure is maintained .

(c) System is more efficient than open type.

Closed system is found in all vertebrates.

15.2 CIRCULATORY SYSTEM OF COCKROACH

The circulatory system of cockroach is of open type. It consists of a pulsatile heart (dorsal blood vessel) and sinuses through which the blood flows. The blood is colourless and fills the entire body cavity which is rightly called **haemocoel**. Thus the blood is called haemolymph. Haemocoel is divided into three sinuses (chambers) by two horizontal septa called **dorsal diaphragm** and **ventral diaphragm**. The three sinuses are dorsal sinus or **pericardial sinus** enclosing the heart, middle **perivisceral sinus** lodging the various visceral organs and the ventral **perineual**

sinus enclosing the ventral nerve cord. Both the diaphragms are perforated such that the three sinues remain in communication with each other.

The heart is an elongated, tubular structure, closed behind and open in front, running all along the middle line through thorax and abdomen. It consists of thirteen segmentedly arranged funnel shaped chambers. At the lateral side of each chamber is a pair of ostia one on each side, which are guarded by **valves**. Through these ostia, the heart communicates with the pericardial sinus. Anteriorly, the heart continues into the head as anterior aorta which opens into the haemocoel of head. Attached to each segment, is a pair of triangular **alary muscles** present on either side of the heart.

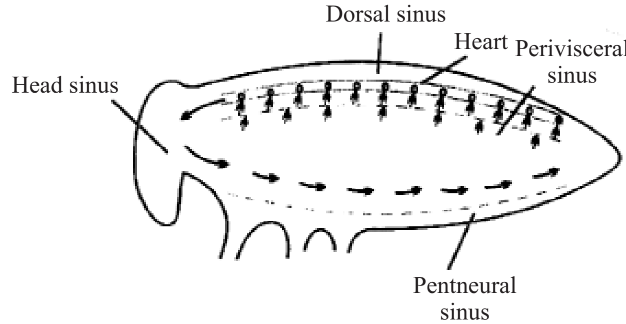


Fig. 15.1 Circulatory system of cockroach

The blood is a colourless fluid, made up of plasma and cells termed haemocytes. Since the blood of cockroach lacks any respiratory pigment, it is not involved with the transportation of respiratory gases. It serves only for (i) the transportation of the nutrients (ii) maintenance of hydrostatic pressure and (iii) acts as a reservoir of water. The blood of cockroach circulates due to contraction and relaxation of the heart and the alary muscles.

15.3 ORGANS OF HUMAN CIRCULATORY SYSTEM

The circulatory system consists of the following parts :

1. Heart – the central pumping organ.
2. Blood vessels – the connecting tubes – arteries, veins and capillaries.

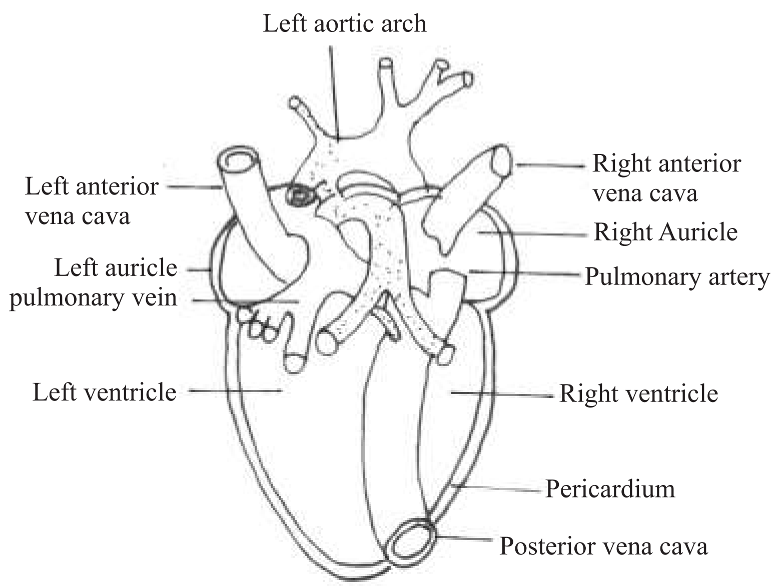


Fig. 15.2 (a) External structure of humnan heart (Front view)

3. Blood – is the circulating fluid, a connective tissue made of a fluid matrix and cells.
4. Lymphatic system comprises of lymph nodes and lymph vessels.

1. The human heart

It is a muscular organ made of cardiac muscle fibres (Fig. 15.2). It is able to perform its function by coordinating contraction and, relaxation and opening and closing of a number of valves present inside the heart. This fist sized organ consists of 4 chambers, the two upper chambers – the **atria** and two lower chambers – the **ventricles**. Ventricles have thick muscular walls for pumping blood to longer distances. Heart is covered by a membrane – the **pericardium**.

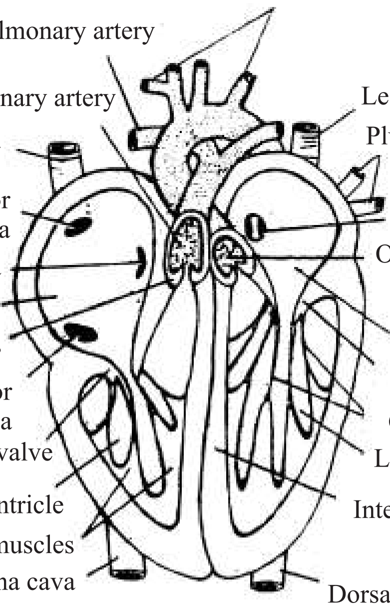


Fig. 15.2 (b) Internal structure of human heart.

(i) Valves inside the heart

Locate the following valves in figure 15.3. The atrio-ventricular valves are between Atria and Ventricles.

(a) Right **atrio-ventricular valve** or **tricuspid valve**

(b) Left **atrio-ventricular valve** or **bicuspid valve**

Semilunar valves at the origin of aorta and pulmonary artery.

Valves open only on one side like a door. They regulate the flow of blood by opening on one side to let blood flow out in one direction only and prevent the back flow of blood.

(ii) Heart beat and cardiac cycle

The **beating of heart** goes on by itself as long as one is alive. Each heartbeat consists of the steps mentioned below and makes two sounds – **Lubb** and **Dubb** during each beat.

(a) The heart beat starts with contraction or **systole** of atria, followed by relaxation or **diastole**. The lubb sound or 1^{st} heart sound occurs due to closure of atrioventricular valves, the atrial systole.

(b) Contraction of ventricles followed by relaxation accompanied by the dubb sound or the 2^{nd} heart sound occurs due to closure of semi lunar valves. At the beginning of every heart beat the four chambers of the heart are in the relaxed state (**Joint diastole**). At this stage the venae cavae pour deoxygenated blood into right atrium and the pulmonary vein pours oxygenated blood into left atrium.

Heart beat originates at the **Sinu-Atrial Node or S.A Node** which is a modified part of the muscular wall in the upper corner of the right atrium (Fig. 15.3).

As a result right atrium contracts, tricuspid valve is pushed open and deoxygenated blood enters the right ventricle. At the same time, the bicuspid valve is pushed open and oxygenated blood flows into left ventricle.

Atrio-Ventricular Node (A.V. Node), modified muscle is located in the interatrial septum. When impulse comes from SA node to AV node, the contracted atria begin to relax and impulse passes to **Bundle of HIS** lying in the interventricular septum and then passes to **Purkinje Fibers** lying in the walls of ventricles. As a result ventricles contract (Ventricular systole)

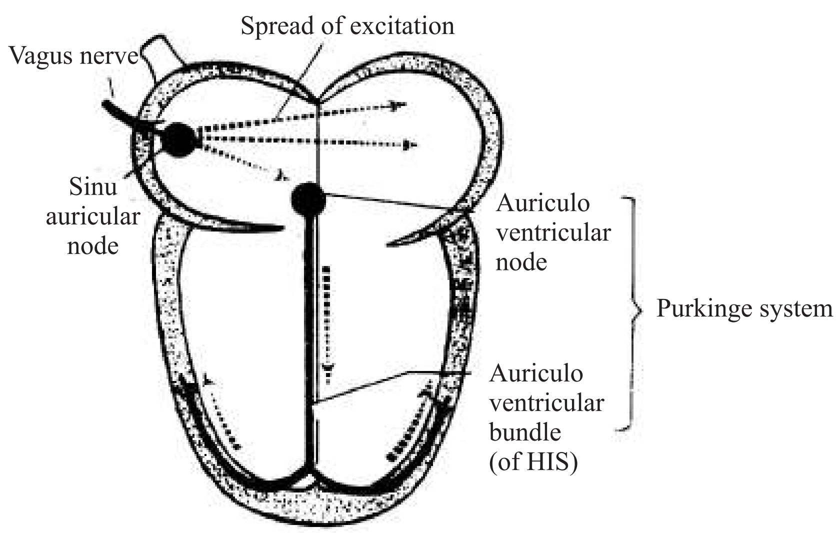


Fig. 15.3 Position of the Sino-atrial and atrio-ventricular nodes and the bundle of HIS and conduction of impulse for heart beat.

Since Sinu-atrial Node initiates and regularizes the heartbeat, it is also called the **pacemaker**. The pacemaker is influenced by nerves, hormones, CO_2 and O_2 content of blood, and heat.

Do You Know?

Sometimes the S.A. (Sino-Atrial) Node may become defective or damaged. A person may need to have an artificial pacemaker grafted in the chest. This regularizes the heartbeat.

Electro Cardiogram (ECG) is the instrument that records the conduction of heartbeat .

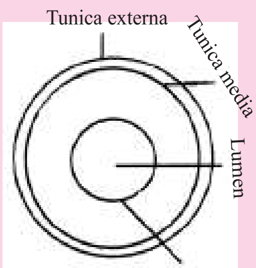
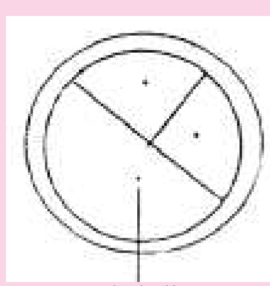
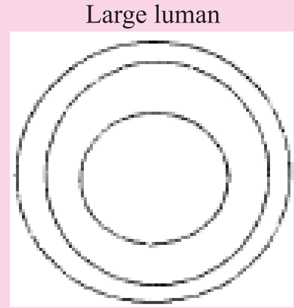
This helps in detecting heart beat disorders.

15.3.2. Blood vessels

The tubes transporting blood are called **Blood Vessels**. The wall of a blood vessel has three layers, tunica externa, tunica media and tunica interna. There are 3 kinds of blood vessels:

(i) Artery (ii) Capillary and, (iii) Vein. These three vessels differ in structure and speed of blood flow, as shown below.

Table 15.1 Comparison in structure and function of an artery, the capillary and the vein.

Artery	Capillary	Vein
• Transports blood away from the heart.	• Capillaries link arteries to . veins for exchange of material between blood and tissues which also have capillaries	• Site of Transport of blood towards the heart.
• Tunica media is thick and composed of elastic, muscular tissue.	• No tunica media. Only single layer of cells forming **endothelium**. No elastic fibers	• Tunica media is relatively thin and only slightly muscular. Few elastic fibers.
• No semi-lunar valves. along arteries	• A semi-lunar valve present.	• Semi-lunar valves are present all along the length of vein at intervals to prevent back flow of blood
• Pressure of blood is high and arteries are pulsatile.	• Pressure of blood falling and non-pulsatile.	• Pressure of blood low and non-pulsatile.
• Blood flow rapid	• Blood flow slow	• Blood flow slow
• Low blood volume Blood is oxygenated except in pulmonary artery	• High blood volume Mixed oxygenated and deoxygenated blood.	• Increased blood volume • Blood deoxygenated except in pulmonary vein
• Small lumen	• Extremely narrow lumen	• Large lumen
		

Arteries divide into **Arterioles** and then into **Capillaries**. This way they come in contact with all the tissues and bathe the cells with blood plasma. Diagram 15.4 shows the possible route that blood may take between arteriole, capillary bed and venule. Capillaries join to form venule. Venules are thin blood vessels that join to form veins.

(i) Major Arteries and Veins

Blood that has been circulated through the body has lost much of the O_2, it carried. This de-oxygenated blood returns to the heart by two major veins.

1. **Superior vena cava**-brings deoxygenaled blood from head and shoulder region.
2. **Inferior vena cava**-brings deoxygenated blood from lower parts of the body.

These venae cavae open in the right atrium (refer to diagram 15.2). Contraction of right atrium forces this blood into the right ventricle.

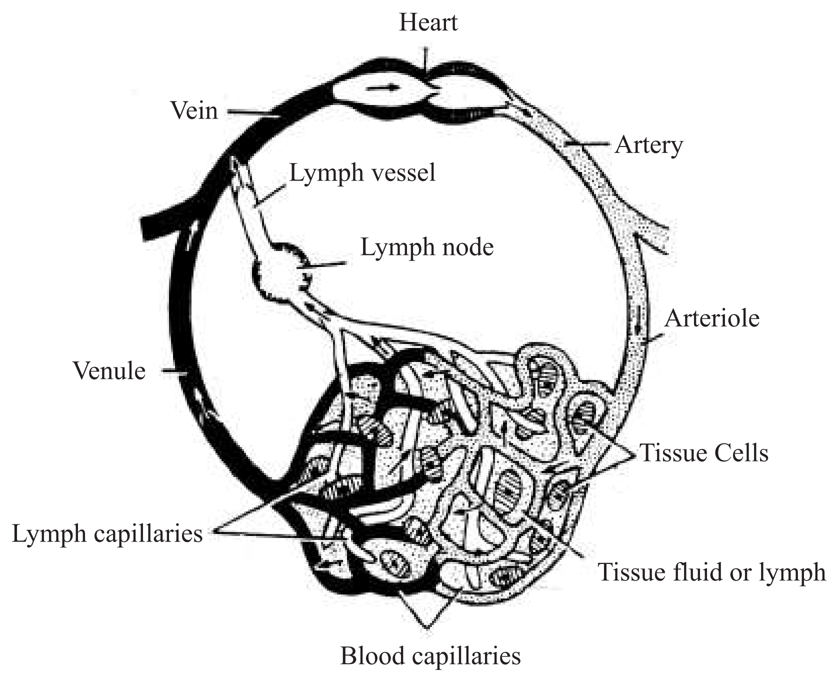


Fig. 15.4 The route that blood takes between arteriole, capillary bed, and venule.

Contraction of right ventricle pumps blood into **pulmonary artery** which transports blood to the lungs. Blood gets oxygenated in the lungs and returns to the left atrium through the **pulmonary vein**.

Blood then passes from the atrium into the left ventricle. Left ventricle pumps blood into aorta. The aorta distributes blood throughout the body.

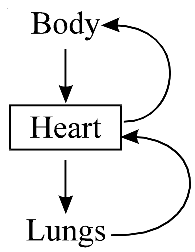
See the flow diagram given below which summarizes the **path of blood** through the entire circulatory system.

Double circulation

Since blood passes twice through the heart, it is termed **Double circulation**

(i) First Deoxygenated blood passes from the body to heart and oxygenated blood from heart to the body.

(ii) Then Deoxygenated blood flows from heart to lungs and oxygenated blood from lungs <u>again to heart</u>, from lungs.



In one circulation, the blood passes through the heart twice. Once from body to heart to lungs and second time from lungs to heart to body.

Path of circulation

First from body to heart

(Venae cavae carry blood from tissues with very little oxygen and lot of CO_2 to Right atrium)

↓

Tricuspid valve opens

↓

Right ventricle

↓

Pulmonary arteries

↓

(Pulmonary arteries carry blood to lungs to give up CO_2 and to collect O_2 from lungs)

Pulmonary veins

↓

(Pulmanary veins carry oxygenated blood back to left atrium of heart)

↓

Left atrium

↓

Bicuspid valve

↓

Left ventricle

↓

Aorta

(carries blood with a lot of oxygen and distributes this oxygenated blood to different parts of the body)

Pulmonary artery is the only artery that carries the de-oxygenated (**blood poor in O_2**) blood. It is called artery as it carries blood away from heart.

Pulmonary vein is the only vein that carries oxygenated blood (blood rich in O_2). It is called vein as it carries blood into heart.

INTEXT QUESTIONS 15.1

1. Give one example each of animals with open and closed circulatory system.
   (i) Open circulation ....
   (ii) Closed circulation ....
2. Where in the heart are the following valves located?
   (i) Bicuspid ....
   (ii) Tricuspid ....
3. Name the following
   (i) Structure where the wave of contraction originates in heart to begin heart beat
   ....
   (ii) Structure connecting arteries with the veins
   ....
   (iii) Blood vessel that brings oxygenated blood from the lungs to the heart
   ....
   (iv) The blood vessel which collects and brings deoxygenated blood from brain and shoulder region to the heart ....

(ii) Components and functions of blood

Blood is a red coloured, thick and slightly alkaline, fluid which keeps circulating in our body through the blood vessels. Why is blood so important? It is important because

1. it transports substances in the body such as Oxygen, nutrients, and hormones. It also carries waste to the kidney.
2. it protects body against disease.
3. it maintains normal body temperature.

The components of blood

Blood is a fluid connective tissue made of plasma and blood cells.

Blood

- **Plasma** 55% (liquid)
  - Water 90%
  - Proteins (little less than 10%)
- **Cellular Components** (45%)
  - Red blood Corpuscles (RBC)
  - White Blood Corpuscles (WBC)
  - Platelets (pieces of cells without nuclei)

A. Plasma

It is a pale yellow liquid consisting of **blood proteins** like **albumin, globulin and fibrinogen.**

Functions : Plasma has the following functions :-

1. Transport of products of digestion from small intestine to various tissues.
2. Transport of waste products from tissues to excretory organs.
3. Transport of hormones from endocrine glands to target organs.
4. Maintenance of temperature by distribution of heat all over the body.
5. Provides factors for clotting of blood (Fibrinogen).
6. Retention of fluids in blood (through plasma proteins).
7. Maintenance of acid-base equilibrium in the blood.
8. Provides body immunity through antibodies (Immunoglobulins) which are made by one kind of WBC and then released into the plasma.

B. Blood Cells

The cells of blood are **Red Blood Corpuscles (RBC)** and **White Blood Corpuscles (WBC)** and cell fragments, the **Platelets**. Blood cells are formed in the bone marrow. Their formation is termed **haemopoiesis**. Table 15.2 gives the idea of the cellular components, their origin, function and structure.

Table 15.2 Cellular components of blood

Component	Origin of cells/mm	Number	Function
Erythrocytes (Red Blood corpuscle)	Bone marrow	5.000,000	transport of • oxygen to tissues and a large amount of • carbon dioxide back to lungs
Leucocytes (White Blood Corpuscles)	Bone marrow	4,000 8,000	
(a) Granulocytes (72% of total white blood cell count)		4900	• engulf bacteria
neutrophils (70%)	Bone marrow	105	• anti-histamine properties
eosinophils (1.5%)		35	• Produce histamine and heparin
basophils (0.5%)			
(b) Agranulocytes (28%)			
monocytes (4%)	Bone marrow	280	• engulf bacteria (Phagocytosis)
lymphocytes (24%)	Bone marrow, lymphoid tissue, spleen	1680	production of antibodies to provide immunity
Platelets	Bone marrow	250,000	initiate blood-clotting

Do you know about the following blood disorders ?

1. Increase in R.B.C (More than normal) POLYCYTHEMIA
2. Decrease in R.B.C (less than normal) ANAEMIA
3. Increase in W.B.C.(more than normal) LEUKAEMIA
4. Decrease in W.B.C (less than normal) LEUKOPENIA

Coagulation of Blood (Blood Clotting). You must have, sometime or the other, got a cut on your finger and seen blood flowing out of it . You would have noticed that after a few minutes, the blood flow stops, as the blood thickens and forms a lump. This lump is called **clot**. The process of thickening of blood is called **coagulation or clotting of blood**. We are lucky that the blood clots and the bleeding stops. If it did not, a person with a very small wound would lose a lot of blood and die. When blood vessels are injured, a sequence of reactions takes place to prevent loss of blood. Steps involved are as follows :

Thromboplastin (from blood platelets) + Prothrombin (Plasma protein)

Ca^{++} ions

Fibrinogen (Plasma protein) $\xrightarrow{\text{Thrombin}}$ Fibrin (Insoluble fibres)

FIBRIN + R.B.C $\longrightarrow$ CLOT (Scab) Prevents blood loss

Haemophilia – A genetic disease that results in a condition where blood fails to clot

Blood group

The blood of an individual may belong to any one of the four blood groups, A, B, AB, and O. Blood group remains constant throughout lifetime as it is genetically controlled and is inherited from parents. These blood groups are due to the presence of special proteins present on the membrane of RBCs termed as antigens. Antigens present could be A, B both A and B or no **Antigen** may be present in the cell membranes of RBC of a particular blood group. Blood plasma, on the other hand, contains **antibodies** a, b, or both a and b, or neither of the two. Antigen A reacts with antibody b and antigen B with antibody a causing clumping of blood.

Blood Group	Antigen	Antibody
A	A	b
B	B	a
AB	A, B	–
O	–	a, b

Blood transfusion

When excessive blood is lost from the body either due to an accident, hemorrhage or during surgery (operation), doctors transfer blood from a healthy person (Donor) to the patient (Recipient). This is called **Blood Transfusion.** When blood transfusion is needed, the red blood cells selected must belong to a group which will not be affected by any antibody in the patient's plasma.

Clumping of donor's blood (Agglutination) may take place upon transfusion if the blood group of donor does not match with that of the recipient. Table 15.3 shows blood groups and possibility of their transfusion.

> **Clumping** is a condition where the antibodies present in the plasma of recipient link donor's blood cells with each other to form a clump
>
> **Agglutination** is the process by which red blood cells clump together when the antigens on their surface react with complementary antibodies.

Table 15.3 Matching of Blood Group, Safe and Unsafe After Transfusion of Blood.

Those who can safely receive blood of donor type	Donor	Blood group types who cannot
O, A, B, AB	O	
A, AB	A	O, B
B, AB	B	O, A
AB	AB	O, A, B,

The above table indicates that :

Blood group of recipient	Donor's blood group				
	Group O	Group A	Group B	Group AB	√ Safe transfusion
Group O	√	×	×	×	
Group A	√	√	×	×	×
Group B	√	×	√	×	
Group AB	√	√	√	√	Dangerous transfusion

The above table indicates that :

1. Blood group of O type can be given to all groups. It is thus the **Universal Donor**. This is because there are no antigens in the blood of Group O.
2. Blood groups AB can receive blood from all other groups and is thus called **Universal Recipient**. No Antibodies present in the blood of Group AB, so no reaction with antigens of other blood groups.

Rh Factor

Presence or absence of another blood protein in addition of ABO antigens makes a person Rh^+ or Rh^-.

> Rh factor in expectant mothers can sometimes cause problems. The blood of an Rh^+ embryo whose mother is Rh^- is in danger of severe clumping.

Antibodies are produced in the mother against the Rh^+ blood cells of the embryo and whenever there is even the slightest mixing of foetal blood mothers blood.

15.3.5 Blood Pressure

You have already learnt that during systole, the ventricles contract and force the blood into the arteries, which carry it to all parts of the body. The flow of the blood in the arteries exerts a pressure on their elastic walls. This pressure is called **blood pressure**.

The pressure of blood at the time of ventricular contraction is higher and is called **systolic pressure**. When ventricles are relaxed and are being filled by blood, there is a drop in pressure. This lower pressure is called **diastolic pressure**. These two pressures can be measured in the arteries of the arms. The device used for measuring blood pressure is called **Sphygmomanometer**.

A reading of 120/75 means that the person's systolic pressure is 120 mm of mercury and diastolic pressure is 75 mm of mercury. A typical reading for a healthy adult is 120 ± 570 ± 5 mm of mercury.

The difference between diastolic and systolic pressure can be felt as a throb in the arteries of the wrist. This throb at the wrist is called **Pulse**. The number of throbs felt at a particular point on the wrist (due to systole) per minute is called **Pulse Rate**. It is equal to the number of heart beats i.e. around 70 beats per minute for a normal adult.

INTEXT QUESTIONS 15.2

1. Name the following
   (i) The term given to the production of blood cells ……...........………
   (ii) The three proteins present in the plasma
   (i) ……………. (ii) ……………. (iii) …………….
   (iii) Cell fragments of blood involved in the clotting of the blood
   ………………………………...................................………………………
2. Fill in the blanks
   (i) Transfer of blood from donor to recipient is called …..............………
   (ii) Antigens are present on ………………, and antibodies in the ……………..
   (iii) People from blood group O can receive blood from blood group /groups ………………………
   (iv) Blood pressure is measured by an instrument called………………. The reading for a person with normal blood pressure will be around ….....………………………......

4. Lymphatic system

Our body has the presence of two kinds of circulating fluids – blood and lymph. Of these you have seen and felt the first (i.e. blood) in your own body, but lymph remains unnoticed even if it oozes out at any point of injury because it is colourless.

This system consists of a series of branching vessels and a collection of lymphatic organs. Let us understand. A continuous exchange of materials between the blood capillary and the intercellular fluid (fluid present between cells of tissues) goes on. Some important components like proteins that could not be sent back to blood capillaries from intercellular fluid, are taken up by the lymph capillaries as lymph and drained into veins in the lower neck portion of the body (subclavian vein). Lymph should be regarded as **modified tissue fluid**.

The clear, colourless liquid moving out of the capillary wall is called Lymph. Lymph comes into direct contact with body cells. (Fig. 15.5)

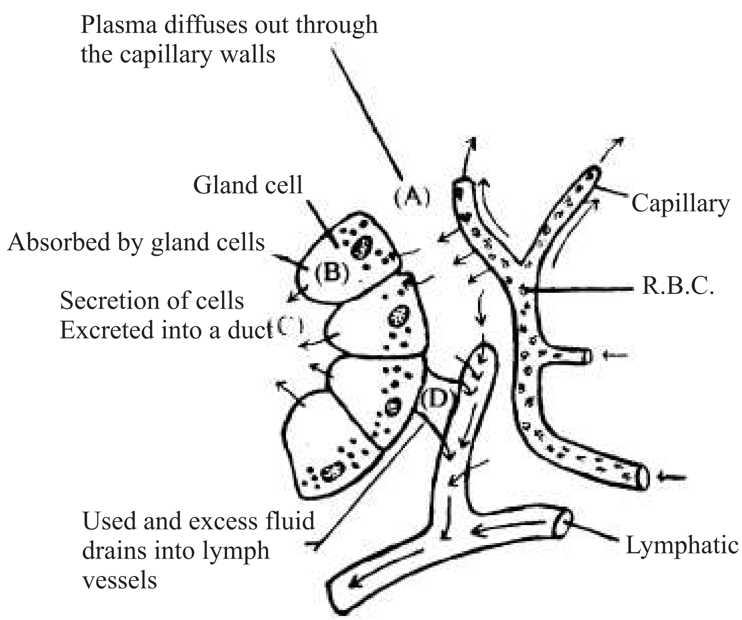


Fig. 15.5 Flow of lymph between capillaries and lymph vessel

(a) Functions of lymph

(i) Supplies nutrition and oxygen to those parts of body where blood cannot reach

(ii) Drains away, excess tissue fluid from extra-cellular spaces and pours back into the blood.

(iii) Absorbs and transports fats absorbed from small intestine (lacteals)

(iv) Collects nitrogenous waste

(v) Lymphocytes and antibodies present in lymph help in removing bacteria

(b) Differences between blood and lymph

Blood differs from lymph in a number of ways as shown in table 15.4

Table 15.4 Differences between Blood and Lymph

Blood	Lymph
1. Red in colour due to presence of haemoglobin	1. Colourless fluid
2. Flows rapidly	2. Flow is very slow
3. Contains RBC, WBC, Platelets and Plasma	3. Contains plasma and WBC
4. Route of blood flow Heart ↓ Arteries ↓ Capillaries ↓ Veins ↓ Heart	4. Route of lymph flow Tissue Spaces ↓ Lymph Capillaries ↓ Lymph Vessels ↓ Subclavian Vein ↓ Heart

The clear, colourless fluid that collects in a blister to provide protection to the underlying tissue is **lymph**.

The lymphatic system consists of a large number of **lymph ducts, lymph nodes and lymph vessels** (Fig. 15.6). It lacks a pumping mechanism. Fluid is pushed by muscle movement.

The lymph nodes are scattered throughout the body. They are more concentrated in the neck, armpits and groins

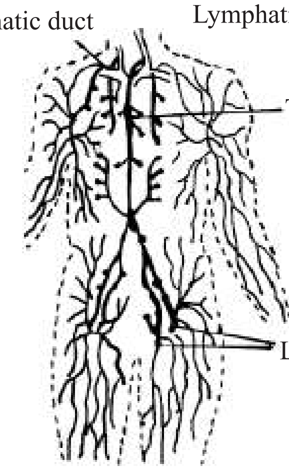


Fig. 15.6 Lymph vessels and lymph glands

Lymph nodes

Each node is a clump of tissue housing a number of lymphocytes. These nodes act as filters for bacteria, viral particles and cancerous cells. These resident lymphocytes then immediately attack the disease causing germs or pathogens.

The spleen and tonsils are lymphoid organs.

Spleen

It is the largest lymphoid organ and has the following functions

(i) Haemopoiesis – Formation of Blood cells in the foetus

(ii) Destruction of old and worn out blood cells and hence termed as 'grave yard' of RBC.

(iii) Blood reservoir

(iv) Defensive action by engulfing bacteria

15.5 IMMUNITY

The body's ability to resist or protect itself from the harmful effects of disease producing substance or organisms is called Immunity.

Any substance that causes production of antibodies in response of the body metabolism, is known as **antigen**. Antigen may be bacteria, viruses, or allergens (such as pollen grains) which cause allergy.

Antigens enable the body to protect itself with the help of antibodies produced by lymphocytes (WBC)

Immunity could be **natural or acquired**. Natural immunity is by birth. Acquired immunity develops during lifetime. It develops due to exposure to a disease or by vaccination.

Acquired immunity is of two types

(a) Active Immunity : Develops during exposure to disease causing germs. The body produces antibodies that remain in the blood to prevent further infection by that particular pathogen or disease causing organism. Vaccine containing weakened germs is administered to provide active immunity e.g DPT vaccine is given for developing immunity against diphtheria, pertusis (whooping cough) and tetanus and BCG vaccine is given for immunity against tuberculosis

People also develop immunity against chicken pox, small pox and measles after suffering from these diseases. This form of immunity is usually a life long immunity.

(b) Passive Immunity : This form of immunity is shortlived. It is developed by injecting readymade antibodies (collected from other animals). **Anti tetanus serum (ATS vaccine)** provides temporary immunity against tetanus.

A vaccine is a sample of an antigen, too small to cause a disease, but enough to produce antibodies. Vaccines have been developed for a number of diseases like polio, mumps, measles, tetanus, diphtheria, and cholera.

Cells Of Immune System

Lymphocytes are cells of the immune system. There are two major types of lymphocytes, T-cells and B-cells, both develop in the **Bone Marrow.**

T-Cells	B-Cells
1. Mature in thymus glands	Mature in lymphoid tissues like tonsils and appendix
2. T-cells identify antigens and destroy them	Recognise antigen with the help of surface receptors
3. Attack directly	Produce a large number of antibodies for attack
4. Life span is upto 3-4 years	Anitbodies are short lived

A person may lack T-cells or B-cells, or both. Such persons are highly prone to infections

Immuno Deficiency Disorders

Hereditary, congenital (by birth) or acquired defects in immune response are called **Immuno Deficiency Disorders.**

SCID and **AIDS** are two common examples of such disorders.

SCID (Severe Combined Immuno-Deficiency Syndrome) is caused due to the absence of both T-cells and B-cells. This defect is present from birth.

AIDS (Acquired Immuno Deficiency Syndrome) causes considerable reduction in T-cells and ultimate destruction of the Immune System. It is caused by HIV (Human Immuno Virus).

You should know

AIDS may be caused by

1. Sexual contact with a person infected with HIV
2. Blood transfusion from HIV infected person
3. Sharing of contaminated needles with HIV sufferers or Drug addicts
4. From infected mother to foetus through the placenta

15.6 DISORDERS RELATED TO BLOOD AND HEART

You must have heard of people suffering from high blood pressure. In these people, the blood pressure is more than the normal (120/75). The state of having high blood pressure is called **hypertension**. Hypertension is usually related to stress, overweight, age or faulty diet.

Other heart related disorders are **atherosclerosis** and **arteriosclerosis.** Sometimes, especially if too much of fatty food is taken over a long period, there is a tendency for fat to deposit on the inner wall of the arteries. Such a deposit is called **atheroma** and the disorder **atherosclerosis**. This narrows the lumen of the arteries supplying the heart and consequently interfere in the functioning of the heart.

Also with age the wall of the arteries harden and lose their flexibility. Further, there may be deposits on the inner side of the walls of the arteries supplying the heart.

This condition is **arteriosclerosis** and interferes with normal functioning of the heart. To remedy the situation, the lumen of the arteries of the heart have to be widened by placing a small piece of tube (stent). This is called **ballooning angioplasty**. Sometimes the artery may have to be replaced and this treatment is called 'heart by-pass'.

ECG

Electrocardiograph is a machine which can record the heartbeat like a graph which is called **eletrocardiogram (ECG)**. From the ECG, the doctor can make out which chamber of the heart is not contracting or relaxing properly and suggests treatment accordingly.

INTEXT QUESTIONS 15.3

1. Fill in the blanks :
   (i) The clear colourless liquid flowing out of the blood capillary walls is called ……………….
   (ii) Lymphatic system consists of ………………. lymph nodes and ……………….
   (iii) A number of ………………. are present in lymph nodes and attack bacteria
2. Give one example of lymphoid organ in your body ……………………………
3. Give **two** examples of Immuno Deficiency Syndrome ……………………………
4. Name the **two** kinds of lymphocytes of your immune system ……………….
5. Name **two** heart related disorders
   (i) .... (ii) ....

WHAT YOU HAVE LEARNT

- Circulatory system is of two kinds; closed and open type.
- Circulatory system consists of muscular pump (heart), tube like vessels (blood vessels) and circulating fluids (blood, lymph).
- Blood helps in transport of gases, collection of wastes, maintenance of body temperature and protection from diseases.
- Wave of contraction in the heart is conducted from S.A. node to A.V. node to bundle of HIS, to Purkinje fibers.

- Blood vessels are arteries, capillaries and veins
- Superior and inferior venae cavae bring deoxygenated blood to the heart. Pulmonary vein brings pure (oxygenated) blood to the aorta and aorta supplies it to the body.
- Production of blood is called haemopoiesis which takes place in the bone marrow
- Blood consists of plasma and cell components viz., RBC, WBC and Platelets
- In the A, B, O Blood group system, a person with blood group O is a universal donor and person with blood group AB is universal recipient.
- Rh factor is important in matching blood groups for transfusion as well as in the case of expectant mothers.
- Normal blood pressure for healthy person is 120 ± 5/75 ±5 mm of mercury and is measured by Sphygmomanometer.
- The colourless fluid moving out of capillary wall is called lymph
- Spleen and tonsils are examples of lymphoid organs and house lymphocytes (T-cells and B-cells)
- Body's ability to protect itself from harmful substances is called immunity
- Disorder of the immune system diminishes resistance to diseases. SCID is an immunodeficiency disorder from birth; AIDS is another one caused by HIV virus.

TERMINAL EXERCISES

1. Give one function of each of the following :
   (i) R.B.C.
   (ii) Platelets
   (iii) Plasma
2. With the help of a flow chart describe the steps involved in the coagulation of blood
3. Why is a person with blood group AB called universal recipient?
4. Differentiate between the systolic and diastolic pressures. What are the values of these pressures for a normal human adult?
5. Give **three** differences between lymph and blood.
6. What is immunity? Differentiate between active and passive immunity.
7. What are (i) hypertension and (ii) atherosclerosis?
8. What is an ECG and what is its function?

Notes

ANSWERS TO INTEXT QUESTIONS

15.1 1. Name the following
- (i) Prawn, insects etc
- (ii) Vertebrates like human, fish, birds

2. (i) Between left atrium and left ventricle
   (ii) Between right atrium and right ventricle
3. (i) Sino-atrial node (ii) capillaries (iii) pulmonary vein
4. Superior vena cava

15.2 1. (i) Haemopoiesis
   (ii) Ablumin, globulin and fibrinogen
   (iii) Platelets
2. (i) Blood transfusion
   (ii) Cell membrane of RBC; plasma
   (iii) Only from blood group O
   (iv) Sphygmomanometer, 120 ≠ 5 / 75 ± 5 mercury

15.3 1. (i) Lymph
   (ii) Lymph ducts and lymph vessels
   (iii) Lymphocytes
2. Spleen or tonsils
3. SCID and AIDS
4. T-cells, B-cells
5. Hypertension, atherosclerosis, arteriosclerosis (any 2)

16

LOCOMOTION AND MOVEMENT

Movement is the temporary or permanent displacement of a body or its parts from its original position. Living beings and parts thereof move in response to stimulus from outside or from within the body. Locomotion, on the other hand, is the displacement of the entire body from one place to another. It is a characteristic feature of all animals, Protoctista and zoospores and zoogametes of lower plants.

OBJECTIVES

After studying this lesson, the learner will be able to

- assert that movement is an important feature of all living beings.
- emphasize that locomotion is a characteristic of the Protoctista, gametes and spores of some lower plants, and animals.
- differentiate between movement and locomotion with the help of examples.
- explain the functions of cilia and flagella as organelles for movement and locomotion in Protoctista and animals.
- recognise skeleton and muscles as organs which help in locomotion in animals.
- describe the structure and working of muscles.
- describe the types of contractile proteins and their role in muscle contraction.
- explain the mechanism of muscle contraction.
- provide an outline of human skeletal system and mention functions of its parts.
- give a brief account of disorders related to muscular and skeletal systems such as Myaesthenia Gravis, Tetany, Muscular Dystrophy, Arthritis, Osteoporosis and Gout.

16.1 MOVEMENT AND LOCOMOTION

Consider the following examples

(i) Your arm stretches to pick up an apple or flexes to scratch the face.

(ii) Your tongue is in motion when you sing, the dog wags its tail, the frog's tongue is shot out to catch insects.

(iii) The gill cover of the fish flips up and down to draw in a current of water.

(iv) Cytoplasm streams within cells

The above examples signify movement, not locomotion. In locomotion, the entire body of an animal or a protozoan or an alga moves away from its original position. In the unicellular organisms like bacteria and Protoctists specific organelles like flagella and cilia cause locomotion. Recall the microscopic structure of these organelles from lesson 4 of your text book entitled Cell Structure and Function. Sperms, the male gametes have a flagellar tail by which they move about. Among the multicelled animals, molluscs locomote with a muscular foot and the starfish with the help of tube feet. Birds fly using muscles and other animals use muscles to walk or run.

INTEXT QUESTIONS

What would you call the following as – movement (M) or locomotion (L) ?

- The elephant uses its trunks to pick up sticks ( )
- The cow uses its tail to drive away flies ( )
- A mouse runs into a hole. ( )
- The bees leave their hive in search of pollen ( )
- Johan kicks the football into the goal ( )
- The cat jumps on to the window ( )

16.2 TYPES OF MOVEMENTS FOR LOCOMOTION

16.2.1 Ciliary Movements

Cilia are minute hair like processes which are motile and extend from cell surfaces. In smaller organisms like the ciliate protozoa, cilia help in locomotion from one place to another. In animals, the cilia help to propel fluids and materials.

Cilia beat in a pattern which is different from that of the flagellum although their internal structure is the same. Ciliary beat begins with fast stroke ahead in one direction called effective stroke and then it bends back and returns to its original position. This second stroke is called recovery stroke. (Fig 15a.1a & b). During ciliary beat, water is propelled parallel to ciliated surface.

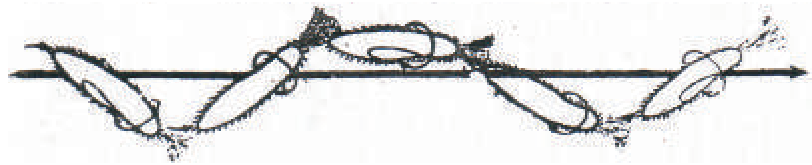


Fig. 16.1(a) Locomotion in *Paramecium*. Solid line represents the general direction;

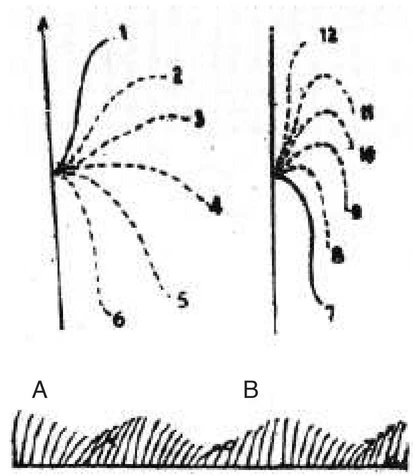


Fig. 16.1(b) A – Effective stroke of a cilium, B – Recovery stroke of a cilium, C – Metachronous wavy movement of a row of cilia.

16.2.2 Flagellar movement

A flagellum is a long, whip like structure. While cilia cover the entire surface, flagellum is mostly present singly or in a small number at one end of a cell. Flagella occur in flagellate protozoan like *Euglena* or an alga like *Chlamydomonas* and in animal sperms. A flagellum beats symmetrically in a snake like manner and propels the water parallel to long axis of flagellum. See figure of flagellum of *Euglena* and *Chlamydomonas* in Module 1, lesson 2, unit 2.2.2 of your text book.

INTEXT QUESTIONS

1. State the similarity in internal structure between a cilium and a flagellum as learnt in lesson 4 of your text book?
2. What is an effective stroke ? Which stroke is called the recovery stroke as depicted during ciliary movement ?
3. State the difference between flagella and cilia with regard to location and number.

16.3 MUSCULAR MOVEMENT IN ANIMALS

16.3.1 Structure of muscle

You have already learnt about muscular tissue in lesson 5, Module 1, unit 5.3.3. Go back to the lesson and revise the structure of striated muscle fibres. Stuated muscles are also called skeletal muscles as they are attached to bones and are responsible for movements of the limbs.

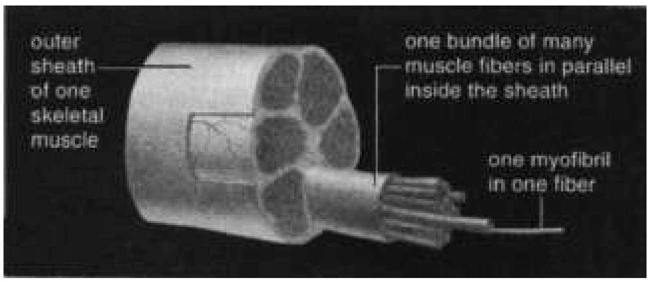


Fig. 16.2 The skeletal muscle

Striated muscle fibres are packed into bundles enclosed in a tough connective tissue. These bundles are grouped to form a muscle. Every skeletal muscle is also enclosed in a thin connective tissue as shown in the above figure.

The ends of muscles connect to bones through another kind of connective tissue called **tendon**. So, tendon joins a bone to a muscle.

16.3.2 Myofilaments

The muscle cell, also called muscle fibre because of its long shape, is multinucleated and contains myofibrils made of myofilaments. Myofilaments are proteins which are of two types:

(i) thick filaments made of myosin protein and

(ii) thin filaments made of actin protein.

Myosin and actin proteins are contractile proteins and responsible for muscular contraction.

The functional unit of the myofibril is called sarcomere. It lies between two successive dense linear structure called Z lines.

The thin filaments also contain two other proteins, tropomyosin and troponin Troponin is the switch, which in the presence of calcium ions controls muscle contraction.

Study the figure below to understand the structure of myofilaments:

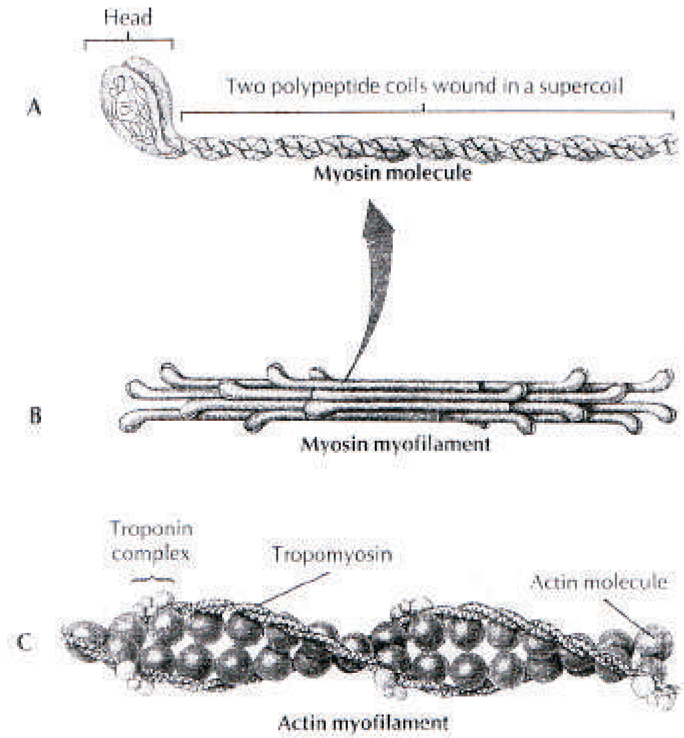


Fig. 16.3 Molecular structure of thick and thin myofilaments of a skeletal muscle. A. the myosin molecule is with coiled expanded ends forming a globular head. B. The thick myofilament is composed of a bundle of myosin molecules with their globular heads extended outward. C. The thin myofilament consists of a double strand of actin surrounded by two tropomysoin strands. A globular protein complex, troponin, occurs in pairs on actin.

16.3.3 The sliding model of muscle contraction

Striated muscle contraction is explained by **Sliding Filament Theory**. This theory can be explained through the following steps:

(i) The thick and thin filaments myosin and actin are linked by crossbridges of troponin and tropomyosin.

(ii) These crossbridges, on contraction, pull the thin filaments back over thick filaments.

(iii) As a result, the thin filaments slide over the thick filaments. Calcium and ATP are required for attaching and releasing Troponin.

(iv) Because of this sliding action, Z lines come closer (Fig 16.4) and sarcomere shortens.

(v) All sarcomeres shorten together so the entire muscle contracts.

(vi) The muscle relaxes when crossbridges relax and sarcomere regains original position.

See figure given below

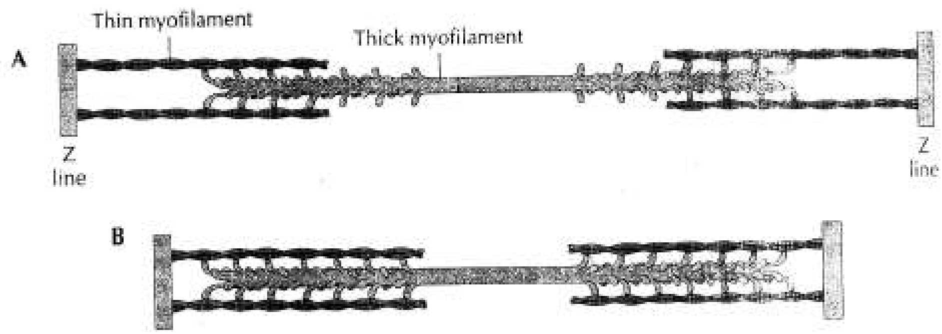


Fig. 16.4 Sliding myofilament model, showing how thick and thin myofilaments interact during contraction, A. Muscle relaxed. B. Muscle contracted.

Stimulation of muscle contraction

Muscles cannot contract on their own unless stimulated by a nerve. The nerve branches on a muscle and this area of the muscle fibre is called **myoneural junction** (myo: muscle; neuro: nerve).

Summary of events of muscle contraction

Impulse at nerve ending of muscle fibre
|
Muscle fibre stimulated
|
Ca^{++} released from muscle fibre
|
Binding sites of actin filaments released
|
ATP releases energy → Crossbridges flex & reattach to new sites
|
Actin & Myosin slide over each other
|
Muscle cells shorten
|
As a result the muscle contracts

INTEXT QUESTION 16.3

1. Name the structure that connects (i) a bone to another bone (ii) muscle to bone. Which type of tissue are these ?
2. Why is the muscle cell also called muscle fibre ?
3. Why is the mechanism of muscle contraction called 'sliding movement'?
4. What is the chemical composition of myofilaments.
5. In a muscle, where can you find the following ? myofilaments, muscle fibres.

16.3.4 Energy for muscle contraction

The biological energy, ATP or Adenosine triphosphate is required for muscle contraction. Muscle also has a reservoir of high energy phosphate called creatine phosphate which can be converted to ATP.

16.4 THE SKELETAL SYSTEM

16.4.1 The types of skeleton.

Skeleton supports the body, gives rigidity to body, provides surface for attachment of muscles, and protects soft internal organs like the brain, heart, lungs etc.

In the vertebrates, skeleton is made of bone and cartilage about which you have studied in the lesson on tissues. It is located inside the body and hence termed endoskeleton. Another rigid skeleton is the exoskeleton in the form of hard, calcareous shells in molluscs and the covering of chitin (a carbohydrate) in insects and other arthropods. Many invertebrates, such as the earthworm use their muscles, which are not attached to any rigid skeletal elements, by contracting against fluid in their body cavity. Coelomic (Coelom = body cavity) fluid within limited space acts as skeleton for muscle movement and is hence termed hydrostatic skeleton.

16.4.2 The human skeleton

The human skeleton is divided into following parts:

- Human Skeleton
  - Axial Skeleton
    - Skull and jaws
    - Vertebral column
  - Appendicular Skeleton
    - Girdles
      - Pectoral
      - Pelvic
    - Limbs
      - Arms
      - Legs

See the figure given below and locate the rib cage, the skull and the girdles.

16.5 MUSCULAR AND SKELETAL DISORDERS

You have all seen some people who are wheel chair bound. They are unable to move on their own. You have just learnt that muscle contracts only when stimulated by nerves. If nerve supply to muscle get severed, muscle gradually weakens or **atrophies**.

The old may limp because of calcium deficiency or deficiency of vitamin D_3 which is responsible for calcium absorption.

Injury to limb or girdle bones also hamper locomotion. But, these apart, some muscular and skeletal disorders are **hereditary** e.g. **Myaesthenia gravis** and **Muscular dystrophy**. **Arthritis** and **Rheumatoid arthritis** may or may not be hereditary. **Osteoporosis** and **Gout** are due to nutritional deficiency and **metabolic errors**. Let us learn a little about them.

Myaesthenia gravis is because of a gene on X chromosome and so is hereditary. The muscles slowly waste away and the patient gradually becomes immobile and in the last stages even the jaw muscles do not work and patient is unable to eat.

Muscular dystrophy is an autosomal dominant disorder. In this hereditary disorder, muscles waste away and person becomes immobile.

Arthritis and Rheumatoid arthritis are disorders of bones especially joints. There is constant joint pain in Rheumatoid arthritis which is a crippling disease. Hands and feet become crooked due to inflammation in the joints.

Osteoporosis is the softening of bones due to calcium deficiency. You know that calcium absorption is dependent on availability of Vitamin D. So it is important to expose oneself to the sun every day for atleast half an hour. You have aleady learnt that sunlight helps to generate Vitamin D. Women, post menopause are prone to osteoporosis. Estrogen, the female hormone mobilises calcium and sends it to bones. In the absence of estrogen, bones tend to crack and break.

Gout results in painful inflammation of joints due to elevated level of uric acid in blood. Uric acid is a product of protein metabolism. Gout can be cured.

INTEXT QUESTION 16.4

1. Name an animal with endoskeleton and one with exoskeleton.
2. Name main parts of skeleton and mention their functions.
3. Name any two disorders of the musculo–skeletal system which are hereditary.

4. What causes osteoporesis and gout ?
5. Which limbs are supported by which girdles and which kind of muscles are attached to the limb skeleton ?

16.6 MOVEMENTS IN PLANTS

Plants are rooted to the soil, hence they are unable to undertake locomotion. But plants show movements in response to external stimuli like light, water, gravity, called TROPIC MOVEMENTS. When a plant part, such as the root or stem, move towards the source of stimulus, it is termed positively tropic e.g. shoot moves and grows towards sunlight, it is positively phototropic. Root moves away from light, it is negatively phototropic. Similarly there are movements in response to stimuli which are given in the table below.

Stimulus	**Term for Response**
Touch/Contact	Thigmotropism
Gravity	Geotropism
Water	Hydrotropism

In tropic movements, plants are fixed but their parts e.g. a branch or a flower move in the direction of stimulus. Turgor movements are due to difference in water potential in different parts of plant. Examples are given below

- Leaf closes in the insectivorous plant Venus fly trap when an insect enters.
- *Mimosa pudica* called 'chhui mui ' in Hindi, droops when touched.
- Guard cells cause opening and closing of stomata due to changes in tugor pressure.

NASTIC MOVEMENTS are induced by certain stimuli like contact, change in day length, temperature etc. Unlike tropic movements in nastic movements the plant parts do not move in the direction of stimulus e.g. flowers of *Portulaca*, bloom in the day. But when light fails at sunset, the petals close in response to darkness and lowered temperature. In other words, direction of movement of an organ is fixed but the stimulus may come from any direction.

WHAT YOU HAVE LEARNT

- Movement is an important feature of all living beings and locomotion is characteristic of protoctista and animalia.
- While in movement, an organ or organelle may shift from its original position and come back to it, in locomotion, the entire body of the animal or the protoctist moves away and is displaced from its original location
- Ciliate protozoa or alga carry out locomotion by means of cilia, organelles made of microtubules. Ciliary beating begins with fast stroke and ends in a recovery stroke.
- Flagellum is long and whip like organelle made of microtubules. While cilia are many, flagella may be one or two.
- Muscles and bones help the vertebrates to locomote from one place to another, muscles are joined to bone by ligaments and one muscle is joined to the other by a tendon.
- Muscles are a tissue made of muscle cells, also called muscle fibres. Muscle fibres are made of thick and thin myofilaments made of myosin and actin protein molecules respectively.
- Muscles contract and relax to cause movement. Muscle contraction is explained by sliding filament theory of muscle contraction.
- Ca and ATP are required for muscle contraction.
- Vertebrate skeleton is made of bone and cartilage
- Axial skeleton is made of skull and vertebral column and appendicular skeleton is made of girdles and limbs.
- Hereditary muscular and skeletal disorders are myaesthenia gravis and muscular dystrophy. Arthitis and Rheumatism are bone disorders. Osteoporosis to softening is the bones due to Ca and Vitamin D deficiency. Gout results from increase in level of uric acid in blood.

  Plant movements may be tropic movements or nastic movements.
- Movement is a characteristic of living beings. It means a temporary or permanent displacements of the body or its parts.
- Locomotion is the displacement of the entire body from one place to another. It is a characteristic of protoctists and animals.
- Cilia and flagella are organslles which help in movement. Ciliary protozoa Locomote with the help of cilia. Human sperms, certain algae like *Chlamydomonas* move from one place to another with the help of flagella.

- Cilia are many and move together causing a wavy motion. Flagella may be one or two and with whip like strokes help in Locomotion.
- Most animals carry out Locomotion with the help of muscles.
- Muscles are made of muscle fibres. Muscle fibres have protein filaments called myofilaments.
- Actin and myosin filaments in a muscle fibre (muscle cell) slide over each other to cause Locomotion.
- Hence the muscle is said to contract through sliding of these two kinds of myofilaments and this is termed sliding model of muscle contraction.
- Apart from actin and myosin protein molecules, two other protein molecules named Troponin and Tropomyosin participate in muscle movement.
- The unit of contraction is termed a sarcomere and it contains both the myofilaments which slide between Z lines.
- Nerve impulse stimulates muscle movement.
- Human skeleton is divided into axial skeleton which includes skull and vertebral column and appendicular skeleton comprised of bones of girdles and limbs.
- Bones are connective tissues made of ossein and cartilage which are also part of human skeleton. Bones are joined to each other by ligaments & to muscles by tendons.
- Muscular & Skeletal disorders include Muscular dystrophy, arthritis, Myaesthenia graive, Osteoporosis and gout.

TERMINAL EXERCISES

1. Distinguish between the following pairs of terms:
   (i) movement and locomotion
   (ii) thick and thin myofilaments
   (iii) tendon and ligament
   (iv) cilia and flagella
   (v) tropic and nastic movement
2. Enlist the steps in muscle contraction as explained by sliding filament theory.
3. How does *Paramecium* swim in water?
4. Answer in one word or sentence

(i) What is the shape of actin molecule?

(ii) What is the chemical nature of troponin and tropomyosin?

(iii) What is meant by recovery stroke of cilia?

(iv) Give an example each of geotropism and phototropism.

(v) Why do we say that vertebrate muscle contraction is energy dependent?

ANSWER TO INTEXT QUESTIONS

16.1

M, M, L, L, M, L

16.2

1. Both made of microtubules arranged in a similar manner.
2. Fast stroke – cilium beats to move ahead

   Recovery stroke – cilium bends back to original position
3. Location – cilia all over body, flagella at anterior or posterior end

   Number – cilia many, flagella 1 or 2

16.3

1. Ligament; tendon; connective tissue
2. because of its elongated structure
3. because thick and thin myofilaments slide over each other to cause muscle contraction.
4. Protein
5. myofilaments in muscle fibre

   muscle fibres in muscle tissue

16.4

1. any vertebrate named

   any insect/mollusc named
2. axial, appendicular

   support, protection to interanl organs; locomotion and movement; blood cells manufactured in bone marrow gives shape to body

3. Myaesthenia gravis; muscular dystrophy
4. Osteoporosis – lack of Ca

   Gout – High level of uric acid in blood
5. Pectoral – fore limbs; Pelvic – hind limb; Striped or striated

17

COORDINATION AND CONTROL : THE NERVOUS AND ENDOCRINE SYSTEMS

Every organism performs movements and a number of other tasks for its survival. Besides, several other actions are continuously occurring inside the body that need to be properly timed and coordinated. All this is the outcome of two organ systems – the nervous and the endocrine (hormonal) systems.

OBJECTIVES

After completing this lesson, you will be able to :

- *describe the functions of the nervous system and list its subdivisions;*
- *list, draw and label the major parts of the human brain and spinal cord and explain their functions;*
- *describe the nervous system of cockroach*
- *explain the structure of a neuron, a nerve and describe the conduction of impulse through a nerve fibre and across the synapse;*
- *define reflex action and draw the components of the reflex arc;*
- *list various sensory receptors in human body and describe the structure and functioning of the sense organs–eye, ear, nose, tongue and skin;*
- *distinguish between exocrine and endocrine glands;*
- *list various endocrine glands and locate their position in human body;*
- *identify properties of hormones and mention their nature and manner of functioning;*
- *differentiate between hormones and pheromones;*
- *name the various hormones secreted by pituitary, thyroid, parathyroid, thymus, adrenals, pancreas and reproductive organs in humans and mention their functions;*
- *relate the hormonal imbalance with hormone related disorders in humans;*
- *state the effects of over functioning (hyperactivity) and hypoactivity (underfunctioning) of pituitary and thyroid;*
- *explain the feedback mechanism of hormonal control.*

17.1 FUNCTIONS OF THE NERVOUS SYSTEM

The major functions of the nervous system in humans are as follows:

(i) It keeps us informed about the outside world through the sense organs.

(ii) It enables us to remember, think and to reason out.

(iii) It controls all voluntary muscular activities like running, speaking etc.

(iv) It regulates several involuntary activities such as breathing, beating of the heart, movement of food through the food canal, etc.

Thus, the nervous system makes our body parts work together in proper coordination, as one single integrated unit.

Some basic terms

Before you learn about the various aspects of the nervous system, get familiar with the following related terms.

Stimulus : an agent or a sudden change of the external or the internal environment that results in a change in the activities of the organism.

Impulse : a wave of electrical disturbance that travels accross the nerve cell and its fibre.

Response : a change in the activity of the organism caused due to stimulus.

Receptors : The nerve cells which on receiving the stimulus, set up wave of impulses towards the central nervous system (brain and spinal cord).

Effectors : muscles or glands, which on receiving the impulse from the brain or spinal cord contract or secrete substances.

Nerve : A bundle of axons (nerve fibres) of separate neurons connecting the central nervous system with other parts of the body.

Sensory (afferent) nerve or the cell : bringing the impulse from the receptor (sensory organ) to the main nervous system.

Motor (efferent) nerve or the cell : Carrying the impulse from the main nervous system towards a muscle or a gland.

17.1.1 Nervous System in Animals

Various activities of an animal's body are controlled and coordinated through two systems viz. the nervous system and the endocrine system. We will discuss the nervous system of cockroach here. A detailed account of the nervous system in humans is given in your text book lesson 16: module 2: Book l. Recall that the nervous system basically consists of two parts:

(i) Central nervous system

(ii) Peripheral nervous system

The nervous system of cockroach also follows the same basic plan and consists of:

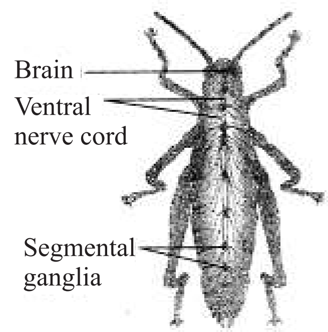
(i) Central nervous system

(ii) Peripheral nervous system

(iii) Sympathetic or visceral nervous system

Central Nervous System

It consists of **brain** or **supra-oesophageal ganglion** that lies above the oesophagus in the head. A **sub-oesophageal ganglion** lies below the oesophagus and is formed. The brain gives off a pair of short and stout **circumoesophageal connectives** that meet the sub-oesophageal ganglion. A double ventral **nerve cord** extends from the sub-oesophageal ganglion. It bears three thoracic and six abdominal ganglia (See figure below).



Nervous System of Cockroach

Peripheral Nervous System

It consists of nerves which are given off from the ganglia so as to innervate all the parts of the body (See the figure).

Sympathetic Nervous System

It consists of frontal ganglion and a visceral ganglion. Various nerves are given are given off from the visceral ganglion.

(a) **Central Nervous System (CNS),** consisting of brain and spinal cord. It is the site of information processing (receiving information and responding to it).

(b) **Peripheral Nervous System (PNS),** consisting of all the nerves entering and leaving the brain and the spinal cord.

Further division of these two components is shown in Fig. 17.1.

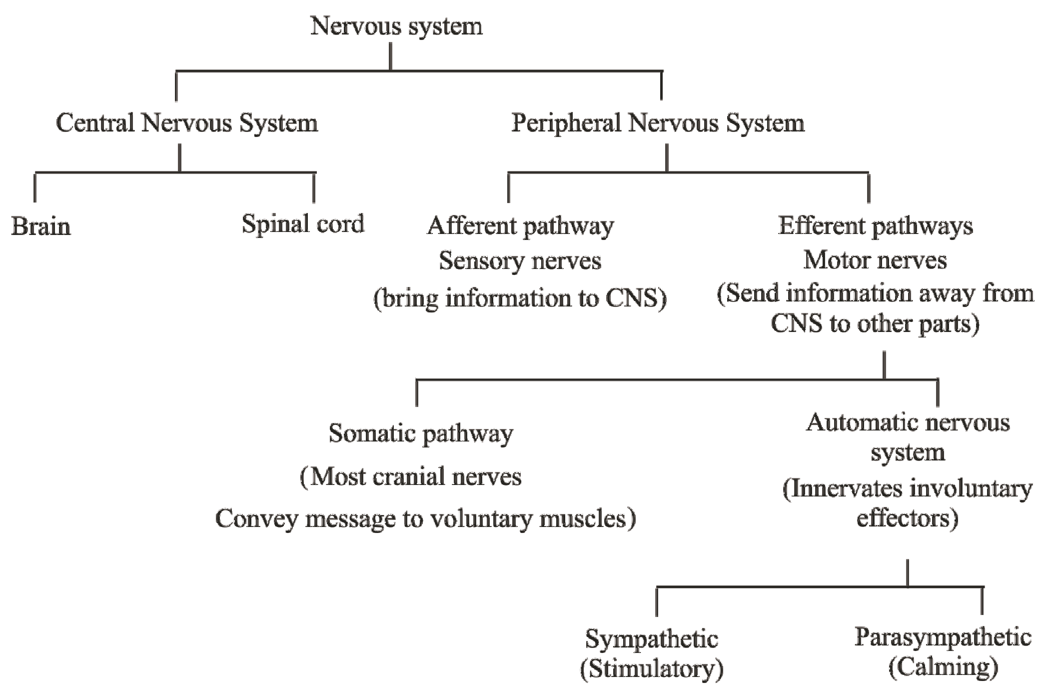


Fig 17.1 The basic components of nervous system

17.4 NERVOUS SYSTEM OF HUMANS

The central nervous system of humans includes a highly developed brains and spiral card (Fig. 17.1). Peripheral Nervous system is made of nervous as shown in Fig. 17.1.

17.4.1 The Brain

The brain is a very delicate organ lodged inside the cranium of the skull (Fig.17.2a) It is protected by three coverings, the **meninges** (meninx: membrane): an outer tough **duramater** (dura: tough; mater: mother), a thin delicate web-like middle **arachnoid** (arachne: spider), and the innermost highly vascular **piamater** (pia: tender) richly supplied with blood vessels. The space between the membranes is filled with a fluid called **cerebrospinal fluid**. There are cavities inside the brain, which are also filled with the same fluid.

The brain consists of three main regions:

(i) ***forebrain*** consisting of cerebrum and diencephalon,

(ii) ***midbrain*** a small tubular part between the fore and the hindbrain,

(iii) ***hindbrain*** consists of cerebellum, pons, and medulla oblongata.

The individual parts of the brain are described below:

(a) **Cerebrum.** This is the largest part of the brain, divided into two (the right and the left) parts called **cerebral hemispheres**. Their outer surface is highly convoluted with ridges and grooves. Each hemisphere is hollow internally and the walls have two (an inner and an outer) regions. The outer region (cerebral cortex) contains cell bodies of the nerve cells and being grayish in colour it is called ***gray matter***. The inner region is composed of whitish axon fibres and is called the ***white matte***r. **Corpus callosum** is a sheet of cris-cross nerve fibres connecting the two cerebral hemispheres (Fig. 17.2b). Left side of the cerebrum controls the right side of the body and vice-versa.

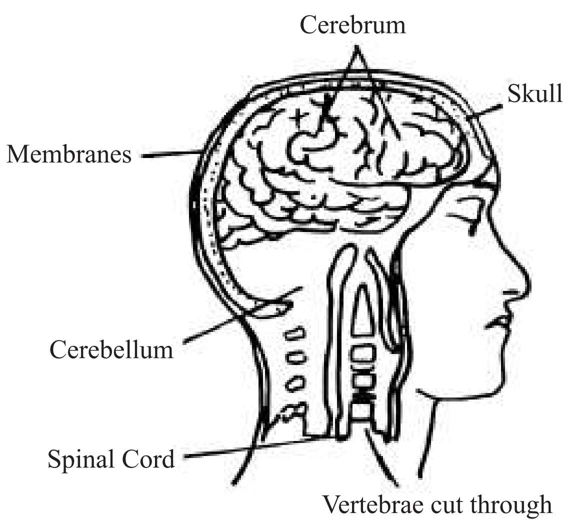


Fig. 17.2 (a) Brain lodged inside cranium

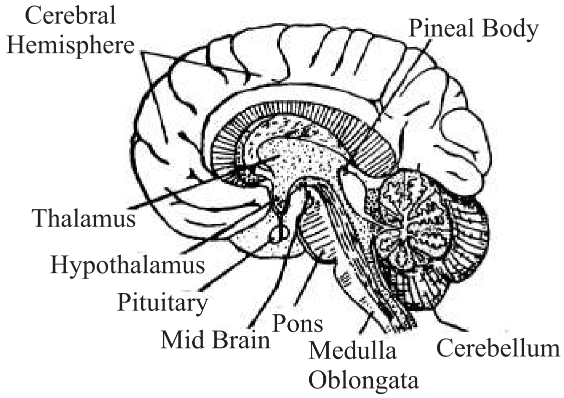


Fig. 17.2 (b) brain in median section.

The **cerebral cortex** has three main functions:

(i) It controls and initiates voluntary muscle contractions.

(ii) It receives and processes information form the sense organs, like eyes, ear, nose etc.

(iii) It carries out mental activities of thinking, reasoning, planning, memorizing etc.

(b) **Diencephalon.** This is the part of the forebrain lying below the cerebrum. It consists of the following two parts;

1. **Thalamus.** This is an egg shaped mass of gray matter, located in the centre below the cerebrum. It is the relay centre for sensory impulses (e.g. pain and pleasure) going to the cerebrum.

2. **Hypothalamus.** This is a region of the brain located below thalamus. It controls motivated behavior such as eating, drinking and sex. It controls the secretions of pituitary gland hanging below it. It also serves as the regulation centre of body temperature and body fluids (see lesson 17).

(c) **Cerebellum.** The cerebellum is a smaller region of the brain located at the base and under the cerebrum. It has numerous furrows. It also has a cortex of gray matter. Its two main functions are.

(i) to maintain the balance of the body, and

(ii) to coordinate muscular activities.

(d) **Medulla oblongata.** This is the last part of the brain, which is connected to the spinal cord. Its functions are as follows:

(i) It is the cente for breathing, coughing, swallowing, etc.

(ii) It controls heartbeat, the movement of alimentary canal and many other involuntary actions.

In all, **12 pairs of nerves** (cranial nerves) come out of the brain, some of these are sensory, some motor and some are of mixed type.

17.4.2 The Spinal cord

The spinal cord extends form the medulla of the brain downward almost the whole length of the backbone. It is also wrapped in the same three meninges as the brain and the space between them contains the same cerebrospinal fluid. The arrangement of the white and gray mater is reversed in it i.e. white matter is outside and the gray matter inside.

Fig. 17.6 shows the general structure of the spinal cord as seen in its cross section. It also shows the manner in which the spinal nerves originate from it.

Functions of spinal cord.

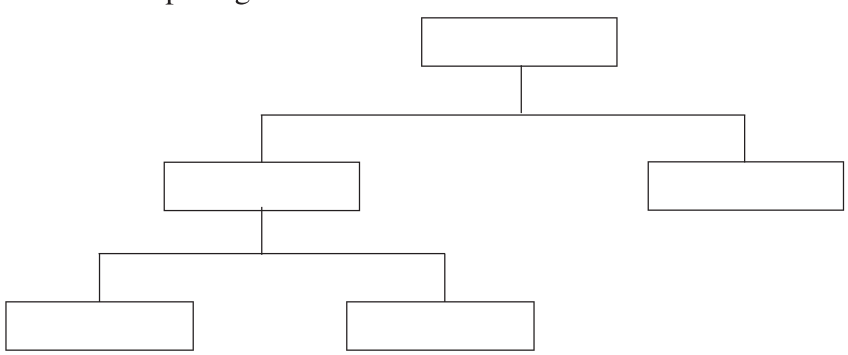
(i) Carry out reflexes below the neck,

(ii) Conducts sensory impulses from the skin and muscles to the brain,

(iii) Conducts motor responses from the brain to the trunk and limbs.

INTEXT QUESTIONS 17.1

1. With the help of a flow chart write down the basic components of the nervous system in the space given below.



2. Name the ganglia which
   (a) forms the brain
   (b) lies below the oesophagus and is joined to brain.
3. Which part of nervous system of cockroach can be compared to our spinal cord though our spinal cord is dorsal and this part of nervous system of cockroach is ventral?

4. Name the main parts of the brain.

   ....

5. Mention the one functions each of :

   (i) Cerebrum ....

   (ii) Cerebellum ....

   (iii) Medulla oblongata ....

   (iv) Hypothalamus ....

6. What are the

   (i) gray matter, and ....

   (ii) white matter made of? ....

7. Name the fluid in the cavities of the brain.

   ....

17.4 PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system consists of all nerves arising from the brain and the spinal cord. Overall, it consists of two kinds of pathways: the afferent (receiving) sensory pathways and efferent (carrying aways) motor pathways.

A. The **afferent (receiving/sensory) pathways** are included in two kinds of nerves.

- Purely sensory nerves, for example the cranial nerves received from the eyes, ears, nose, etc.
- Mixed cranial nerves like the fifth (facial nerve) which contains sensory fibres bringing sensations from the face but it also contains motor fibres which carry impulses away to the jaw muscles.

B. The **efferent (sending) pathway** may be subdivided into somatic and autonomic nervous systems.

(i) **The somatic nervous system** controls the voluntary muscles. It includes most **cranial nerves** as well as the motor nerve fibres of the **spinal nerves**. Both these convey message from the CNS to the **voluntary muscles**.

(ii) **Autonomic nervous system** (ANS). This innervates the involuntary muscles and the glands. It consists of a pair of chains of ganglia and nerves on either sides of the backbone (Fig. 17.3) This system is essentially a motor system, which regulates the involuntary actions of the internal organs. It consists of two parts: (a) Sympathetic nervous system and (b) parasympathetic nervous system. (Fig. 17.3).

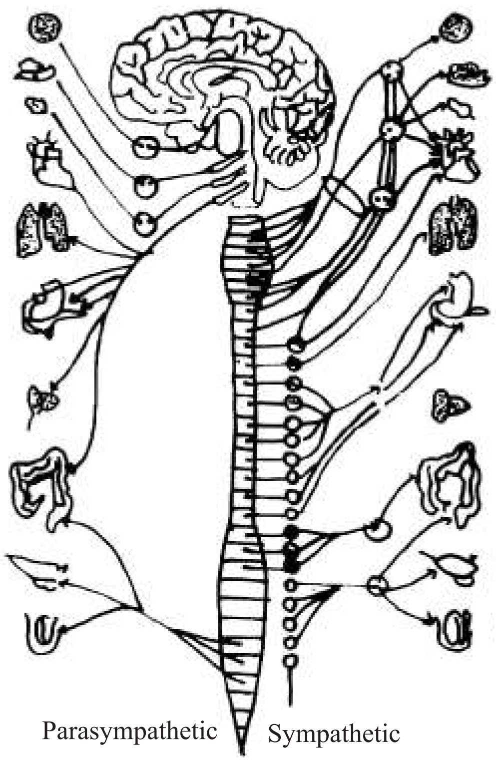


Fig. 17.3 Autonomic nervous system - sympathetic and parasympathetic

Sympathetic nervous system prepares the body for facing emergency situations and the **parasympathetic nervous system** reestablishes the normal conditions once the emergency is over.

The opposite effects of the two subdivisions of the autonomic nervous system on the different organs are listed below in the table 17.1.

Table 17.1 Effects of autonomic nervous system

Organ	Effect of Sympathetic Activity	Effect of Parasympathetic activity
1. Eye pupil	Dilated	Constricted
2. Heart beat	Speeded up	Slowed down
3. Blood vessels		
a. on skin	Constricted	Dilated
b. on muscles	Dilated	No effect
4. Bronchioles	Dilated	Constricted
5. Urinary bladder	Muscles relaxed	Muscles contract (feeling of urination)
	Sphincter contracted	Sphincter relaxed
6. Sweat secretion	Increased	No effect

7. Blood sugar	Increased	No effect
8. Salivary secretion	Stops	Increased
9. Tear glands	Activated	Slowed down
10. Erector muscles of skin hair	Stimulated (hair raised)	Relaxed (hair flattened)
11. Adrenal glands	Increased secretion of Adrenalin	No effect
12. Intestine	Peristalsis decreased	Peristalsis increased
13. Stomach glands	Decreased secretion	Increased secretion

The autonomic nervous system is strongly influenced by emotions such as grief, anger, fear, sexual stimulation, etc.

INTEXT QUESTIONS 17.2

1. What are the two subdivisions of the autonomic nervous system?

   ....

2. Name the specific subdivisions of the autonomic nervous system concerned with the following:

   (i) Slowing down heart beat ....

   (ii) Increasing salivary secretion ....

   (iii) Dilatation of the pupil ....

   (iv) Increasing intestinal peristalsis ....

   (v) Muscle contraction of the urinary bladder giving the feeling the need for urination. ....

3. Why is the peripheral nervous system called so?

   ....

4. State the alternative terms for sensory and motor nerves.

   ....

17.5 NEURON – THE STRUCTURAL AND FUNCTIONAL UNIT OF NERVOUS SYSTEM (FIG. 17.4)

You have already studied about the nerve cell. This is to refresh your memory for relating the structure of the neuron with the conduction of nerve impulse.

- The **cell body** contains nucleus and cell organelles in the cytoplasm.

- **Dendrites** (short branching processes) extend out from the cell body. They bring signals (impulses) from the receptor or from the axon endings of another neuron. There may be as many as 200 dendrites in a single neuron allowing as many connections with the axon endings of other neurons.
- A long **nerve fibre or axon** carries the impulse from the cell body towards its terminal branches which may either pass on the impulse to another neuron, or into a muscle or gland to bring about the required action. Synapse is the point of communication between one nerve cell and another or between nerve cell and a muscle.
- A sheath of fatty material (myelin) often covers the axon, and such nerve fibres are called medullated or myelinated fibres.

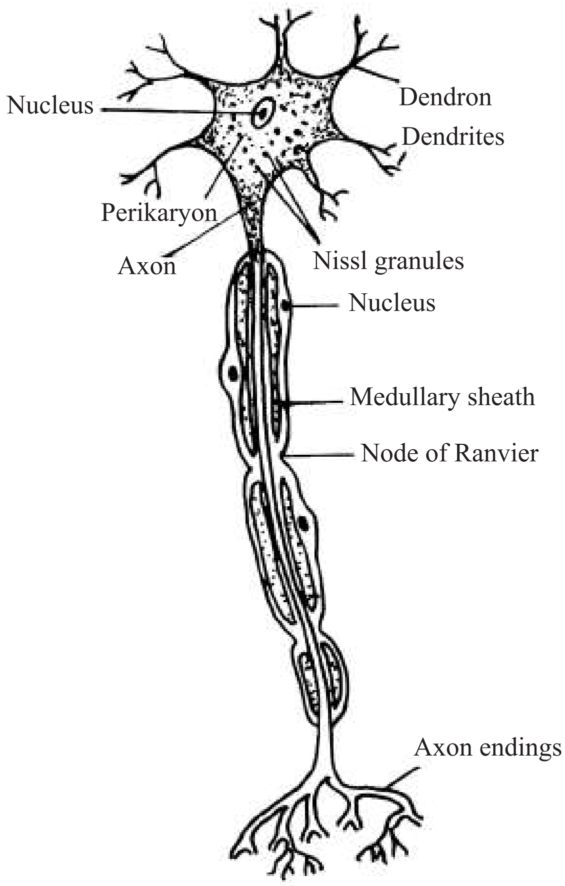


Fig. 17.4 The nerve cell

17.6 CONDUCTION OF NERVE IMPULSE ALONG THE NEURON AND OVER THE SYNAPSE

The conduction of nerve impulse through the nerve fibre is electrical in nature and the one through the synapse is chemical in nature.

A. Along the neuron–Electrical Signalling

The transmission (moving from one end to another) of the nerve impulse through the nerve fibre is electrochemical. It is not simply a flow of electrons through an electric wire but it travels as a wave of **depolarization** (Fig. 17.5). Read the following to understand depolasis atom.

In normal resting condition the outside of the nerve fibre carries positive (+) charge. In this condition nerve fibre is said to be polarized. The polarization is due to the presence of more Na^+ ions outside the cell membrane. Such state is maintained due to the sodium ions being continuously pumped out by means of the **sodium potassium pump** and operated by **active transport** using ATP for energy.

> **Sodium potassium pump** is a carrier protein on the plasma membrane which transports sodium and potassium ions across the membrane. Normally ions move from the region of their high concentration to the region of their low concentration.

The changes when a stimulus arrives at the nerve fibre are as follows:

- The axon membrane at that spot becomes more permeable to Na^+ ions, which move inward and bring about **depolarization** or localised change of charge from positive to negative (see diagram) on that spot.
- This point of depolarization itself becomes the stimulus for the adjoining area of the membrane, which in turn becomes depolarized.
- Meanwhile the previous area becomes repolarized due to active movement of the sodium ions to the outside of the membrane by means of what is called 'sodium pump'.
- And now the fibre is ready for the next wave of depolarization.

Thus a nerve impulse is a self- propagating wave of depolarization and repolarization

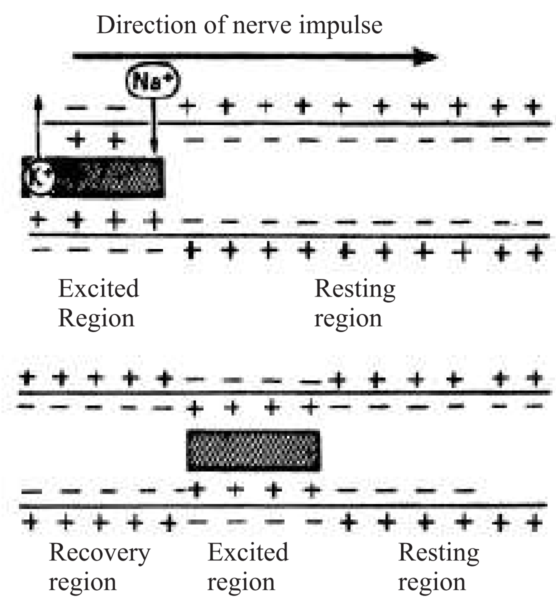


Fig. 17.5 Conduction of nerve impulse.

B. Over the Synapse – Chemical Signalling

The impulse travelling through a nerve fibre may reach either its destination. (muscle or gland) for action or the dendrites of another neuron for further transmission. The meeting place is called **synapse**. The transmission over a synapse is a chemical process. As the impulse reaches the terminal end of the axon, the following events occur :

– a chemical acetylcholine is released by the end of the axon.

– acetylcholine stimulates the next neuron to start the new impulse.

– acteylcholine is soon broken down there to make the synapse ready for the next transmission.

In case the axon endings are branched and in contact with the dendrites of other neurons the impulse will travel through all of them.

'**All or none**' **principle.** If the stimulus is strong enough (with a minimum threshold) to produce the impulse, the impulse will set up and travel at its own speed. Threshold is the minimum strength of a stimulus that can initiate an impulse. ***Increasing the intensity of the stimulus cannot raise the speed of transmission***.

17.7 REFLEX ACTION

Reflex action is an automatic, quick and involuntary action in the body brought about by a stimulus. For example,

- You instantaneously withdraw your hand on accidentally touching a hot plate or a sharp thorn.
- Watering (salivation) of the mouth takes place on seeing or just smelling a familiar tasty food.

Two types of reflexes – simple and conditioned

The two examples of reflex action given above are basically different. The first one is inborn or natural, which did not require previous learning. Such reflexes are called **simple reflexes**.

The other example is the outcome of repeated experience. Here the brain actually remembers the taste of food and works in an unconscious manner- such reflexes are called **conditioned reflexes**.

Some other examples of reflexes are as follows:

(A) Simple Reflex

- **Quick closing of eyelids** on noticing an object suddenly approaching the eye.
- **Coughing** when the food swallowed enters the windpipe instead of the food pipe.
- **Narrowing of the eye pupil** in strong light.
- If the foot of sleeping person is tickled, it is **jerked away.**

(B) Conditioned Reflexes

- **Applying brakes** in your vehicle (car or bicycle) on noticing someone suddenly coming in front of it.

- **Tying shoe laces** while talking to someone, not knowing whether you are first putting the left lace over the right or the vice versa.
- **A dog runs away** if it notices you kneeling down as if you are picking up a stone for striking.
- **Standing up on** seeing the teacher entering the classroom.

Mechanism of Reflex Action

Some reflexes are brought about through the brain (cerebral reflexes) such as the closing of the eyelids due to approaching objects while other are brought about through the spinal cord (spinal reflexes). The pathway in a simple spinal reflex action is represented in the diagram below (Fig.17.6).

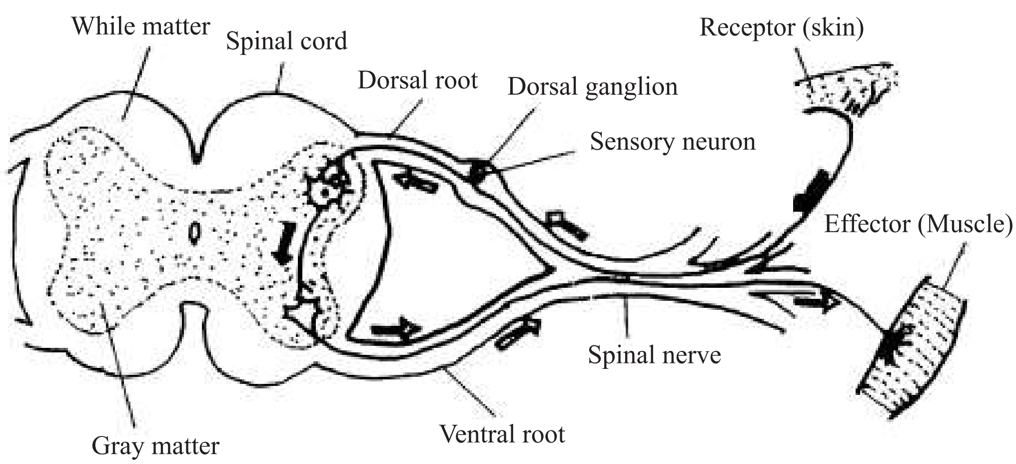


Fig. 17.6 Nerve pathways in a simple reflex action

In this, there are five necessary parts:

The stimulus (prick, heat etc.) → receptor in the sensory organ → the afferent (sensory) nerve fibre running through the dorsal root of the spinal nerve bringing the impulse into the spinal cord → a (motor) neuron sending out the command through its efferent fibre in the ventral root of the spinal nerve → a muscle or the gland.

Mostly there occur an **intermediate neuron** between the axon ending of the afferent fibre and the motor neuron inside the spinal cord.

INTEXT QUESTIONS 17.3

1. Given below are a few examples of reflexes. Write against each, the category of reflex, whether simple or conditioned.

   (i) Knee jerk..

Notes

(ii) Salivation on seeing a favorite dish ....

(iii) Tying of shoe laces while talking ....

(iv) Closing of eyelids if a strong beam of light is flashed across ....

(vi) Mistaking a coiled rope as snake if you happen to step on it in darkness ....

17.8 SENSORY RECEPTORS (THE SENSE ORGANS)

Sense organs are the organs through which we sense or detect changes in the external environment. Each sense organ has special sensory cells, which receive the stimuli and transmit the impulses produced through the concerned nerve to the brain or the spinal cord. The brain sorts out the impulses, interprets them and transmits message for the required response. In human there are typically five sense receptors, eyes for seeing, ears for hearing, nose for smelling, tongue for taste and skin for sensing touch, pain, heat, etc.

17.8.1 The Eye (the sense of vision)

The eye is nearly spherical in shape, bulging a little in front, and is able to rotate freely in the bony socket. It is a hollow ball containing several structures inside (Fig.17.7).

The wall of the eyeball is made up of three layers: the sclera, choroid and retina.

- **Sclera** is the outermost tough white layer. In front it is continued as the transparent **cornea**.
- **Choroid** is the middle layer. It is composed of connective tissue having a dense network of blood vessels. Its inner surface is dark brown or black. This prevents reflection, which would otherwise interfere with the clarity of the image.

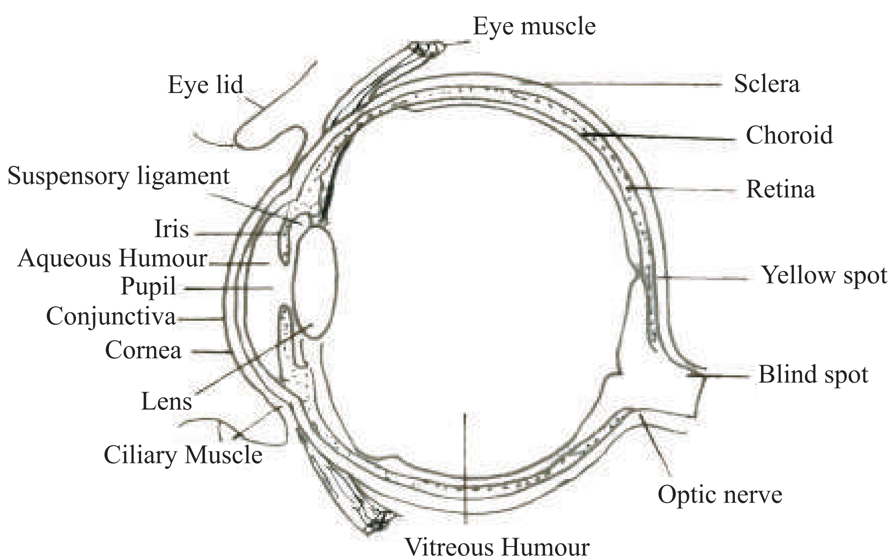


Fig. 17.7 Vertical section of the human eye

- **Retina** is the innermost sensitive layer. It contains two kinds of sensory cells– the **rods** (sensitive to dim light) and **cones** (sensitive to bright light and colours).
  - **Yellow spot** lying at the visual axis is the place of best vision in the normal eye. It contains maximum number of sensory cells and particularly the cone. The rest of the retina has fewer cones and more rods.
  - **Blind spot** is the point where the nerve fibres (axons) from all the sensitive cells of the retina converge to form the optic nerve which connects the eye to the brain. There are no sensory cells at the blind spot and any image formed here is not perceived.

The parts of the eye

Internally the eye is divided into two main chambers separated by the lens.

- **Aqueous chamber** is the front part containing a watery fluid (**aqueous humour**) and **vitreous chamber** is the back part containing a thick jelly like glassy substance (**vitreous humour**, *vitro* : glass). The aqueous humour keeps the lens moist and protects it from physical shocks. The vitreous humour helps in maintaining the shape of the eyeball and protects the retina.
- The **lens** is biconvex in shape and semi-solid. It is composed of soft gelatinous tissue. It is held in position by suspensory ligament, which attaches it to the muscular **ciliary body**. The shape of the lens is influenced by the amount of tension in the suspensory ligament.
- **Iris** is a sort of circular curtain in front of the lens. It is black, brown or blue. The colour of the eye is the colour of its iris. It contains two kinds of muscles : **circular muscles** for narrowing the pupil, and **radiating muscles** for dilating it. The size of the pupil is adjusted involuntarily to control the amount of light entering the eye. Can you think of the situations when the pupil gets narrower and when it becomes wider?

How Do We See

- **Transmission of light :** Reflected light rays from the object enter the eyes through the transparent structures of the eye i.e. conjucativa, cornea, aqueous humour, lens and vitreous humour.
- **Formation of image**. The curvature of the cornea bends the rays to some extent and the lens bends them further to form an image on the retina.
- **Nature of image**. The image is inverted and real.
- **Production of nerve impulse and its transmission**. The light energy of the image produces chemical changes in the sensory cells (rods and cones). These changes produce nerve impulses, which travel through the optic nerve and reach the brain.
- **Perception.** The brain interprets the image in many ways; e.g. it sees the object vertical although the actual image formed is inverted.

- **Accomodation (focusing)**. Focusing the image on retina is called **accommodation**. Changing the curvature of the elastic lens brings about accommodation.
  - **For distant vision :** The lens is more flattened or thinner; this is the normal condition of the lens, which is kept stretched by the suspensory ligaments.
  - **For near vision :** The ciliary muscles which are circular, contract and tend to reduce the circumference of the eyeball there. This releases the tension on the suspensory ligament and the lens becomes thicker (more rounded) on account of its own elasticity.

> A normal eye is constantly accommodating while walking, playing or just looking around.

- **Binocular vision**. In all primates including humans, both eyes are placed forward. Each eye views at a slightly different angle. The images from the two eyes are perceived overlapped inside the brain giving the impression of depth (3-dimensional/stereoscopic vision).

Three Common defects of the eye

1. **Near sightedness (Myopia).** Nearby objects are clearly seen but not the distant ones by those suffering from myopia because the image of the object is formed in front of the retina. This can be corrected by using concave lens (worn in frames (spectacles) or as contact lenses).
2. **Long sightedness (Hypermetropia).** Distant objects are clearly seen but not the nearby because the image of the object is formed behind the retina. This can be corrected by convex lens (worn in frames as spectacles or as contact lenses).
3. **Cataract (opacity of the lens).** The lens usually loses its transparency and turns opaque with age. Such a lens can be surgically removed and replaced by an intra-ocular lens.

INTEXT QUESTIONS 17.4

1. State the function of the following parts of the eye:
   (i) Iris ....
   (ii) Ciliary muscles ....
   (iii) Pupil ....
   (iv) Vitreous humour ....
   (v) Retina ....

2. Name the following:
   (i) Area of sharp vision in the eye ....
   (ii) The kind of lens used for correcting near-sightedness ....
   (iii) The condition in which the lens of the eye turns opaque ....
   (iv) The capacity of eye to focus objects at different distances ....

17.8.2 The Ear-Sense of Hearing and Balance

The ear serves two sensory functions: hearing and maintaining balance of the body. The ear has three main parts – external ear, middle ear, and internal ear (Fig. 17.8)

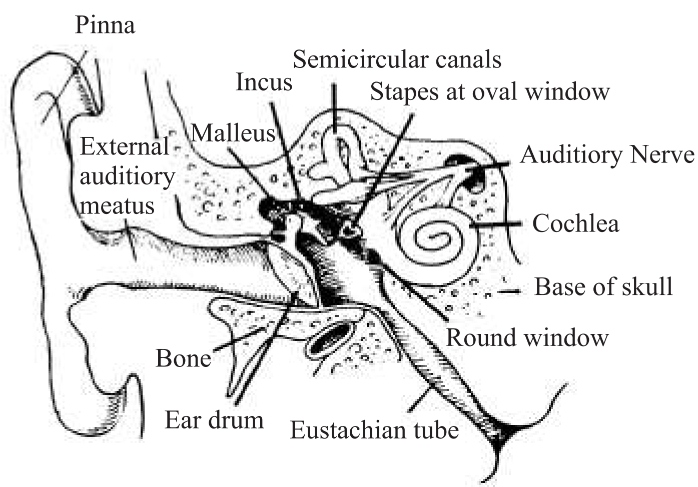


Fig. 17.8 The human ear.

The **external ear** consists of the following :

– an outwardly projecting ear to be called **pinna** supported by cartilage. It directs the sound waves inwards.
– The **auditory canal** through which the sound waves travel up to the ear drum (tympanic membrane)

The **middle ear** consists of the following:

- An air-filled tympanic cavity
- The **tympanum** or ear drum
- Three tiny bones-**malleus** (hammer) connected to the ear drum, incus (anvil) in between and **stapes** (stirrup) forming a contact with the oval window of the internal ear.
- **Eustachian tube** connects the tympanic cavity with pharynx. It equalizes the pressure on both sides of the eardrum or tympanum :

The **internal ear** contains two main parts:

(a) **Cochlea** – It is a long coiled structure which looks like the coils of the shell of a snail. It has two and a half turns. The inner winding cavity of the cochlea is divided into three parallel tubes of canals separated by membranes. The canals are filled with a fluid called endolymph. The middle canal possesses sensory cells (organ of corti) for hearing.

(b) **Vestibule** – is concerned with physical balance of the body. It consists of three **semicircular canals** arranged at right angles to each other and a part joining the cochlea and differentiated into a **utriculus** and a **sacculus**. One end of each semicircular canal is widened to form an **ampulla,** which contains sensory cells, and the nerve fibres from them continue into auditory nerve.

Mechanism of hearing

- The sound waves enter the auditory canal and cause the eardrum to vibrate
- The vibrations of the eardrum are transferred to malleus, to incus, and then to stapes. Stapes transfers the vibrations through oval window into the cochlea.
- These vibrations move the fluid in the cochlea. The organ of corti catches the movement of the fluid and transfers it to the auditory nerve that carries the impulses to the brain

Perception of body balance

Static balance due to gravity – Any bending or change in the body posture causes the fluid inside the semicircular canals to move. The semi circular canals are arranged in different planes. The sensory hairs in the ampulla of the canal pick up these movements and the impulses are transmitted through the auditory nerve.

Balance during motion – Utriculus and sacculus perceive dynamic equilibrium (while the body is in motion). Fine particles of calcium carbonate present in the endolymph press on the sensory hairs whenever the body is in some motion. The impulses are carried through the auditory nerve.

17.8.3 Tongue and Nose (Sense of taste and smell)

The tongue perceives the taste and the nose perceives the smell. The perception depend upon the nature of chemical substance coming in contact with the sensory cells. For taste there is a direct contact of the substance with the sensory cells located in the taste buds on the tongue. For smell, the molecules of the chemical are carried inward by the air inhaled and they stimulate the sensory epithelium of the nose.

17.8.4 Skin (Touch and some other miscellaneous senses)

There are a variety of nerve endings in the skin. Some of these are concerned with touch (gentle pressure), some with deep pressure and others with cold, heat and pain.

The sense of hunger is due to receptors in the stomach wall. The sense of thirst is due to stimulation of nerves in the pharynx. And the sense of fatigue is located in the muscles.

INTEXT QUESTIONS 17.5

1. Which part of the ear is involved when:

   (i) a gymnast performs various balancing feats. ....

   (ii) you hear a song. ....

2. Name the following :
   (i) The part into which the sound waves are directed by the ear pinna.
   ....
   (ii) The kind of balance with which the semi-circular canals are concerned.
   ....
   (iii) Any two sensations felt through free nerve endings in the skin.
   ....

17.9 COORDINATION THROUGH HORMONES—THE ENDOCRINE SYSTEM

Hormones are secretions from specific cells or glands in the body called endoerine glands Harmones are carried by blood to target organs. Their effect is produced in one or more specific parts only. Most hormones are secreted by special glands called the endocrine glands. These are also called ductless glands because their secretions are poured directly into the blood and not through ducts. Certain hormones are produced by other glands or body parts also, for example, the stomach and the duodenum.

17.9.1 Nature and Function of Hormones

- Hormones are secreted from their source directly into the blood.
- Blood carries the hormone to the **target cells** which respond to it.
- Hormones **regulate** the physiological processes.
- They are produced in **very small quantities** and are **biologically very active**. For example, adrenaline is active even at a concentration of 1 in 300 million parts.
- Their **excess** and **deficiency**, both, cause serious disorders.
- Chemically, the hormones may be water-soluble **proteins (peptides), glycoproteins** and **amines** or lipid-soluble **steroids**.
- The extra hormones are not stored in the body and are excreted out.

17.9.2 Hormone Secretors — the Endocrine Glands

In humans there are more than a dozen tissues and organs that produce hormones. Most of these are shown in Fig. 17.8. These can be listed under two categories

(a) **Exclusively endocrine** : the **pituitary,** the **thyroid,** the **parathyroid, thymus** and the **adrenals.**

(b) **Partially endocrine** : The **pancreas, gastric and duodenal epithelium,** the **gonads** (testis in males and ovary in females) and **placenta** in females.

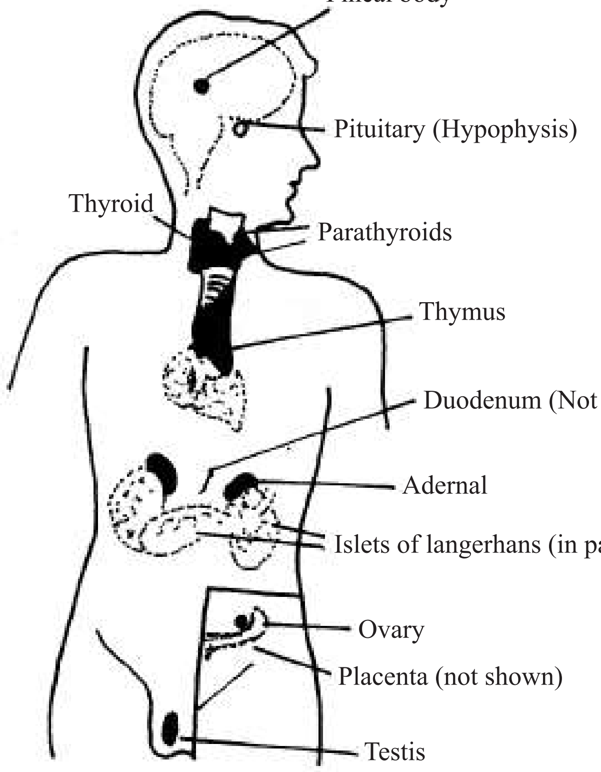


Fig. 17.8 Location of principal endocrine glands in the human body

1. Pituitary — the master gland

The pituitary gland (also called hypophysis) (Fig. 17.9) is a small projection (about the size of a pea) which hangs from the base of the mid-brain. It is connected to the hypothalamus of the brain by the pituitary stalk. The hypothalamus, although a part of the brain, also secretes some hormones.

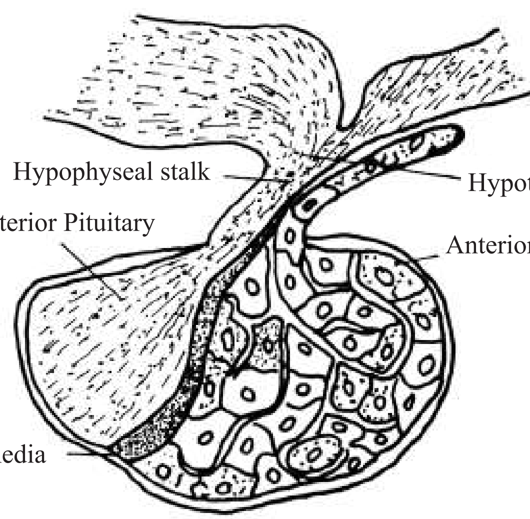


Fig. 17.9 Pitutary gland

The pituitary controls most other endocrine glands. It has two distinct parts: the **anterior pituitary** and the **posterior pituitary**. Various hormones produced from these two parts and their actions are listed below in Table 17.2.

Table 17.2 Pituitary hormones, their action and abnormalities due to its oversecretion or undersecretion

Source	Hormones	Action and abnormalities produced
Anterior lobe of pituitary	Growth hormone (GH), also known as somatotropic hormone (STH)	Promotes growth of whole body, particularly of the skeleton. Undersecretion in childhood lead to Dwarfism; oversecretion in childhood causes gigantism and in adult, acromegaly.
	Tropic hormones (stimulate other endocrine glands)	1. Thyroid stimulating hormone (TSH) stimulates thyroid. 2. Adrenocorticotropic hormone (ACTH) stimulates adrenal cortex.
	Gonadotropic hormones	3. Follicle stimulating hormone (FSH) stimulates egg formation in females and sperm formation in males. 4. Luteinizing hormone (LH) stimulates ovulation and the formation of corpus luteum which produces the female hormone progesterone and LH stimulates testis to produce the male hormone testosterone. 5. Prolactin stimulates milk production.
Posterior lobe of pituitary	Antidiuretic hormone (ADH) or vasopressin	Increases absorption of water from the kidney tubules (osmoregulation). Its deficiency causes **diabetes insipidus**.
	Oxytocin	Stimulates contractions of the uterus during childbirth.

2. Thyroid

Thyroid is a bilobed structure situated in the front region of the neck (Fig. 17.10). It secretes two hormones—**thyroxine** and **calcitonin.**

Thyroxine regulates basal metabolism i.e. the rate of cellular oxidation resulting in heat production. Controls growth and development, ossification of the bones, body temperature, mental development, etc.

Undersecretion of thyroxine (hypothyroidism) produces three conditions

- Simple **goitre.** Enlargement of thyroid visible as a swelling in the neck. It is caused due to iodine deficiency in food as iodine is needed for production of thyroid hormones.
- **Cretinism.** Poor body growth (dwarfism) and mental retardation
- **Myxoedema.** Swelling of the face and hands. General sluggishness.

Oversecretion of thyroxine (hyperthyroidism) produces exophthalmic goitre. This condition causes marked increase in the metabolic rate, rapid heart beat, shortness of breath and the eyes protrude out together with goitre in the neck.

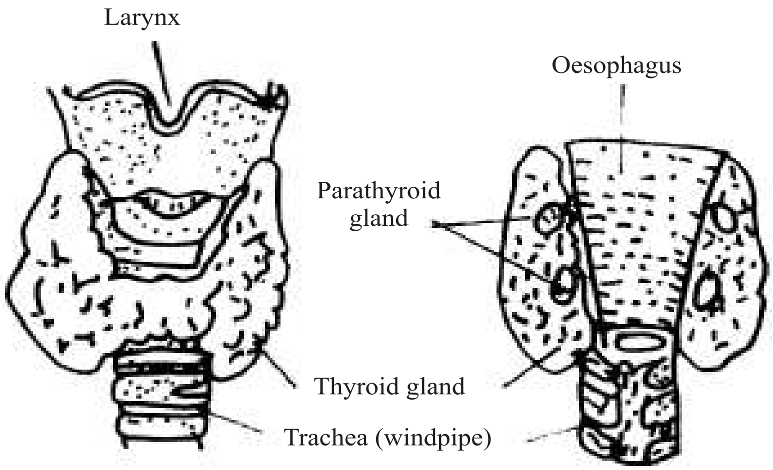


Fig. 17.10 The thyroid gland

Calcitonin. It regulates the calcium and phosphate levels in the blood. If the calcium level in blood is high more calcitonin is secreted and the calcium ions are moved from the blood to the bones making them harder. The reverse happens when the calcium level in the blood is low making the bones soft.

3. Parathyroids

These are two small pairs of glands wholly or partially embedded in the thyroid gland. Their secretion **parathormone** raises blood calcium level by stimulating release of calcium from bones.

4. Thymus

It is located at the base of neck. It produces some hormones involved in maturation of T lymphocytes. It begins to atrophy after puberty.

5. Adrenals

The adrenals (ad: adjacent, renal; kidney) are a pair of glands situated like caps one above each kidney. Each adrenal consists of two parts: a central **medulla** and a peripheral **cortex**.

The **adrenal medulla** secretes adrenaline which,

- increases heart beat accompanied by an increase in the blood pressure.
- increases blood supply to the muscles while decreasing blood supply to the visceral organs.
- releases more glucose into the blood from the liver.

The **adrenal cortex** secretes two categories of hormones: **glucocorticoids** and **mineralocorticoids**.

(a) **Glucocorticoids** e.g. **cortisone**

- In response to stress it raises blood glucose through action of the liver including deamination of amino acids. During starvation and prolonged fasting the required glucose is partly provided through this hormone.
- It adapts the body to stresses such as extreme heat or cold, burns, infections, etc.
- Some of the cortical hormones behave like sex hormones.
  - **Overgrowth of adrenal cortex in young children** causes premature sexual maturity.
  - **Overgrowth of adrenal cortex in mature females** results in the development of male characters such as beard and deep voice.
  - **Overgrowth of adrenal cortex in mature males** results in the development of some feminine characters such as enlargement of breasts.

(b) **Mineralocorticoids** e.g. **aldosterone**

This hormone is concerned with water retention. It increases reabsorption of sodium and chloride ions in kidneys. Read the role of aldosteronl in increasing blood volume and blood pressure in increasing blood volume and blood pressure in lesson 14 (14.3.6)

6. Pancreas

Pancreas is an endocrine as well as an exocrine gland. It has special groups of cells called **Islets of Langerhans**, which consists of three kinds of cells – *alpha cells* producing the harmone glucagon, *beta cells* producing harmone *insulin* and *gamma* cells producing harmone **somatostatin**.

(i) **Glucagon.** It stimulates breakdown of glycogen to glucose in the liver, leading to rise in the blood sugar level.

(ii) **Insulin**. It performs two principal tasks;

- Promotes glucose utilization by the body cells.
- Stimulates deposition of extra glucose in the blood as glycogen in the liver.

Gluccagon and insulin have oppsite functions.

Non-secretion or under secretion of insulin causes **diabetes mellitus** (***hyperglycemia***, meaning 'more than normal sugar in blood'.

A diabetic person,

- has higher glucose in blood;
- excretes a great deal of urine loaded with sugar;
- feels thirsty because of loss of water through too much urination;
- loses weight and becomes weak. In some cases, the patient even loses the eyesight.

Oversecretion of insulin causes **hypoglycemia** or low blood sugar. The brain may enter a state of coma if the level of sugar in blood becomes too low.

(iii) **Somatostatin** also called Growth Hormone-Inhibiting Hormone (GHIH) inhibits secretion of insulin as well as glucagon.

7. Gonads (testis and ovary)

Testes in males possess two kinds of cells : the sperm-producing germinal cells and the hormone-producing interstitial cells. The hormones produced are called androgens and the commonest one among them is **testosterone**.

The **testosterone** stimulates the development of the male characters during which the body at **puberty** starts developing facial hair**,** and their voice cracks and deepens.

Ovaries in females produce two kinds of hormones—**estrogen** and **progesterone**. **Estrogen** is secreted from the follicles of the ovary and stimulates the development of breasts and fat deposition on the hip in a mature woman. Estrogen prepares the wall of the uterus for receiving the fertilized egg.

Progesterone is secreted by the corpus luteum (follicle left after the release of ovum). It brings about the final changes in the uterus for the retention and growth of the foetus during pregnancy.

8. Placenta

Placenta of a pregnant woman produces certain hormones. One such hormone is **human chorionic gonadotropin** (HCG), which maintains the activity of corpus luteum in secreting progesterone continuously, when a women becomes pregnant.

9. Hormones from stomach and intestine

(i) **Gastrin** is the hormone secreted by the mucus membrane of the pyloric end of the stomach. It stimulates the gastric glands to secrete gastric juice.

(ii) **Secretin** is the hormone secreted by the inner lining of the duodenum. It stimulates the production of pancreatic juice while the hormone **cholecystokinin** stimulates release of bile from gall bladder.

17.10 THE FEEDBACK MECHANISM (CONTROL OF HORMONAL SECRETION)

The amount of hormone released by an endocrine gland is determined by the body's need for the particular hormone at any given time. The product of the target tissue exerts an effect on the respective endocrine gland. This effect may be positive ('*secrete more*') or negative ('*secrete no more*' or '*slow down*'). This can be explained by taking the example of thyroid gland.

Feed back mechanism of thyroid activity (Fig. 17.11). Hypothalamus releases a hormone TSH-RH (TSH- Releasing Hormone) which instructs the anterior pituitary to release TSH (thyroid stimulating hormone). The TSH stimulates thyroid to release thyroxine. If the level of thyroxine in blood increases, the pituitary stops the release of TSH. When the level of thyroxine falls in the blood, the thyroid gets stimulated to secrete more of it. In feedback mechanism the starting point of an activity receives back the information whether to continue or increase, or to slow down or even stop.

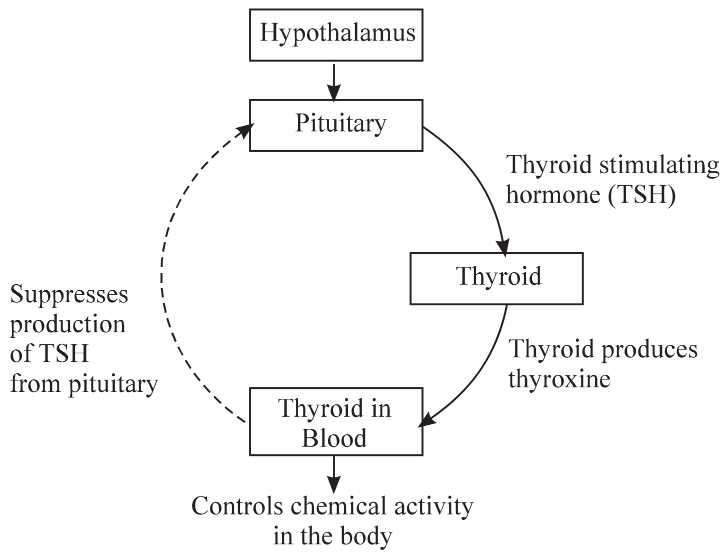


Fig. 17.11 Feed back mechanism in hormone action
(solid line = stimulation; broken line = suppression/inhibition)

17.11 COMPARISON OF HORMONAL AND NERVOUS COORDINATION

The table 17.2 below lists a few major differences between these two different kinds of control and regulating mechanisms.

Table 17.2 difference between hormonal and nervous control

Property	Hormonal control	Nervous control
1. Nature of signal	All hormones are chemical signal	Nerve impulses are electrical signals. Chemical signalling takes place at synapses
2. Speed of signal	Slow	Rapid. Between 0.7 metres per second and 120 metres per second
3. Effect in the body	General effect. The hormones can influence cells in many different parts of the body.	Localized effect – affects only the particular muscle or the gland

4. Effect on growth	Can affect growth	Cannot affect growth
5. Capacity for modification	Cannot be modified by learning from previous experience	Can be modified by learning from previous experiences
6. Duration of effect	Short term or long lasting.	Short – lived

17.12 PHEROMONES—THE CHEMICAL MESSENGERS AT SOCIAL LEVEL

Pheromones are the secretions given out by **an individual** into the environment, which bring about a specific response **in other members of the same species**. Some of the examples of the pheromones are as follows:

- **Common ants march on the floor or walls in a trail** on an invisible path laid down by a secretion from their bodies. It helps them to reach the destination one after another, as well as to return correctly to their own nest.
- **When disturbed honey bees give out an alarm pheromone** from their sting at the back and mandibles in the mouth. This alerts the inmates of the hive to face the attack.
- Females of a particular moth gives out a scent which can attract a male from as much distance as 3-4 kilometers.
- Introduction of a male mouse into a group of female mice shortens oestrus cycle (cycle of development of eggs in the ovary and ovulation).
- Introduction of a **strange male mouse** of a different strain disturbs to the extent that the **newly pregnant females abort their foetuses**. The source of pheromone of the strange male mouse is in its urine.

INTEXT QUESTIONS 17.6

1. Name the following

   (i) The organ in the neck on the trachea close to which thyroid is located

   ....

   (ii) The condition caused due to oversecretion of thyroxin

   ....

   (iii) The hormone concerned with facing dangers

   ....

(iv) The condition of passing much glucose in the urine

....

(v) The source gland of ADH

....

2. What are pheromones?

....

WHAT YOU HAVE LEARNT

- The coordination of body activities inside the body of an organism is brought about by two systems- the nervous and the endocrine systems.
- The nervous system is composed of the central nervous system (brain and spinal cord) and the peripheral nervous system (cranial and spinal nerves and the autonomic nervous system).
- The autonomic nervous system consists of a pair of chain of ganglia by the side of spinal cord. It is largely concerned with the normal functioning of the visceral organs.
- The nervous system of cockroach is made of brain or cerepral gangha, suboeso phaegeal ganglion, thoracic ganglia gangha and six abdominal ganglia from which nerves come out.
- Cerebrum is the largest part of the brain and is the seat of intelligence.
- Cerebellum is the centre of balance.
- Medulla oblongata controls breathing and heart beat.
- Spinal cord is the centre for simple reflexes.
- The sensitive layer of the eye is the retina which is composed of rods (sensitive to dim light) and cones (sensitive to bright light and for colour vision).
- The internal ear performs two tasks perception of sound by the cochlea and that of disturbance in body balance by the semicircular canals, utriculus and sacculus.
- The nose perceives chemical stimuli by the chemicals carried by the air and the tongue by direct contact with them.
- Skin possesses receptors for touch, pain, heat cold etc.
- Chemical coordination is brought about by hormones produced by the ductless glands, that are carried by the blood and which act on the target cells or organs away from their source.
- There is a close link between the nervous and the endocrine systems, shown by the way in which the pituitary gland interacts with the hypothalamus of the brain.

- Our endocrine glands include the pituitary, thyroid, parathyroid, thymus adrenals, pancreas, gonads and placenta.
- The pituitary controls and regulates the activities of almost all other endocrine glands.
- The undersecretion as well as the oversecretion of the hormones, both produce ill effects.
- Hormone levels are generally controlled by feed back mechanism.
- Pheromones are secretions released outside in the enviroment, which produce response in other individuals of the same species.

TERMINAL QUESTIONS

1. Name the two divisions of the nervous system?
2. What is gray matter?
3. Name the chemical involved in the transmission of nerve impulse across a synapse.
4. Give two examples of sensory nerves.
5. Name the respective areas of the retina concerned with best vision and no vision.
6. What is the role of the eustachian tube in the ear?
7. Name the hormone and its source glands, whose deficiency leads to diabetes insipidus.
8. What are pheromones?
9. Name and explain the event that happens immediately when a nerve fibre gets stimulated?
10. Are the endocrine glands and the ductless glands one and the same thing? Give one example.
11. Describe any one example of condition reflex in the humans.
12. List the functions of medulla oblongata.
13. Differentiate between sympathetic and parasympathetic nervous systems.
14. What are the two principal tasks of insulin?
15. Explain the following terms: (i) synapse (ii) stimulus and (iii) impulse
16. Draw a diagram to show the arrangement of the bones inside the middle ear.
17. Write short notes on the following :
    (i) myopia
    (ii) taste buds
    (iii) accommodation of the eye

18. How do sympathetic and parasympathetic nervous systems act differently on (i) pupil of the eye, and (ii) urinary bladder?
19. Draw a labelled diagram of the cross section of the spinal cord and the nervous pathway of a simple reflex concerned with it.
20. Explain the role of ciliary muscles in our eyes
21. Taking the example of thyroxine secretion, explain what is meant by feedback mechanism?

ANSWERS TO INTEXT QUESTIONS

17.1

1. FIg. 16.1, page 337
2. (a) supraoesophageal ganglion (b) sub oesophageal ganglion
3. Ventral nerve cord
4. Cerebrum, cerebellum, medulla oblongata, thalamus and hypothalamus
5. (i) Cerebrum–intelligence/thinking/reasoning/memory;
   (ii) Cerebellum– balance/muscular coordination
   (iii) Medulla oblongata–involuntary actions
   (iv) Hypothalamus–homeostasis
6. Gray matter–composed of neuron cell bodies
   White matter–composed of axon fibres
7. Cerebrospinal fluid

17.2

1. Sympathetic nervous system and parasympathetic nervous system
2. (i) parasympathetic nervous system
   (ii) parasympathetic nervous system
   (iii) sympathetic nervous system
   (iv) parasympathetic nervous system
   (v) parasympathetic nervous system
3. because it connects the periphery (surface) of the body
4. sensory = afferent, motor = efferent

17.3 1. (i) simple (ii) conditioned (iii) conditioned

(iv) simple (v) conditioned

17.4 1. (i) contracts and dilates pupil

(ii) helps in near vision/contracts to make lens thicker

(iii) controls amount of light entering the eye

(iv) maintains shape of the eye ball and protects retina

(v) produces nerve impulses into the optic nerve

2. (i) yellow spot (ii) concave lens

(iii) cataract (iv) accommodation

17.5 1. (i) vestibule (ii) cochlea

2. (i) auditory meateus

(ii) static balance

(iii) touch/pressure/warmth/cold/ ….

17.6 1. (i) larynx, (ii) cretinism, (iii) adrenaline (iv) diabetes mellitus,

(v) posterior pituitary

2. Pheromone is a secretion from one individual that is given out into the environment and which elicits a response in other members of the same species.

18

HOMEOSTASIS : THE STEADY STATE

In the previous lesson you studied about the nervous system. There, you noted how the body functions in a coordinated manner to bring about any required effect or change. You also learnt about the hormones and how they work in a way so that the body knows when to start, when to speed up, when to slow down and when to stop an event that ocurs inside the body. In this lesson, you will study about the phenomenon called **homeostasis** which means ‘keeping steady state’. Homeostasis operates for a variety of needs inside our body and one such need is the regulation of body temperature called **thermoregulation**. This lesson mainly covers various aspects of thermoregulation.

OBJECTIVES

After studying this lesson, you will be able to :

- *define the term homeostasis and explain its needs in the body;*
- *explain the term thermoregulation and justify its need in the body;*
- *differentiate between endotherms and ectotherms;*
- *list the body parts involved in thermoregulation and explain how they contribute towards heat production and heat loss;*
- *name the principal heat regulating centre in our body and describe how it acts;*
- *explain the term ‘feed back’ and differentiate between positive and negative feedback mechanisms.*

18.1 CONCEPT OF HOMEOSTASIS

Homeostasis (*homeo* : same/steady, *stasis* : state) is a phenomenon in which the body regulates its functions to keep the internal conditions as stable as possible.

Homeostasis is necessary because the body cells need to have suitable conditions around them for proper functioning. These conditions include, the presence of proper concentration of chemicals, proper temperature, and a suitable pH (degree of salinity or acidity), etc. inside its cells. But these conditions inside our body as well as inside other organisms keep fluctuating within a narrow range. Tolerance to any change from this range differs in different organisms. Organisms adopt a variety of measures to cope with such changes.

To understand the concept of homeostasis (keeping steady state) consider the following five examples in the humans:

Example 1. Drinking water and keeping a 'steady water balance'.

In all kinds of weather, your blood and other body fluids must maintain a particular percentage of water. If the volume of water in the body tends to rise, the excess is passed out in urine and, if it tends to fall short, more water is withheld inside the blood to the extent required. Thus, the body maintains a steady state (= homeostasis) of water content.

- In hot summers you feel thirsty at regular intervals. You drink lots of water or even cold drinks, yet you do not urinate much. The urine passed out is more concentrated. This is because during hot weather you lose more water through perspiration but your body needs to maintain its requisite amount of water and so the water is withheld within, by passing out only little and concentrated urine.
- In cold winters you donot feel much thirsty. You do not drink large quantities of water. But, may be, you take more of hot drinks only to keep warm. During such days you urinate more frequently and the urine passed out is more dilute.

Example 2. Eating sugar and keeping steady sugar level in blood

Suppose you have been consuming too much sugar in food, beverages and sweets. Presuming you are otherwise normal, your body will handle the excess sugar (more than the normal percentage in the blood) by storing it in the form of **glycogen** in the liver.

At some other time, when you are fasting or doing much physical work, your blood sugar is used up rapidly. At that time, the liver converts the stored glycogen back into its usable form, that is glucose, to fill the gap and restore the normal blood sugar level.

Example 3. Maintaining normal steady state of blood alkalinity

Sometimes you eat too much salt (sodium chloride) in your food. But your blood normally maintains only the particular level of alkalinity (pH 7.34-7.43) which is only slightly alkaline. Any extra salt consumed is passed out through urine as it cannot be stored in the body.

If at some other time you have been eating too little salt, or you are losing much of it through sweating, your kidneys will hold back the required quantity through sodium-potassium balance.

Example 4. Managing the number of red blood cells

A normal human adult possesses about 5 million red blood corpuscles (RBCs) per cubic millimetre of blood.

Whenever a plain-dweller visits a hill station at high altitude without any break-journey in between, he is likely to feel exhausted for a couple of days. Later, the person becomes normal. At high altitudes the atmospheric pressure is lower and the amount of oxygen carried by this normal number of RBCs is insufficient. Within a day or two, the body adds more RBCs into the blood to pick up the normal required quantity of oxygen.

When the same person returns to the plains at a lower altitude the higher RBC level that was acquired at the hills now begins to take up oxygen in excess, which is harmful. The body readjusts the red blood cells which get reduced in number to become stable at the original level.

Example 5. Warming and cooling of the body (maintaining steady body temperature)

During hot summers you wear light clothes. You perspire a lot, you sit under a fan or under a tree and feel comfortable. Your body is trying to cool against the higher temperature outside.

Then, there is the reverse side, that is, cold winter. Inspite of wearing thick warm clothes you still feel cold. In mid-daytime, you go out in the open sunshine to warm yourself. At night, you cover yourself with a thick blanket. You are doing all this to maintain warmth inside steadily your body.

In both the above situations, you are trying to regulate your internal body temperature. This is called thermoregulation. You will learn more about thermoregulation in subsequent sections of this lesson.

INTEXT QUESTIONS 18.1

1. Define homeostasis.

   ....

2. List any three chemicals whose concentration in our body has to be maintained at partcular levels.

   (i) ....

   (ii) ....

   (iii) ....

3. To obtain enough oxygen for respiration at high altitudes, what does the body do?

   ....

18.2 THERMOREGULATION — WHY IS IT NECESSARY?

18.2.1 Limits of heat tolerance

The living organisms can normally survive only within a certain range of temperature of about 0-45° C. However, organisms tend to make adjustments, if they happen to be at places of higher or lower temperature.

A. **Above 45°C,** the organisms may suffer in many ways:

- the enzymes are destroyed,
- proteins get denatured,
- plasma membrane breaks down, and
- cells suffer lack of oxygen.

B. **Below 0°C.** At temperatures below freezing point, the cells may burst by the formation of needle-like ice crystals inside and between the cells and the organisms cannot survive.

The above stated effects due to temperature changes are because enzymes function normally within a certain range of temperature.

18.2.2 Efficiency of enzymes at different temperatures

Enzymes carry out almost all the chemical reactions occuring inside our body. They have several characteristics and the most important one is their relation with respect to temperature.

- **At 0°C**. The enzymes are inactive.
- The rate of enzyme-catalyzed reactions doubles with every 10 degrees rise in temperature between 4-40°C.
- **On warming.** Whenever the temperature rises, the enzymes start working faster. If the temperature becomes too high (more than 40°C) the enzymes begin to work too rapidly and produce unwanted intermediate chemicals and not the required ones. At still higher temperatures the enzymes get denatured (destroyed).
- The enzymes act best at a narrow temperature range, usually between 35-40°C (optimum temperature meaning the most suitable temperature)
- **On cooling.** At temperatures lower than the optimum temperature the enzymes become less and less efficient. At freezing temperatures the enzymes may turn totally inactive.

INTEXT QUESTIONS 18.2

1. How do the following temperatures affect the enzymes?

   (i) 45°C and above ....

   (ii) 0°C and below ....

2. (i) At what temperature range do enzymes act best?

....

(ii) What technical term do you use for this temperature?

....

18.3 CLASSIFICATION OF ANIMALS BASED ON THEIR TEMPERATURE TOLERANCE

Based on the capability and the manner of regulating body heat, all animals found on earth are grouped into two main categories: endotherms and ectotherms

18.3.1 Endotherms and Ectotherms

A. **ENDOTHERMS** (*endo* : inside, *therm* : heat) : Examples: All birds and mammals. Endotherms are organisms, which maintain a steady body temperature irrespective of the temperature of the surroundings. Two other terms often used synonymously for endotherms are

- **Homoiotherms** (homoio: same; therm: heat) refers to keeping the same or constant (warm) body temperature, and
- **Warm-blooded** (oldest term and seldom used now) means animals which are felt warm whenever touched. If you hold a pigeon in your hand or feel a rabbit by touch even when it is intensely cold outside, you will find them warm.

B. **ECTOTHERMS** (ecto: outside, therm: heat) : Those animals whose body temperature rises and falls with the rise and fall of surrounding temperature are termed Ectotherms. All animals other than birds and mammals are ectotherms. Examples: Fish, frogs, lizards, insects, earthworms, etc. Two other terms often used synonymously with ectotherms are

- ***Poikilotherms*** (*poikilo* : changing/varying, therm: heat) referring to acquiring the body temperature from that of the surroundings.
- ***Cold-blooded*** (oldest term and seldom used now) means animals which are cold when touched. If you hold a frog in your hand or feel the touch of a cockroach, they are always colder than your body.

18.3.2 Characteristics of Endotherms

1. With an **internal heat-regulating mechanism,** the endotherms (birds and mammals) are able to maintain their body temperature within a narrow range of 2°C (37-39°C.) irrespective of the outside temperature whether intensely cold or severely hot. Birds are usually slightly warmer than the mammals.
2. An **efficient insulation mechanism** helps maintain body temperature
   - Birds have feathers to trap air for preventing heat loss. When cold, the feathers are raised (fluffing) to trap more air to increase insulation.

- Mammals have two sources of insulation: (i) hairs and (ii) subcutaneous or under-skin fat. The hairs trap the air. When it is too cold the hairs are raised (goose flesh) to increase insulation. The under-skin fat prevents conduction of heat outwards. This fat layer is thicker in the colder region inhabitants for better prevention of heat loss and thinner in those living in warmer regions to allow greater heat loss.

18.3.3 How some endotherms cope with unfavorable temperatures

- **Polar bears, penguins** and several other animals live in the ice-covered polar regions. They maintain their body temperature by generating heat and preventing heat loss through thick fur and a thick layer of under-skin fat.

- **Camels, desert rats** and several other tolerate the intense heat of the tropical deserts mainly by promoting heat loss.

> Camel is a desert dweller of hot climate. It needs to possess more of heat loss mechanisms and cut down the heat- retaining ones. Most of its skin has no fat layer. But, look at the hump, it stores a huge bulk of fat only as reserve food.

- **Squirrels, goats, pigeons** etc. live in moderate climate and they too have to adjust their body temperature according to the changing conditions of the outside. They adjust both in winter and summer to maintain normal body heat.

  Humans too are endotherms. When required we supplement our natural heat-regulating mechanisms by artificial methods like clothing, using the fan, bathing, room heating, room- cooling, etc.

18.3.4 Some ectotherms and how they cope unfavorable temperature conditions

Consider the following examples:

- **Frogs** hibernate under the ground in cold winters and aestivate during hot summers to avoid heat and escape from cold. Hibernation or wintersleep is characterised by the animal slowing down its activites and resting underground. During hibernation the 'basal metabolic rate' remains low.
- **Fishes** live in water. Water seldom undergoes extreme temperature changes like the ones on land. Still, fishes either make minor adjustments in their body parts to minimize the heat loss or heat gain or, if they are unable to do so, they migrate to less harsh regions.
- **Lizards** and **crocodiles** bask in the open sun to warm themselves during cold weather. When hot, they move to shades. When feeling hot, the crocodiles even open their mouths wide to allow evaporation of water for cooling purposes, something like the panting of dogs.
- **Honey bees**, during cold winter nights, huddle together inside the hive to conserve body heat collectively. During hot summers they even operate a kind of 'desert cooler' by sprinkling some water on the honeycombs and fanning with their wings for cooling the honey combs.

INTEXT QUESTIONS 18.3

1. Classify the following animals as endotherm or ectotherm:
   Camel, Bat, Earthworm, Cockroach, Fish, Wall lizard, Polar bear, sparrow
   Endotherms ....
   Ectotherms ....
2. Explain the following terms and give one or more synonymous terms for each:
   (i) Poikilotherms ....
   (ii) Homoiotherms ....
3. Mention one way each by which each of the following fight severe cold:
   (i) Crocodile ....
   (ii) Honey bee ....
   (iii) Common frog ....
   (iv) Wall lizard ....

18.4 MECHANISM OF HOMEOSTASIS OF BODY TEMPERATURE (THERMOREGULATION) IN HUMANS

18.4.1 Normal core body temperature

The starting point in any homeostasis is the identification of its set or the normal point. The set point of human body temperature is taken as 37°C, which is also called the normal or core body temperature. The core body temperature refers to the temperature of the combined portion of the trunk, head and upper part of arms and legs. Our body temperature otherwise is not uniform throughout.

- The surface skin temperature is usually lowest but it varies considerably due to a variety of external and internal conditions.
- The armpit usually records 1 degree less than the temperature inside the mouth.
- The anal temperature is 1 degree higher than the core body temperature. In very young children, the clinical thermometer is placed inside the anus and the temperature recorded is reduced by one degree to assess if the child is having any fever.
- For all practical purposes, the oral (mouth) temperature is taken as normal body temperature, which is usually 37°C (±0.5).

Whenever the core body temperature departs from the normal, the body takes corrective measures. For example :

- If the temperature falls, there is increased heat production in the body along with prevention of heat loss.
- If body temperature rises there is cooling to give out excess heat.

You will read about such steps in more details in the next sub-section.

18.4.2 Mechanisms of Thermoregulation

The principal heat-regulating centre is located in the **hypothalamus**, a part of the forebrain. This part acts like a thermostat.

- When the body has to face cooling below the normal temperature, it '*switches on*' or speeds up the heat-producing processes and simultaneously '*shuts off*' the heat-losing ones.
- When the body faces overheating during summer or after intense physical exercise, it accelerates the cooling process and '*switches off*' the heat- producing ones.

A. Keeping warm in cold weather

Thermoregulation in cold weather is achieved in two ways : preventing loss of body heat and generating more body heat.

1. **Preventing loss of body heat** - This is achieved in two ways:

   (a) ***Vasoconstriction***. Vasoconstriction means narrowing of blood vessels (Fig.18.1a). As a result of vasoconstriction in the skin,

   - the blood supply to the skin is reduced and there is less loss of heat by convection, conduction and radiation.
   - With the reduced blood supply to the sweat glands in the skin, there is less or no secretion of the sweat and thus there is no evaporation of water and no loss of heat

   Have you ever observed that in very cold weather you look pale or bluish? This is due to reduced blood supply to the skin caused by vasoconstriction.

   (b) ***By posture***. At times when we feel cold,

   - We hold our arms cross-folded tightly over the chest while standing or sitting.
   - While sleeping in bed we often hold our arms and legs closely folded near the body in a curved posture.

   Such postures reduce the exposed body surface for heat radiation.

2. **Generating more body heat :** The metabolic rate is increased and more heat is produced in the body cells. The muscular activity is also increased which is sometimes in the form of shivering.

B. Keeping cool in hot weather (Fig. 18.1b)

When the outside temperature is high or when a person is engaged in strenuous physical work there is overproduction of heat within the body. The extra heat is given out in two principal ways.

1. **Increased heat radiation from the body**. This is brought about by increasing the blood supply to the skin through vasodilation (widening of the blood vessels). The increased blood flow into the skin allows more heat to reach the body surface and radiate out heat. (Fig. 18.1b).
2. **Increased sweating.** Increased blood supply to the skin through vasodilation makes more water available to the sweat glands. They pour out more sweat and the evaporation of sweat cools the body. We often speed up evaporation of sweat by using fans. The fans by themselves do not cool the air, it is the movement of air that increases evaporation of the sweat to produce more cooling.

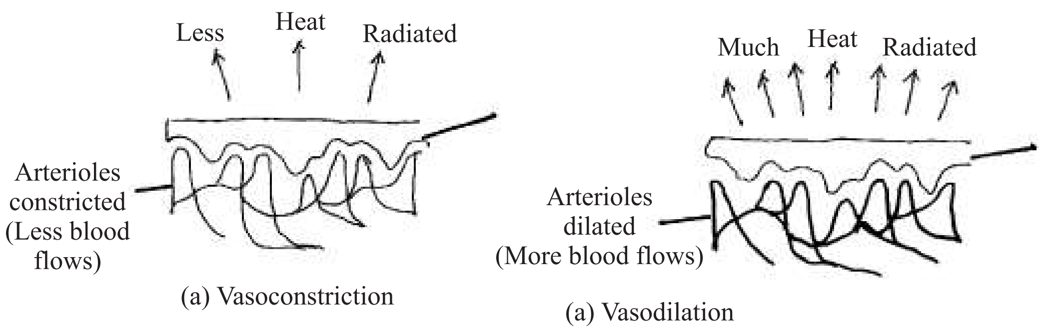


Fig 18.1 Blood vessels in the skin during temperature regulation.
(a) Vasoconstriction for cutting down heat loss
(b) Vasodilation to increase heat loss

18.4.3 Components of Homeostasis

Homeostasis of any kind involves four components:

1. **Set point or the norm** - This is the normal level of any factor in the body. The set point may have a small or large range. For example, the normal set point of human body temperature is approximately 37° C (with 0.5° C plus or minus).
2. **Sensor -** This consists of the sensory part that perceives the change in the set point. The sensor in thermoregulation comprises the heat receptors in (i) the skin and (ii) hypothalamus, the part of the brain which perceives the temperature of the flowing blood.
3. **Integrating centre -** The integrating centre is the part, which receives the information about the change in the set point of the particular state, interprets it and then sends the command for correction. In thermoregulation the integrating centre is hypothalamus plus some adjoining parts of the brain.
4. **Effectors -** The effectors are the agencies, which act to restore the set point. For example, (i) ***Sweat glands***, which pour out the sweat to produce cold by evaporation, (ii) ***Skin blood vessels***, which widen (vasodilate) to bring more blood to the body surface for radiating out heat and (iii) ***Skeletal muscles***, which vigorously contract (shivering) to produce heat

The flow chart given here (Fig.18.2) explains the different steps in thermoregulation in humans.

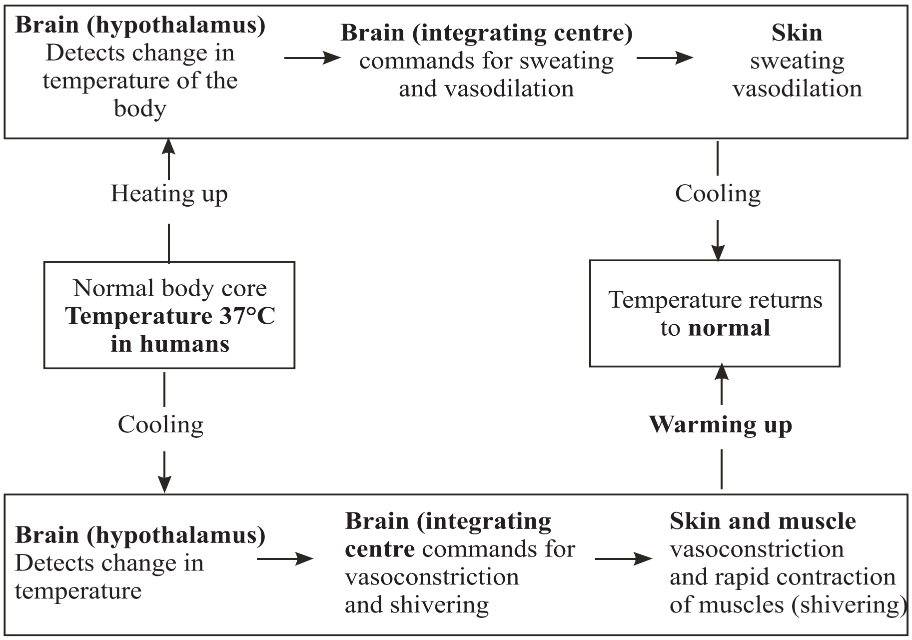


Fig 18.2 Mechanism of temperature control in humans

18.4.4 Types of Regulatory Systems– Physiological and Behavioral

The regulatory steps for thermoregulation in humans as described above can be considered under two headings – **physiological** and **behavioral.**

Physiological regulation : Changes in blood circulation like vasodilation or vasoconstriction, sweating or not sweating, increase or decrease in cell metabolism, shivering, etc. All these adjustments are not under the control of will.

Behavioral regulation. It includes the conscious and subconscious acts. For example:

When it is hot we often

- Fan ourselves (to promote evaporation of sweat)
- Move to any shaded or cooler place,
- Stretch out the limbs while resting in the bed.

When it is cold we

- move to warmer places (open sunshine or in front of heat radiators)
- prevent entry of cold winds (close the windows)
- wrap ourselves inside blanket (to cut down heat radiation)
- fold both arms or both arms and legs tightly close to the body (to reduce radiation of heat from the body).

INTEXT QUESTIONS 18.4

1. Rearrange the following in their correct sequence in homeostasis:

   Effector, Set point, Integrating centre, Sensor.

   ....

2. State in one word or sentence :

   (i) The normal body core temperature of humans.

   ....

   (ii) The function of feathers in bird and the hairs of rabbit.

   ....

   (iii) Effect of shivering.

   ....

18.5 FEEDBACK MECHANISMS–NEGATIVE AND POSITIVE

The feedback in the living systems are of two types: negative to reverse a condition and positive to continue in the direction of the change.

In thermoregulation the kind of feedback mechanism operating is of the negative type. Any **deviation from the set point has to be reversed** to bring it back to the normal condition. Therefore, a command has to be given to the organs concerned to function in a manner so that the deviation is corrected and brought back to the normal state.

Positive feedback is very rare in the living systems. One such example is that of coagulation of blood. This process includes several steps in succession. The first feedback does not revive the set point, so it is not a negative feedback, instead it produces the next and the third and so on until the last one completes the process by plugging the cut in the blood vessel. All the feedback mechanisms in blood coagulation are of the positive type.

INTEXT QUESTIONS 18.5

1. Name the two kinds of feed back mechanisms.

   ....

2. Which kind of feed back mechanism normally operates in homeostasis?

   ....

WHAT YOU HAVE LEARNT

- The term homeostasis means steady state. The homeostatic processes keep the conditions in the body within narrow limits.
- Homeostasis occurs for several conditions in the body such as water content, sugar level, body temperature, etc.
- Most homeostatic regulations work through negative feed back which means reversing the change to the norm. Very seldom there is positive feedback which produces changes in the same direction as the first one.
- Enzymes are highly sensitive to temperature changes. They work best at about 37°C called optimum temperature.
- The animals are categorized into two groups: Endotherms with internal heat-regulating mechanisms such as birds and mammals, and ectotherms whose body temperature rises or falls with that of the surroundings, such as frogs, fishes, insects, etc.
- The endotherms have a variety of heat regulating systems such as sweating and vasodilation to lose heat during hot weather, increasing body metabolism or shivering to generate heat and presence of heat insulating structures like feathers, hairs and subcutaneous fat when it is cold.
- The ectotherms avoid excessive cold or excessive heat by hiding underground – hibernation(winter sleep) and aestivation (summer sleep)
- All homeostatic mechanisms consist of a norm or set point, a sensor, an integrating centre and the effectors.
- In thermoregulation in humans, the sense receptors in skin and hypothalamus serve as sensor, hypothalamus and some adjoining parts of the brain as integrating centre, and the skin, blood vessels contained in the skin and skeletal muscles etc serve as effectors.

TERMINAL EXERCISES

1. List the three conditions necessary for the body cells to function properly.
2. When do we pass out more concentrated urine–during hot summers or cold winters ?
3. How does our body deal with any extra sugar absorbed into the blood after meals?
4. What is our normal RBC count per cubic millimetre? Will it go up or go down if a plain dweller shifts to a mountain or hill?

5. In which temperature range do the enzymes in our body act best?
6. Name the two terms often used synonymously for ectotherms.
7. Name any two animals, which tolerate the intense heat of the deserts by promoting heat loss.
8. Which kind of feedback mechanism–the positive or the negative, normally operates in bringing about water-salt balance in our body.
9. How is the enzymatic activity affected upon cooling?
10. How do honeybees fight cold during intense winter?
11. Differentiate between the two terms homeotherms and poikilotherms.
12. Give any two examples of preventing loss of body heat by postural behaviour in humans.
13. List the components of homeostasis in their proper sequence.
14. Differentiate between positive and negative feedback mechanism.
15. Explain the role of the following in thermoregulation in humans:
    (i) Sweat glands
    (ii) Skeletal muscles
    (iii) Blood vessels in the skin
16. What is meant by feed back mechanism? What are its two types? Which one of these is applicable to thermoregulation and why?
17. Why is thermoregulation required in our body?
18. Differentiate between endotherms and ectotherms. Which ones of these do you think can survive better if there is a suden change in environmental temperature?
19. Differentiate between physiological and behavioral responses for thermoregulation in humans.
20. Explain the role of hypothalamus during heat regulation in humans.
21. Explain the relationship between sensor and integrating centre during any one kind of homeostasis.

ANSWERS TO INTEXT QUESTIONS

18.1 1. Homeostasis is the regulation of a steady internal condition.
2. (i) sugar, (ii) salt, (iii) water
3. The body adds more RBCs to the blood

18.2 1. (i) Denatured (ii) inactive
2. (i) 35-40°C, (ii) Optimum temperature

18.3 1. Endotherms : Camel, Bat, Polar bear, sparrow

Ectotherms : Earthworm, Cockroach, Fish, Wall lizard

2. Poikilotherms : Animals whose body temperature changes along with that of the surroundings

Warm blooded : Animals whose body temperature remains steady and does not change with that of the surroundings

3. **Crocodile :** Basks in the sun on the land

Honey bees : Crowd together for collective warmth

Common frog : Hibernates

Wall lizard : Hides at safe places

18.4 1. Set point, Sensor, Integrating centre, Effectors

2. (i) 37°C (ii) trap air to prevent heat loss

(iii) warms up in cold weather

18.5 1. Negative and positive

2. Negative.

19

REPRODUCTION IN PLANTS

Reproduction is one of the most important characteristics of all living beings. It is the production of ones own kind. It is necessary for the continuation of the species on earth and also to replace the dead members of the species. The process by which living organisms produce their offsprings for the continuity of the species is called reproduction.

The modes of reproduction vary according to individual species and available conditions. It may be simply by division of the parent cell as in unicellular organisms, by fragmentation of the parent body, by formation of buds and spores, or it may be very elaborate involving development of male and female reproductive organs (stamens and pistils). Irrespective of the mode of reproduction, all organisms pass on their hereditary material to their offsprings during the process of reproduction. In this lesson, you will study about the process of reproduction in plants.

OBJECTIVES

After completing this lesson, you will be able to :

- *define reproduction;*
- *differentiate between vegetative, asexual and sexual reproduction;*
- *describe the methods of asexual and sexual reproduction in unicellular lower plant (Chlamydomonas) and filamentous green alga (Spirogyra);*
- *describe the mode of reproduction in flowering plants;*
- *explain the parts of a dicot flower and their functions;*
- *describe stages of microsporogenesis;*
- *depict with the help of diagram the structure of ovule and mention the steps of megasporogenesis;*

- *describe the stages of development of male and female gametophytes in flowering plants;*
- *state the types of pollination, their significance and various modes of pollination;*
- *explain the steps involved in fertilization, (syngamy and triple fusion), embryo development, endosperm development, formation of seed;*
- *differentiate between structure of dicot and monocot seeds;*
- *explain the formation of fruit and parthenocarpy;*
- *describe seed germination;*
- *define vegetative reproduction;*
- *differentiate between natural and artificial propagation;*
- *explain the advantages and disadvantages of vegetative propagation;*
- *describe the role of tissue culture technique in micropropagation;*
- *state the advantages of micropropagation;*

19.1 MODES OF REPRODUCTION

The various modes by which plants reproduce are of three types –

(a) Vegetative (b) Asexual (c) Sexual

In **Asexual** and **vegetative** mode of reproduction, offsprings are produced from a vegetative unit formed by a parent without any fusion of gametes or sex cells.

– A single parent is involved

– Offsprings are genetically identical to the parent.

(a) Vegetative reproduction may be of the following types—

(i) **Vegetative reproduction :** It involves formation of new plantlets from vegetative (somatic) cell, buds or organs of the plant. Here, a vegetative part of the plant (Root, stem, leaf or bud) gets detached from the parent body and grows into an independent plant. It is similar to asexual reproduciton in that it also requires only mitotic division, no gametic fusion is involved, and newly-formed plants are genetic clones of the parent plant.

We will discuss the different types of vegetative reproduction in angiosperms later in this lesson.

(ii) **Fragmentation :** In filamentous algae, an accidental breaking of the filament into many fragments, each fragment having atleast one cell, may give rise to a new filament of the algae by cell division e.g. *Spirogyra*.

(iii) **Fission :** It Occurs in unicellular organisms like bacteria and yeasts where the content of the parent cell divides into 2, 4 or 8 daughter cells and accordingly the fission is known as **binary** or **multiple** fission. Each newly formed daughter cell grows into a new organism.

(iv) **Budding :** It also occurs in unicellular plants. A bud-like outgrowth is formed on one side of the parent cell and soon it separates and grows into a new individual e.g. in yeast.

(b) **Asexual Reproduction :** Takes place by asexual spores which may be flagellate or nonflagellate.

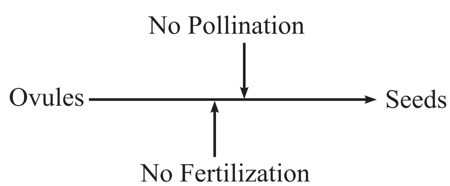
Spore formation : In lower plants including bryophytes and pteridophytes, special reproductive units develop asexually on the parent body. These are called spores. They are microscopic and covered by a protective wall. When they reach the suitable environment they develop into a new plant body e.g. in bread moulds, moss, fern. In higher plants like pea, maize and gymnosperms, asexual reproduction is always heterosporous. Here, spores are produced after meiosis. The small male spores called microspores give rise to male gametophyte. The large female spores are called megaspores, and they give rise to female gametophytes.

(c) **Sexual reproduction** involves fusion of male and female reproductive cells (gametes) which are haploid and are produced by male and female reproductive organs. This fusion is known as **fertilization** and results in the production of a **zygote (diploid)**. Further development of zygote gives rise to a new individual which is diploid.

Here, at some stage of the life history meiosis is involved and the offsprings are not genetic clones of their parents, but are genetically different and generally exhibit mixed characters of their parents.

19.1.1 Apomixis

Apomixis is a unique mechanism of asexual reproduction in certain plants (e.g. dandelions) which produce seeds without pollination and fertilization. (In Greek, apomixis means 'away from act of mixing'). Since there is no fusion of male and female gamete, any somatic cell of ovule which is diploid, gives rise to the embryo and then ovule matures into a seed. The seeds are then dispersed. The interesting fact is that apomixis is an asexual process but disperses its seeds like those of plants that undergo sexual reproduction.



INTEXT QUESTIONS 19.1

1. Define reproduction.

....

2. How is asexual reproduction different from sexual reproduction?

....

3. What is a gamete?

....

4. Name two types of vegetative reproduction.

....

5. Choose the correct option

   Apomixis is:

   (a) Development of plants in darkness
   (b) Development of plants without fusion of gametes
   (c) Inability to perceive stimulus for flowering
   (d) Effect of low temperature on plant growth

19.2 REPRODUCTION IN LOWER PLANTS

We will study the different types of reproduciton in two lower plants, one unicellular alga (*Chlamydomonas*) and the other multicellular filamentous alga (*Spirogyra*).

19.2.1 *Chlamydomonas* (A Unicellular Alga)

(i) It is a haploid unicellular alga found in fresh water ponds:

(ii) The plant body is pear-shaped with two flagella attached at the narrow end.

(iii) On one side of the cell, a light sensitive eye spot is present.

(iv) A large cup-shaped chloroplast is present.

(v) Towards the centre, a definite nucleus is present.

(vi) Chloroplast contains a single pyrenoid. (Fig. 19.1a).

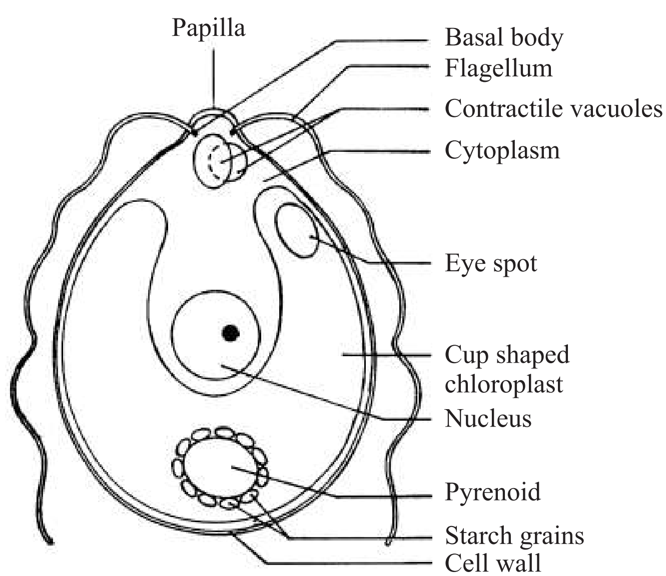


Fig. 19.1a *A Chlamydomonas* cell

Reproduction

A. Asexual reproduction takes place with the help of zoospores, aplanospores or hypnospores depending upon the availability of water for swimming.

Asexual Reproduction by Zoospores :

- If plenty of water is available for free swimming, *Chlamydomonas* reproduces by flagellate thin-walled spores, called zoospores.
- *Chlamydomonas* cell loses flagella and becomes non-motile.
- Its protoplasm (cytoplasm and nucleus) divides mitotically and forms 2-16 daughter protoplasts, each of which develops flagella, and is called a zoospore.
- The parent cell wall is ruptured and zoospores are released.
- Each zoospore develops a cell wall and grows into an adult cell. (Fig. 19.2-b, c)
- After release of zoospores the parent cell does not exist, any more.

A. Asexual Reproduction by Aplanospores and Hypnospores :

- If a thin-film of water is available where swimming is not possible, **Chlamydomonas** produces thin-walled, non-flagellate daughter protoplasts, called aplanospores.
- The parent cell loses flagella and becomes highly extended. Its protoplast divides repeatedly to produce 100 or more daughter protoplasts, each of which is called an **aplanospore**.
- The whole structure containing groups of non-motile aplanospores resembles a non-motile Colonial alga, called **Palmella**, and so this is called **palmella stage** of **Chlamydomonas**.
- If plamella-stage is flooded with water, each aplanospore develops flagella, comes out of the parent cell wall and grows into a normal independent plant.
- If water suddenly dries up, some of the aplanospores develop thick-wall, each of which becomes dark brown or black, and is called a **hypnospore.** When favourable conditions are present and water is available for swimming, each hypnospore ruptures to release protoplast that develops flagella, becomes a zoospore and grows into normal ***Chlamydomonas***-plant.

B. Sexual Reproduction

Chlamydomonas reproduces sexually by isogamy, anisogamy or Oogamy depending upon the species :

Sexual Reproduction by Isogamy

- Isogamy is exhibited by **Chlamydomonas eugametos** and **C. eherenburgii.**
- The male and female cells become non-motile by losing their flagella.

- The protoplasm of each cell divides mitotically into 32-64 daughter cells.
- Each daughter cell develops flagella and is released in water by the rupture of mother cell wall. Each of these cells acts as a gamete.
- The gametes are morphologically identical in structure but differ physiologically or chemically.
- Gametes released in water from two different mother cells fuse in pairs forming quadriflagellate zygotes.
- When the contents of the two gametes fuse, they form a zygote (diploid). This is the only diploid stage in the life cycle of *Chlamydomonas*.
- The zygote develops a thick wall around itself and develops brown to black coloured pigmentation to tide over unfavourable conditions (zygospores).
- On the return of favourable conditions (temperature, food and water) the diploid nucleus of the zygote divides by meiosis and forms four haploid zoospores. (Fig. 19.2 d-i)
- Each zoospore grows into a new adult *Chlamydomonas* plant.

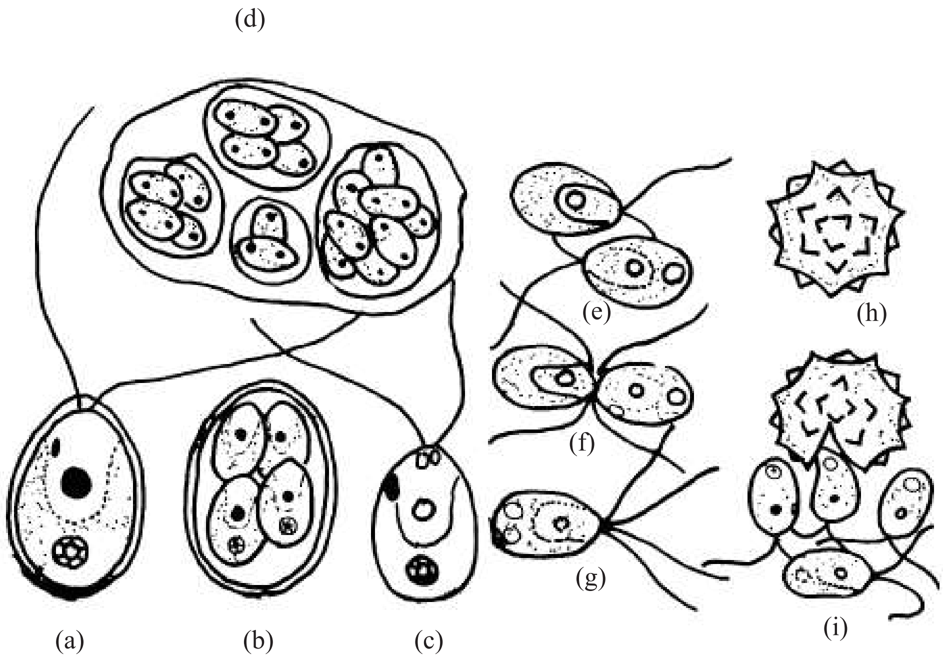
Sexual Reproduction by Anisogamy

- Anisogany is exhibited by ***Chalamydomonas braunii***.
- Male and female cells lose flagella and become non-motile.
- In male cell, protoplast divides repeatedly to produce 32-64 biflagellate gametes but in female cell, protoplast divides to produce 8 to 16 biflagellate gametes.
- Both male and female gametes are released in water.
- When larger female gametes lose flagella and become non-motile, each one is fertilized by a smaller motile male gamete.
- After fertilization, the fusion product loses flagella, becomes spherical and develops thick wall to become a resting zygote.
- On return of favourable conditions of water, temperature and light, the zygote undergoes meiosis and produces four haploid zoospores each of which grows into an independent *Chlamydomonas* plant.

Sexual Reproduction by Oogamy

- Oogamy is exhibited in ***Chlamydomonas coccifera*** and ***C.ooganum***.
- Here, female and male cells lose flagella and become non-motite.
- All the contents of female cell act as female gamete or egg, but the protoplasm of male cell divides to produce 32-64 biflagellate gametes.
- The biflagellate gametes are liberated in water and swim around in search of female gamete.
- Two or more flagellate gametes enter each female cell having nonmotile egg but only one fertilizes the egg and others degenerate, contributing nutrition to the young zygote.

- The fusion product of egg and a motile gamete is called zygote that develops a thick, pigmented wall to enter into resting phase.
- On return of favourable conditions of water, temperature and light, the zygote undergoes meiosis to produce four haploid biflagellate zoospores, each of which on liberation from zygote, grows into an independent plant of *Chlamydomonas*.



(a) Mature cell (b) 4 daughter cells (Zoospores formed by Asexual reproduction) (c) Zoospore after it escapes from the parent cell (d) Palmella-stage of *Chlamydomonas* (e, f, g) Free swimming gametes and fusion of gametes (h) a resting zygote (i) 4 cells formed after meiosis of the zygote cell (zygospores)

Fig. 19.2 Asexual and Sexual reproduction in *Chlamydomonas*

INTEXT QUESTIONS 19.2

1. Define the term isogamy. Which species of *Chlamydomonas* exhibits isogamy.

   ....

2. Where does meiosis occur in *Chlamydomonas* ?

   ....

3. Give the method of asexual reproduction in *Chlamydomonas*. What is the function of zoospores in *Chlamydomonas*.

   ....

4. Name the speicies of *Chlamydomonas* that reproduces by Anisogamy and the species that reproduces by Oogamy.

   ....

5. Define the term zoospore and aplanospore.

   ....

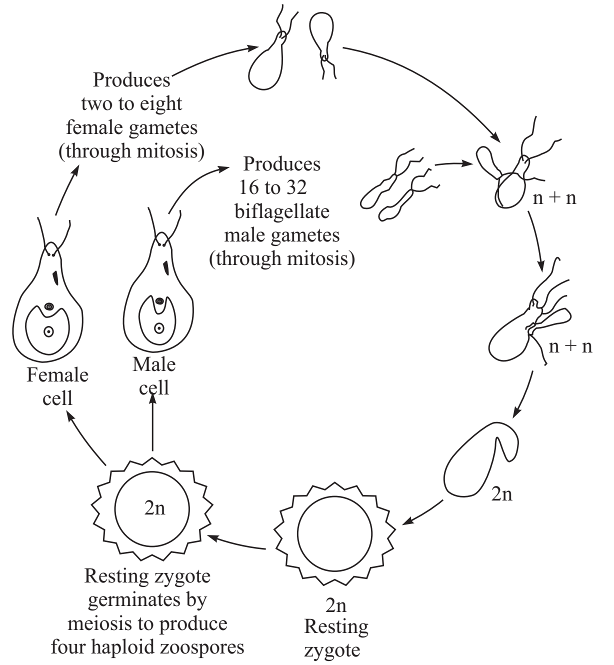


Fig. 19.3 Sexual Reproduction by Anisogamy in *C.braunii*

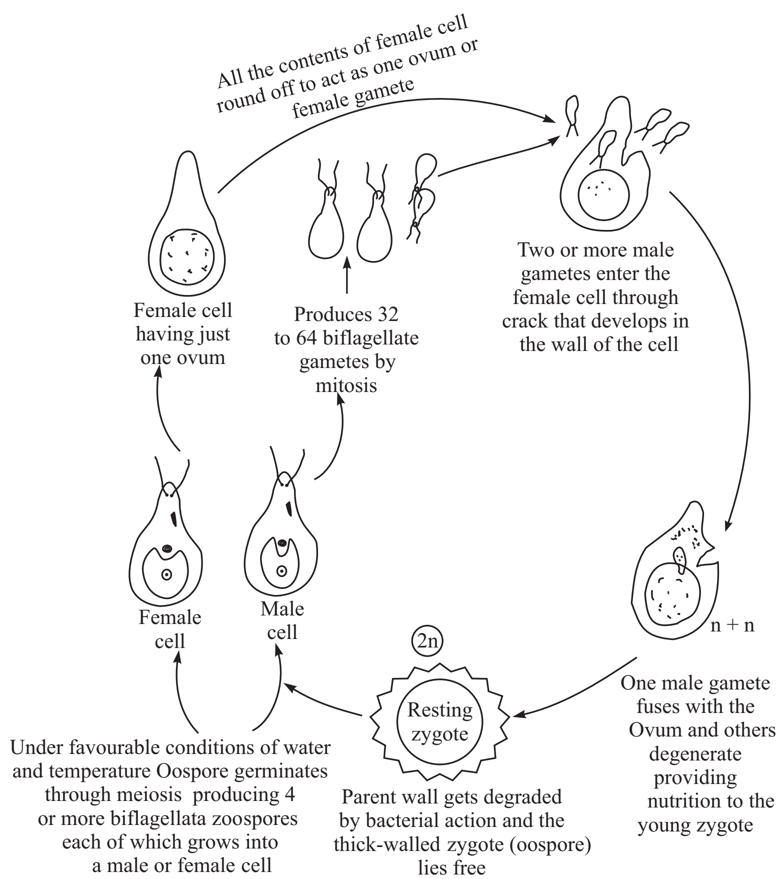


Fig. 19.4 Sexual Reproduction by Oogamy as in ***C.oogamum*** and ***C. coccifera***

19.2.2 *Spirogyra* (A Multicellular Alga)

Structure

(i) It is a free floating alga found in fresh water ponds.

(ii) The body has a row of cylindrical cells joined end to end (filamentous alga).

(iii) Each cell depending upon the species, may have 1 to 14, spiral ribbon shaped chloroplasts with many uni-seriately arranged pyrenoids.

(iv) Central region of the cells has a large vacuole.

(v) The single nucleus is present in the centre of the cells supported by cytoplasmic strands. (Fig. 19.5)

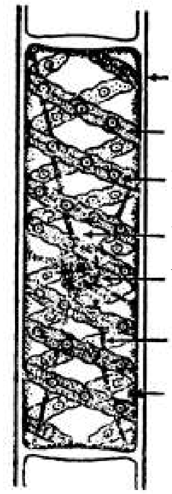


Fig. 19.5 *Spirogyra* : Single cell from the filament.

Reproduction

A. Vegetative Reproduction by fragmentation:

(i) The filament breaks into small fragments, at the point of transverse septum following a physico-chemical change.

(ii) Each fragment having at least one complete cell grows into a new filament by repeated mitotic cell division.

B. Sexual Reproduction : It takes place by scalariform and lateral conjugation.

Scalariform Conjugation (conjugating filaments give a ladder-like appearance). (Fig. 19.6)

- Two filaments come to lie very close to each other so that the cells of the two filaments pair septum to septum and face to face.
- The pairing cells of the two filaments form a contact with the help of a tube called the conjugation tube.
- Cytoplasmic contents of each cell round off to act as a gamete.
- Gamete from one cell (male) passes to the other cell (female) through the conjugation tube, by amoeboid movement.
- The cells of each filament acts either as male or female.
- The contents of two gametes fuse in the female cell and form a diploid zygote. Consequently, after the sexual fusion of gametes, all the cells of male fitament are empty whereas each cell of the female filament has one thick-walled diploid **zygospore**.

- The zygospore develops a thick wall around itself and develops dark brown to black pigment to tide over the unfavourable period.
- On the return of favourable conditions the diploid nucleus divides by meiosis into four haploid nuclei. Three of these nuclei degenerate.
- On germination, wall of the zygospore ruptures and a small tube like structure, containing one haploid nucleus comes out.
- The small tube develops into a long filament by repeated mitotic cell divisions.

Lateral Conjugation

- Here, cells of only one filament are involved in conjugation wherein, male and female cells are arranged in alternate pairs i.e., two male cells alternate with two female cells all along the length of a filament.
- Conjugation tube is formed lateral to the septum separating a male and a female cell. Protoplasm of male cells migrate into female cells.
- After fertilization, a filament would show two empty cells alternating with two cells each having thick-walled diploid zygospore.
- The zygospore under favourabe conditions, germinates as in scalariform conjugation to produce only one independent plant, because 3 haploid nuclei after meiosis, degenerate.

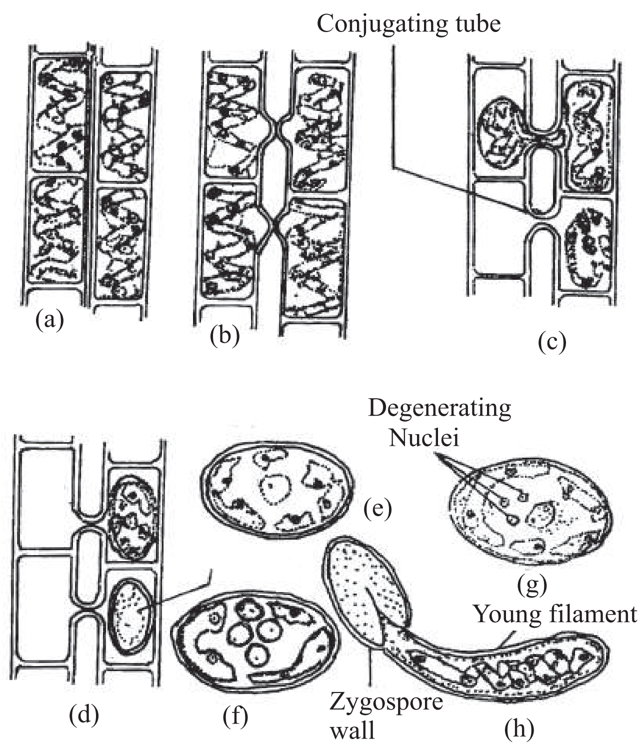


Fig. 19.6 Life cycle of *Spirogyra*: Sexual reproduction-Scalariform conjugation. (a) Two Filaments lie close, (b) Formation of conjugation tube, (c) Transfer of gamete from the donor to the recipient cell, (d) Zygospore within the recipient cell, (e) Zygospore released from female filaments, (f) Meiotic division in zygospore produces haploid nuclei, (g) 3- haploid nuclei degenerate, (h) formation of young filament

The cell in the main plant body form the gametes without meiosis, therefore *Chlamydomonas* and *Spirogyra* are gametophytes (haploid).

INTEXT QUESTIONS 19.3

1. Vegetative reproduction in *Spirogyra* takes place by means of

   ....

2. Name the kind of sexual reproduction that occurs in *Spirogyra*.

   ....

3. When does meiosis occur in *Spirogyra* ?

   ....

4. How many filaments are involved in lateral conjugation ?

   ....

19.3 REPRODUCTION IN ANGIOSPERMS (FLOWERING PLANTS)

Angiosperms reproduce both by vegetative as well as by sexual methods. In this section we will study the sexual reproduciton in angiosperms. As you know sexual reproduction occurs by fusion of male and female gametes produced in the flower. Thus, flower represents the reproductive unit of a flowering plant.

How frequently do plants flower? There is great variation shown by the angiospermic plants in this respect.

Angiosperms can be classified as annuals, biennials and perennials depending upon the time they take to complete the life cycle includings flowering, fruiting, and death.

(a) **Annuals :** The plants which complete their life cycle including flowering to seed formation within **one season** are called annuals eg. pea

(b) **Biennials :** Plants which complete their life cycle in **two seasons** are called biennials. In the first season these plants remain in the vegetative state, and in the second season, they produce flowers, fruits, and seeds and then die e.g. radish.

(c) **Perennials :** Plants which live for **several years** are termed perennials. Their vegetative stage may last from one to a few years after which they produce flowers, fruits, and seeds every year e.g. mango, peepal, and neem.

(d) **Monocarpic :** All the annuals, all the biennials and, some perennial plants that reproduce only once in their life-time and then die, are called Monocarpic e.g. bamboo, agave, all the annuals and all the biennials.

(e) **Polycarpic :** Plants which flower and fruit many times in their life cycle and live for several years, are called polycarpic e.g. many perennial fruit bearing trees e.g. mango, guava, apple and pear.

Initiation of flowering

As the seed germinates a new plantlet emerges from it. The young plant grows vigorously and continues to grow till it attains a definite shape and size with its vegetative parts (roots, stem, leaves) well developed. This phase of the life cycle represents the **young** or the **juvenile** phase.

Then, at a certain point of time on completion of vegetative growth the plant switches over to its **reproductive phase** or **adult phase** and vegetative shoot apex transforms into a reproductive or **floral apex** and starts bearing flowers. This transition from vegetative to the flowering stage may take several years in trees but only a few weeks or days in annuals.

Table 19.1 Differences between a Juvenile and an Adult Shoot

Juvenile Shoot	Adult Shoot
1. Small, soft stem bearing a few young leaves.	1. Well developed branched stem bearing young as well as mature leaves.
2. Shape and size of leaves remain same.	2. Shape and size of leaves change.
3. Shoot does not respond to stimuli to produce flowers.	3. Shoot responds to stimuli to produce flowers.

> In cereals a minimum of seven leaves must be developed before the plant can produce flowers.

Factors Affecting Flowering

Flowering in a plant is affected by *temperature* (vernalisation) and *light (photoperiodism).*

Vernalisation : Low temperature treatment which stimulates early flower formation in some plants is called **vernalisation**.

Photoperiodism : It is the biological response, in growth and flowering, to the duration of light and dark period received by a plant in a specific sequence. (For details refer to lesson 19).

Sex in flowers : You have studied in Lesson 5 on Shoot System (flower, inflorescence, fruit and families), that flowers may be bisexual (having both stamens and carpels) or unisexual (staminate or pistillate (carpellate)).

In some dioecious species there may be a (i) chromosomal basis of sex-determination, for example **xx** and **xy** chromosomes. (ii) The male and female plants may also exhibit differences in the levels of their growth substances. For example – plants of *Cucumis* which bear male flowers have a high gibberellin content as compared to those which bear only female flowers. The application of gibberellin from outside can induce the formation of male flowers even in genetically female plants and treating male plants with auxin or ethylene may develop functional female flowers. The above response has also been seen in *Cannabis*.

Parts of a flower

As you have already studied a typical flower bears four whorls born on a thalamus or stalk. These whorls from outside are

(a) Calyx - consisting of sepals.

(b) Corolla - consisting of petals

(c) Androecium - consisting of stamens

(d) Gynoecium or pistil - consisting of carpels.

Try to recollect their role in reproduction. The two outermost whorls are known as **non essential** or **accessory whorls** as they aid in reproduction but do not directly take part in the process. The other two whorls i.e. **Androecium** (male reproductive organ) and **Gynoecium** (female reproductive organ) are known as the **essential whorls** as their absence from flowers will lead to failure of sexual reproduction.

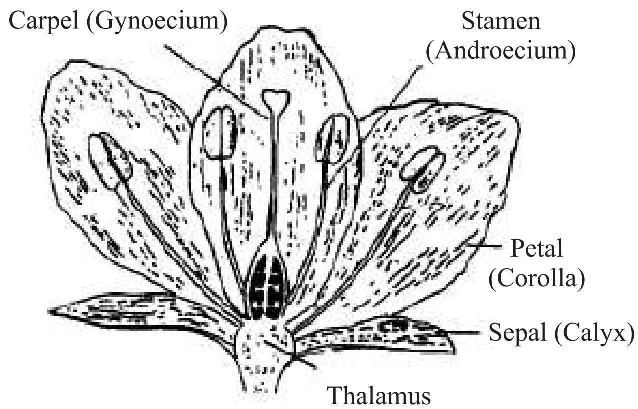


Fig. 19.5 L.S. of a typical flower

INTEXT QUESTIONS 19.4

1. Define the terms (i) Annual (ii) Biennial (iii) Perennial

   ....

2. List the factors which induce flowering

   ....

3. Give one example where external application of hormone can reverse the sex of a flower

   ....

4. Name the essential whorls in a flower.

   ....

19.4 STAMEN, MICROSPORANGIA AND POLLEN GRAIN

Stamen consists of an **anther** containing four pollen sacs or **microsporangia**, supported by a slender filament. Each sporangium contains mass of large cells showing prominent nucleus and abundant cytoplasm. These are the sporogenous cells or the microspore mother cells (Fig. 19.6). Each microsporangium when mature, has a wall made up of distinct layers of cells.

(i) Outer most layer (epidermis)

(ii) Middle layer of thin-walled cells.

(iii) Innermost layer, the *tapetum* consisting of large cells, which nourish the developing pollen grains.

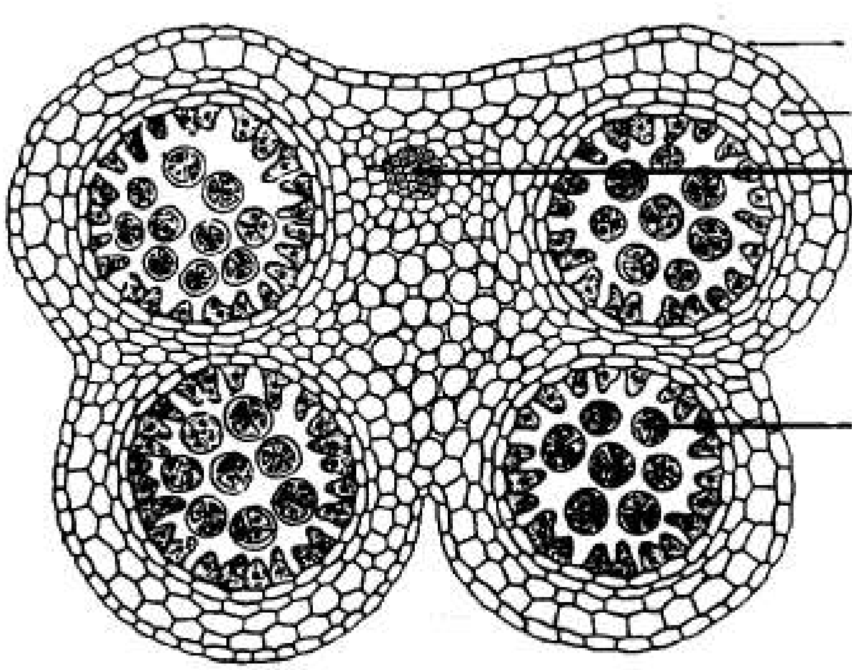


Fig. 19.6 T.S. of anther to show the various tissues.

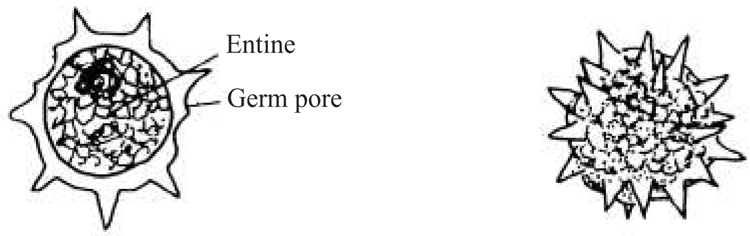
Microspore mother cells undergo meiosis and each of them forms four *haploid* microspores (each of which represents first cell of male gametophyte or the pollen-grain) arranged in a tetrad (Fig. 19.7a)

Development of male gametophyte (pollen grains) from a microspore

(i) The wall of the microspore consists of two principal layers. (Fig. 19.7b)

   1. Outer exine, (design may help in identifying species) with some thin spaces (germ pores). Exine is made up of extremely durable substance called sporopollenin. The pollen tube grows out of the pollen grain through the germ pores.
   2. Inner, thin cellulosic wall, the intine.

(ii) The microspore nucleus moves towards periphery and the cell divides into a large vegetative cell and a small generative cell.



(a) A pollen grain showing internal view (b) Pollen grain showing external view

Fig. 19.7 Structure of pollen grain

At this stage pollen grains are released by the rupture of the stomium along the line of dehiscence of the anther.

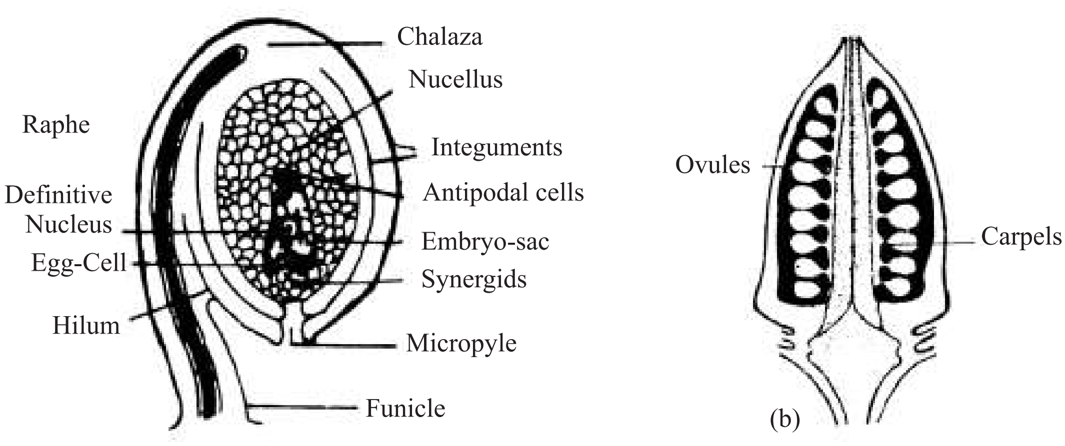
> The Pollen grain itself is not, the male gamete. It is a structure which produces male gametes, therefore pollen grain is regarded as the male gametophyte in the flowering plants.

The pistil, megasporangium and embryo sac

The main part of the ovule is enclosed by two integument (covering) leaving an aperture (micropyle). The ovule is attached to ovary wall by a stalk (funiculus). The region of the ovule opposite the micropyle is called Chalaza (Fig. 19.8a)

Female gametophyte :

The gynoecium or pistil represents the female reproductive part in the flower. Each pistil consists of a stigma, style and ovary. The ovary contains one or more ovules (integumented megasporangia) which after fertilization, give rise to the future seeds. An ovule develops as a projection on the placenta in the ovary. It consists of a parenchymatous tissue called the nucellus which is covered by one or two coverings called integuments. The integuments surround the nucellus all around but leave a narrow passage, the micropyle, through which a pollen tube may enter at a later stage. As the ovule grows it is raised on a stalk like structure called funiculus which is attached to the placenta borne on the inner wall of ovary (Fig. 19.8b).



(a)

Fig. 19.8 (a) Various parts of ovule (b) Pistil

Development of female gametophyte

Within the nucellus, a single hypodermal cell (below the epidermis) enlarges and becomes the megaspore mother cell, which undergoes meiotic division and gives rise to four haploid megaspore cells, usually three of them degenerate and the remaining one becomes the functional megaspore. The functional megaspore enlarges and its haploid nucleus undergoes three successive mitotic divisions. As a result 8 haploid nuclei are formed. This enlarged oval shaped structure with eight haploid nuclei is referred as the young **embryo sac**. These nuclei then migrate and get arranged into three groups. Three nuclei reach the micropylar end of the embryo sac and other three move in the opposite direction (i.e. the chalazal end) and the remaining two remain in the centre. The cell membranes and cell walls develop around all the nuclei excepting the two at the centre of the embryo sac which now is called the central cell.

Thus, in a mature ovule the embryo sac contains eight haploid nuclei but only seven cells. Three cells at the micropylar end, form the egg apparatus and the three cells at the chalazal end, are the antipodal cells. The remaining two nuclei called the polar nuclei may fuse to form the diploid secondary nucleus. In the egg apparatus one is the egg cell (female gamete) and remaining two cells are the synergids. A fully developed embryo sac with the nucellus, integuments and funiculus, together constitute the mature ovule. In this condition the ovule awaits fertilization which must be preceded by pollination.

Function of cells and nuclei of embryo sac

Secondary Nucleus : During fertilization, the secondary nucleus fuses with one sperm to form a triple fusion nucleus ($2n+n = 3n$). This is called primary endosperm nucleus. It gives rise to the food storing **endosperm** of the seed in many plants.

Egg Cell : Fuses with the second male gamete (sperm) to give rise to the **zygote,** which develops into the embryo. This is called double fertilization.

Synergid Cells : Considered to help in fertilization by directing the pollen tube to the egg cell.

Antipodal Cells : Degenerate just before fertilization and contribute nutrition for the young embryo.

INTEXT QUESTIONS 19.5

1. What is the innermost wall layer of microsporangium called?

    ....

2. Name the organ where pollen grains are formed.

   ....

3. Name the two layers of pollen grain .... and ....
4. Name two parts of a mature ovule.

   ....

19.4.1 Pollination

When mature pollen grains, released from anther, are carried to stigma of a flower of the same or different species, it is called pollination.

> **Pollination : Transfer of pollen grains from the anther to the stigma of a flower.**

Pollination is of two types:

Pollination

Self-pollination	Cross-pollination
Transfer of Pollen grains to stigma of the same or from another flower borne on the same plant as in the pea family e.g. pea and gram.	Transfer of Pollen grains from a flower to stigma of another flower borne on another plant of the same species e.g. in palm and maize.

Importance of Pollination :

1. It results in fertilization and stimulates the ovule to get converted into seed.
2. New varieties of plants are formed through new combination of genes in case of cross pollination.
3. During pollination pollen tube produces growth hormones which stimulate ovary to develop into fruit.

Cross pollination is brought about by various external agencies such as, wind, insects, water, birds and other animals. Now let us study the various agencies of cross pollination which carry pollen grains from one flower to stigma of another flower.

Characteristics in Flowers which favour Cross Pollination

1. **Pollination by wind (Anemophily) :** (Anemos : wind, Phile: to love)

   (i) Flowers are small, without colour, nectar and scent.

   (ii) Flowers produce a large number of pollen grains to allow for wastage when pollen-grains are carried by wind to another flower.

   (iii) The pollen grains are small, light and sometimes provided with 'Wings'.

   (iv) The stigmas are comparatively large, protruding and some times hairy, to trap pollen grains from wind for example, grasses and some cacti.

2. **Pollination by insects (Entomophily) :** (entomo : insect, phile : to love)
   (i) Flowers are usually large, coloured and showy to attract insects.
   (ii) Some of these flowers secrete nectar to attract insects. *Salvia* flowers show special adaptations for pollination by bees. (Fig. 19.9a, b).

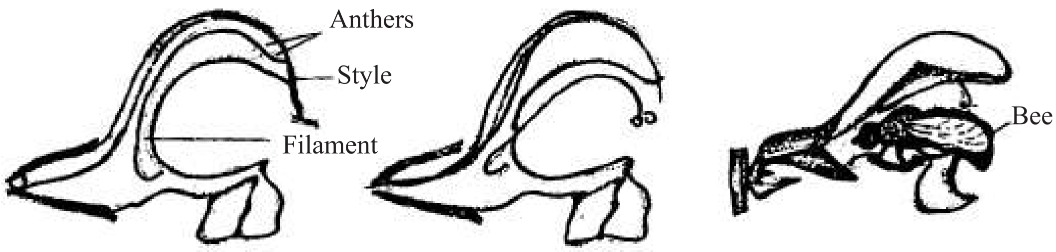


Fig. 19.9 Pollination in *Salvia* by bees

3. **Pollination by Water (Hydrophily)** (Hydros : water)
   This takes place in aquatic plants.
   (i) Pollen grains are produced in large numbers.
   (ii) Pollen grains float on surface of water till they land on the stigma of female flowers e.g. *Hydrilla*, *Vallisnaria*.
4. **Pollination by Animals (Zoophily)** (Zoon : animal)

Flowers of such plants attract animals by their bright colour, size, and scent for example sun bird, pollinates flowers of *Canna*, and gladioli, and Squirrels pollinate flowers of silk cotton tree.

> Humans carry out artificial pollination in a number of plants for producing desirable hybrids.

Some Adaptations to Promote Cross Pollination :

1. **Unisexuality :** Flowers may be only male or female, borne on different plants e.g. papaya, palm, or may be borne on the same plant, e.g. maize.
2. **Dichogamy :** Male and female sex organs mature at different times. In sweet pea, and *Salvia*, Anther matures earlier than the stigma and in custard apple (sharifa) carpel matures earlier than the anther.
3. **Self Sterility :** Pollen grains are incapable of affecting fertilization even after being placed on the stigma of the same flower e.g. Petunia, apple.

Devices to ensure self pollination :

(i) **Cleistogamy :** Flowers remain closed until pollination.
(ii) Male and female sex organs mature at the same time (**homogamy**) e.g. ground-nut.

INTEXT QUESTIONS 19.6

1. What is pollination?

    ....

2. Mention suitable terms for the following :

    (i) Flowers do not open and get self-pollinated.

    ....

    (ii) Male and female reproductive organs mature at different times.

    ....

3. Give two features of insect pollinated flowers :

    (i) ....

    (ii) ....

19.4.2 Fertilization

- Pollen grains on reaching the right stigma become three-celled (if they are not 3-celled bearing two male garmetes and one tube cell or vegetative cell) and begin to germinate.
- Each pollen grain forms a small tube like structure called pollen tube which emerges through the germ pore. The contents of the pollen grain move into the tube and the tube nucleus occupies the tip of the pollen tube.
- Pollen tube grows through the tissues of the stigma and style and finally enters the ovule through the *micropyle*.
- Vegetative nucleus or the tube nucleus degenerates and the two sperms (or male gametes), now occupy the tip of the pollen tube.
- Tip of pollen tube passes through one of the synergids and bursts to release the two sperms into the embryo sac.
- One sperm fuses with the egg (syngamy) and forms a diploid zygote. The other sperm fuses with the secondary nucleus to form the primary endosperm nucleus which is triploid in nature. Since two types of fusion, syngamy and triple fusion take place in an embryo sac, the process is termed as **double fertilization**.
- After triple fusion, the triploid primary endosperm cell develops into an endosperm.

- Endosperm provides food to the developing embryo.
- The synergids and antipodal cells also degenerate to contribute nutrition to the young embryo.

Significance of Fertilisation

(i) Gives stimulus for the growth of ovary, leading to fruit formation.

(ii) Helps in recombination of characters as genes from two different individuals combine and form the zygote.

Post fertilisation changes

Events that follow double fertilisation are development of endosperm and embryo and maturation of the ovule into seed and ovary into fruit.

(a) Endosperm : The endosperm development begins before embryo development. This is needed to provide the nutritive tissue for the growth of the zygote into an embryo. The primary endosperm cell divides repeatedly and forms an endosperm tissue. There are three ways in which the endosperm may develop.

Nuclear type : The primary endosperm nucleus undergoes repeated mitotic divisions to give rise to free nuclei which arrange themselves at the periphery leaving a large central space. Cell wall formation starts subsequently from periphery towards the centre and endosperm becomes cellular at maturity. This is the most common type of endosperm development and is seen in maize, wheat, and rice.

(b) In Cellular type, each nuclear division of primary endosperm nucleus is followed by cytokinesis, making the endosperm cellular from the beginning

(c) In Helobial endosperm, the first mitosis of primary endosperm nucleus is followed by cytokinesis and it gives rise to two unequal cells. Subsequently, mitotic divisions in both the cells are free nuclear but ultimately, mature endosperm becomes cellular after cytokinesis.

Endosperm may be completely consumed by the developing embryo before seed maturation as in many dicot seeds like pea, and beans or it may persist in the mature seeds or may even be massive considerably as in cereals, and coconut.

Development of embryo

(i) The zygote divides into two cells, the upper cell (embryonal cell) and; lower cell (suspensor cell). (Fig 19.10)

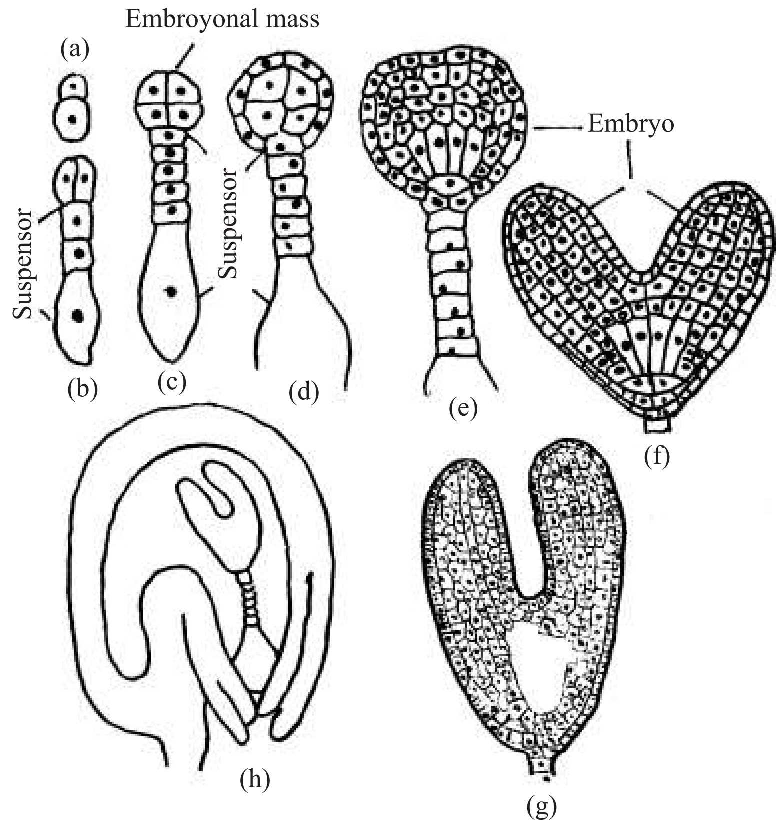


Fig. 19.10 Development of embryo, A-H

(ii) The lower cell divides and forms the suspensor.

(iii) The suspensor pushes the developing embryo into the endosperm to get food.

(iv) The embryonal cell divides several times and finally gets differentiated into radicle, plumule and cotyledon.

(v) The integuments become hardened and thus form the seed coat which protects the seed.

(vi) Thus, a seed may be dicotyledonous with two cotyledons (pea, gram) or monocotyledonous with one cotyledon (wheat, rice).

19.4.3 Polyembryony

Recall embryo development in plants from your text book. Polyembryony is the formation of **more than one embryo** in a single ovule. The development of extra embryos may be due to:

(i) Division of other cells in the embryo sac like synergids or antipodal cells to give rise to additional embryos. This is called **adventive polyembryony**.

(ii) The zygote may divide to give rise to two or more cells each of which develops into a separate embryo. This is called **cleavage polyembryony.**

19.4.4 Seed

The seed is defined as a **ripened ovule.**

- Seed
  - Seed coat
    - Testa
    - Tegmen
  - Embryo
    - Embryonal axis
      - Plumule
      - Radicle
    - Cotyledon (1 or 2)
  - Endosperm (only in albuminous seeds)

Importance of Seed

1. It contains embryo which develops into a new plant.
2. The seed coat protects the embryo against dehydration and mechanical damage.
3. Seeds can be stored and transported from one place to another and thus help in dispersal.

A. Structure of Gram (dicot) Seed :

(i) The seed is enclosed in the pod. (Fig. 19.11a)

(ii) It is somewhat conical in shape. (Fig. 19.11b)

(iii) The seed is attached to a small stalk.

(iv) The point of attachment of seed to the stalk is called hilum.

(v) Testa is the brown seed coat, fused with the inner coat the tegmen

(vi) Below it is a small pore, the micropyle.

(vii) The embryonal axis is enclosed by the two fleshy cotyledons. (Fig. 19.11c)

B. Structure of Maize grain : (Monocot)

(i) The maize grain is broader in shape. (Fig. 19.11d)

(ii) Testa and tegmen are fused together which are further inseparably fused with the pericarp.

(iii) The embryo is towards the narrower side of endosperm.

(iv) The endosperm stores starch and protein. The outermost layer which contains only protein is called aleurone layer.

(v) The embryo consists of one large cotyledon, called scutellum.

(vi) The embryonal axis lies lateral to the scutellum. (Fig. 19.11e)

Notes

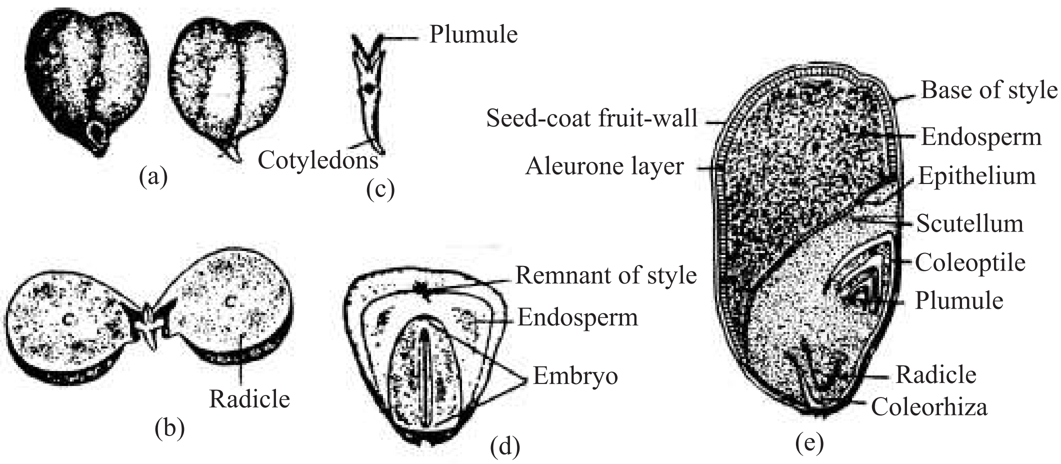


Fig. 19.11 Structure of dicot and monocot seeds : (a) External view of gram seed; (b) Internal structure of gram seed (c) embryo (gram) (d) Maize grain entire; (e) L.S. of maize grain

19.4.5 Fruit

A fruit is defined as a ripened ovary. Different parts are edible in different fruits.

Significance of Fruit :

1. It protects seeds.
2. On decay, fruits which contain chemical substances enrich the soil.
3. It helps in dispersal of seeds.

The unripe fruit has a different taste but no smell. But the same fruit when it ripens has a good taste and smell e.g. mango, banana. The following changes take place during the ripening of fruit :

(i) Starch is converted into sugar.

(ii) The production of various organic substances (esters) gives a different texture, taste and flavour.

(iii) The breakdown of chlorophyll leads to changes in colour of the skin of the fruit.

Parthenocarpy : When fertilisation fails, seeds are not formed. But in certain plants the ovary develops into a fruit e.g. grapes, and banana.

The phenomenon of development of fruit from unfertilised ovary is called **parthenocarpy** and such fruits which are seedless, are called parthenocarpic fruits.

Commercial value of parthenocarpic fruits :

(i) The parthenocarpic fruits are seedless and are hence valued more, for eating purposes and contain abortive seeds which can not develop into a new plant.

(ii) These fruits contain sufficient growth hormones.

INTEXT QUESTIONS 19.7

1. Which part of the ovule forms the seed coat ?

   ....

2. Define a seed.

   ....

3. Give one example of a dicot seed and one of a monocot seed.

   ....

4. Define a fruit.

   ....

5. List the parts of mature seed.

   ....

6. Development of an embryo from a cell of embryo sac other than egg is an example of ....

7. Formation of more than one embryo from a single zygote is called ....

19.4.6 Seed

Seed is the final product of sexual reproduction and on maturity, it becomes relatively dry. The metabolic activity of the embryo slows down and in majority of cases the embryo enters into a phase of inactivity called dormancy or in some cases if favourable conditions are available they germinate. Dormancy helps the plants to survive under unfavourable conditions and ensures its germination only under favourable conditions.

Germination : Embryo lies dormant in the seeds, but when the seed receives the favourable signals and the inputs from the environment (moisture, suitable temperature and oxygen) are available, they germinate. Germination is the process by which the embryo grows and establishes itself as a seedling.

Steps of germination

- Imbibition of water through the micropyle, and by the seed coat.
- Seed swells up as it gets hydrated.
- Enzyme activity converts the reserve seed food into soluble forms (glucose, amino acid, fatty acids)
- The seed coat bursts and radicle emerges (grows into root) and then the plumule grows and develops into shoots.

Germination can be of two types

(a) **Epigeal** where because of more growth of hypocotyl, cotyledons come above the ground and form the first leaves of the new plant e.g. in castor, neem, and bean, and the plumule forms the shoot.

(b) **Hypogeal** where because of poor growth of hypocotyl, cotyledons remain underground and plumule emerges from the soil to develop into the shoot system. e.g. maize, and rice.

19.5 VEGETATIVE REPRODUCTION IN ANGIOSPERMS

Vegetative reproduction in Angiosperm : Reproduciton of new plants from the portion of the vegetative parts of a plant is very common and is called **vegetative reproduction**. Stems, roots, leaves and even buds are variously modified to suit this requirement. This is called **natural** vegetative reproduciton.

The new plants formed by vegetative propagation are genetically similar to the parents.

Natural Method : In natural methods, a portion of the plant gets detached from the body of the mother plant and grows into an independent plant. The parts may be stem, root, leaf or even flower.

You have studied about the various modifications of root, stem and leaf in lesson 4 and 5. You have also learnt that these modified portions perform some special functions and also help to overcome unfavourable conditions.

1. The underground modification of stem, like rhizome, (in ginger), tuber (potato), bulb (onion) and corm (zamikand) are provided with buds which develop into a new plant and are therefore used to carry out vegetative propagation of the plant in the field. Plants with subaerial modification such as *Pistia* (offset) and *Chrysanthemum* (sucker) are also used for vegetative propagation.
2. Similarly, tuberous roots (*Asparagus* and sweet potato) can also be used for propagation as these roots have adventitious buds which grow into a new plant.
3. Sometimes even leaves contribute to propagation of plants for example, leaves of *Bryophyllum* and *Kalanchoe* have buds on the margin and these buds grow into small plantlets. When detached from the mother plant they grow into independent plants.
4. In plants like *Agave* and *Oxalis* multicellular bodies called bulbils develop from flower-buds. These are called bulbils which when fall on the ground, grow into new plant.

Table 19.2 Modes of Vegetative reproduction with examples

Mode of Reproduction	Specialised plant part	Examples
(A) **Natural Methods**		
(a) Roots (Adventitious)		*Asparagus*,
		Sweet potato
(b) Stem	(a) Runner	*Lawn grass*,
	(b) Sucker	*Mint*, *Onion*,
	(c) Bulb	Onion
	(d) Tuber	Potato, *Canna*
	(e) Rhizome	Ginger
(c) Leaves	Adventitious Buds	*Bryophyllum*
(d) Special Parts	Bulbil	*Oxalis*,
		Pineapple, *Onion*
(B) **Artificial Methods**		
(a) Cutting		Rose, Money Plant
(b) Layering		Jasmine,
(c) Grafting		Grapevine
(d) Tissue Culture		*Citrus*, Mango
		Orchids, *Chrysan*
		themum, *Asparagus*.

INTEXT QUESTIONS 19.8

1. Define vegetative reproduction.

   ....

2. Give an example of each of the following :
   (a) rhizome ....
   (b) tuber ....
   (c) bulb ....
   (d) runner ....
   (e) sucker ....
3. Give an example of vegetative reproduction which is carried out by leaves.

   ....

4. Name two ways by which vegetative reproduction occurs in plants.

   ....

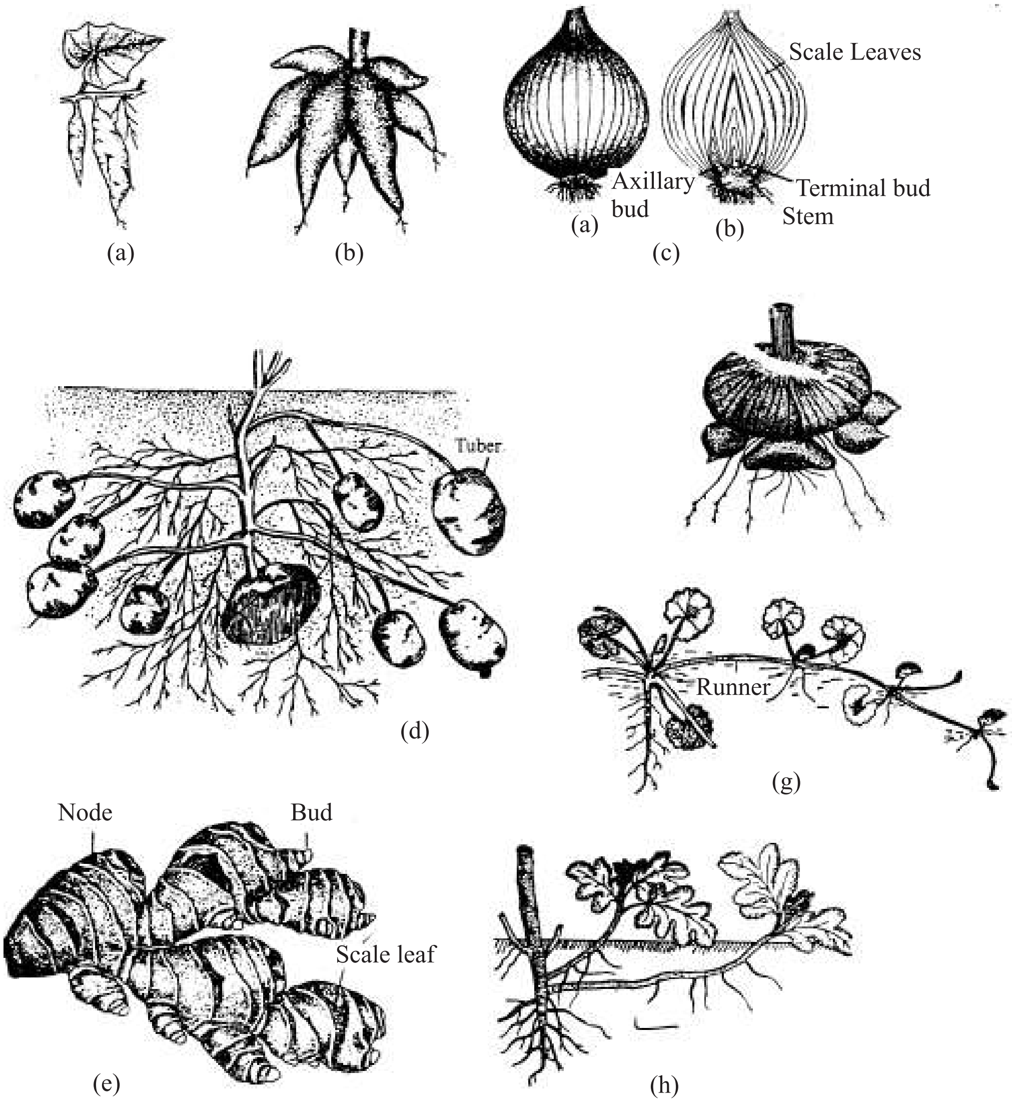


Fig. 19.12a Sweet potato

Fig. 19.12b Dahlia

Fig. 19.12c (a) Bulb of onion (b) L.S. of bulb

Fig. 19.12d Tuber of potato

Fig. 19.12e Rhizome of Ginger

Fig. 19.12f Corm of colocasia

Fig. 19.12g Runner of grass

Fig. 19.12h Sucker of Chrysanthemum

Fig. 19.12 Vegetative propagation of adventitious buds at the margins of leaves in Bryophyllum

19.6 ARTIFICIAL METHODS

Humans have taken advantage of this natural phenomenon and have artificially propagated plants vegetatively by using the specialized parts as described earlier or by cutting, grafting and layering. When, we use the vegetative parts for propagating crops or ornamental plants it is termed as **artificial vegetative propagation**.

(a) Cuttings : Many plants like rose, *Bougainvillea*, *Croton*, Coleus, money plant, and sugarcane are grown through their stem cuttings. (Fig. 19.13). Cuttings of these plants can be grown even in water where they strike roots and develop adventitious buds.

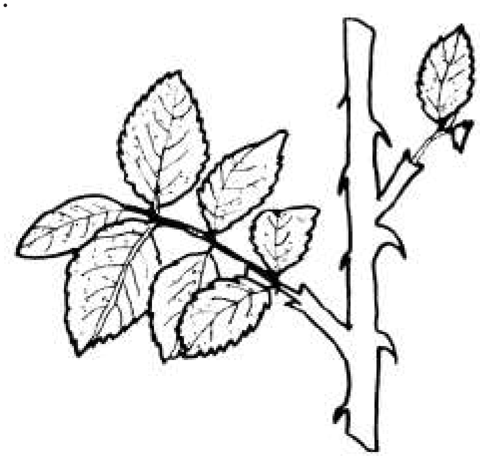


Fig. 19.13 Vegetative reproduction by cutting

(b) **Layering :** In this method, a lower branch of a plant is bent down and covered with moist soil leaving the growing tip above the soil. A ring of bark is removed from the stem before it is bent down (Fig. 19.14). In a few weeks time when enough roots have developed on the underground portion above the ringed part, it is cut off from the parent plant and grown separately as an independent plant. Example: Jasmine, strawberry, grapevine, *Bougainvillea*.

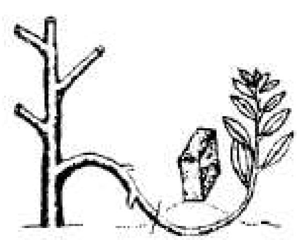


Fig. 19.14 Vegetative reproduction by layering

(c) **Aerial layering or Gootee** is a similar practice where bending of branches is not possible because of the height of plant or due to woody nature of stem. In this method a ring of bark is removed from a selected branch, and it is covered with moist moss and enclosed in a polythene sheet. When roots appear, the stem is cut below the roots and planted to form a new plant Fig. 19.15).

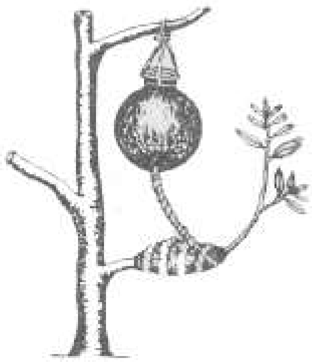


Fig. 19.15 Vegetative reproduction by gootee

(d) **Grafting :** It is especially important for propagation of seedless varieties of plants. It consists of inserting a small branch into a rooted plant. The rooted plant, taken as a stock is resistant to diseases and is physically sturdy. In this stock a branch is inserted which is known as scion or graft. This scion or graft is the stem cutting from the desired plant. Usually the grafted end of stock and scion fit well with each other and are bound firmly with tape or rubber-band until their tissues unite and vascular continuity is established. Grafting is mostly. practised in dicot plants. Grafting has been found extremely useful in propagating improved varieties of various flowers and fruits like rose, *Bougainvillea, Citrus,* mango, apple etc. (Fig. 19.16)

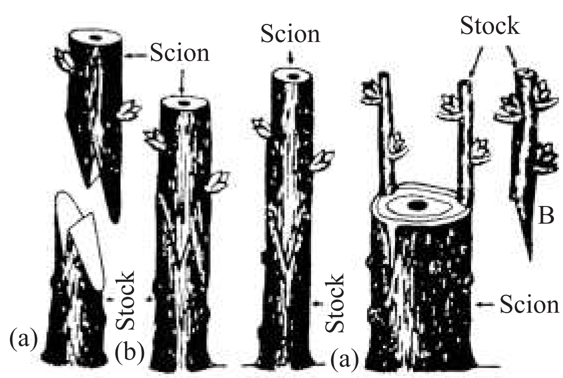


Fig. 19.16 (a) The lower part of the stem of scion is cut in a wedge. (b) The shoot of the plant to be used as a stock is cut off. The stem is slit vertically and the scion is inserted into the stock and is tied with a tape (c) the graft union occurs within a short time

19.7 ADVANTAGES AND DISADVANTAGES OF VEGETATIVE REPRODUCTION

Advantages

(a) Rapid means of reproduction and spread.

(b) Offsprings identical to parent. The desired varieties can thus be preserved genetically for use.

(c) Food storage organs allow perennation or survival in adverse conditions.

(d) Improved varieties of ornamental plants and fruit trees can be multiplied easily.

(e) Vegetative propagation is a quicker, easier and a less expensive method of multiplying plants.

Disadvantages

(a) Overcrowding and competition for space unless separated artificially.

(b) New varieties cannot be produced by this method except by mutation.

(c) Diseases typical of the species are rapidly transmitted and can be detrimental to a crop.

INTEXT QUESTIONS 19.9

1. What are the various methods which man uses for propagating plants artificially?

   ....

2. Name at least four specialised plant parts which help in vegetative ,propagation.

   ....

3. Write one advantage of vegetative reproduction.

   ....

19.8 THE MICROPROPAGATION

The technique of plant tissues culture is utilised for propagation of plants. The process is explained below with the help of diagrams.

A small piece of tissue, organ or even a single cell is taken from a plant and is transferred to a sterilized container with nutrient medium in aseptic conditions. The tissue grows very-very fast into an unorganised mass, called **callus**. The callus can be maintained and multiplied for an indefinite period. When small portions of the tissue are transferred to another specialised medium with hormones, it induces differentiation and plantlets (little plants) are formed.

The plantlets can be transplanted into pots and or soil by a gradual process and are grown to mature plants.

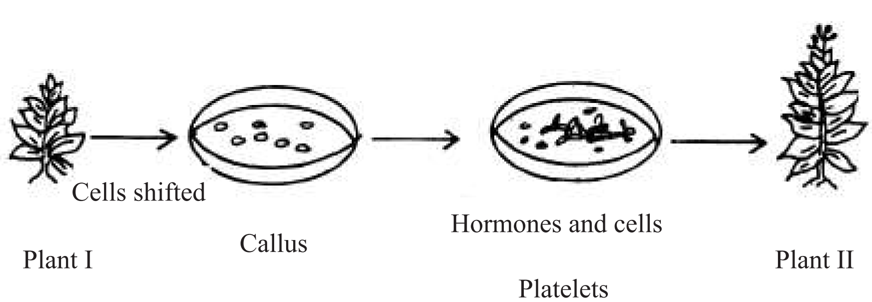


Fig. 19.17 Steps of micropropagation.

19.8.1 Advantages of micropropagation

By this method an indefinite number of identical plants can be obtained vegetatively starting from a small amount of parent tissue.

In orchids, carnations, *Chrysanthemum* and *Asparagus*, micropropagation is being successfully tried in some parts of our country.

INTEXT QUESTIONS 19.10

1. Give two examples each of plants which are propagated by the following methods:

   (a) Cutting

   (i) ....

   (ii) ....

   (b) Layering

   (i) ....

   (ii) ....

   (c) Grafting

   (i) ....

   (ii) ....

2. Name the artificial means of vegetative propagation commonly used in the laboratory.

   ....

3. Give two examples of plants which are propagated by micropropagation technique.

   ....

WHAT YOU HAVE LEARNT

- *Chlamydomonas* reproduces asexually by zoospores and sexually by isogamy, anisogamy and orgamy.
- *Spirogyra* reproduces by vegetative fragmentation, and sexually, by lateral conjugation and scalariform conjugation.
- In angiosperms flowers are the organs of sexual reproduction.
- Temperature and light are two main factors which influence flowering.
- Stamens and carpels are the male and female reproductive organs, respectively.
- Male gametes are produced in pollen grains, formed inside the anther, and pollen grains, are regarded as the male gametophytes in flowering plants.
- Female gamete is produced in the embryo sac in the nucellus of the ovule.

- The mature embryo sac is the female gametophyte of flowering plants, having 3-celled egg apparatus, three antipodal cells and a secondary cell having diploid secondary nucleus.
- Egg cell fuses with one of the male gametes received from pollen grains. Secondary nucleus fuses with the other male gamete. Occurrence of two such fusions is called two flowers borne on the same plant or on two **double fertilisation**.
- Pollination is the transference of the pollen grains from anther to stigma. It may be in the same bisexual flower of a plant (self pollination) or in different plants (cross-pollination).

  Wind, water, insects and animals are agencies of cross pollination.
- Wind pollinated flowers have light pollen grains or winged pollegrains and the stigma is usually large, hairy and projecting out of the flowers.
- Insect pollinated flowers are usually large, brightly coloured, scented and with nectar.
- Most plants have devices to favour cross pollination.
- The zygote develops to produce an embryo.
- The embryo is present in the ovule which later becomes seed and fertilized ovary on maturity becomes fruit.
- Development of fruit without fertilisation is called parthenocarpy.
- Ripening of fruit involves chemical changes in the stored food and pigments of the fruit wall.
- Vegetative reproduction is the production of new plants from plant parts other than flower and seeds.
- Specialised plant parts which bring about vegetative reproduction are as follows
  (a) Roots - tuberous root of *Dahlia*
  (b) Stems - runners and suckers near ground surface, rhizomes, tubers, corm and bulb are underground parts.
  (c) Leaves - adventitious buds in leaf notches as in *Bryophyllum*.
  (d) Bulbils - Modified buds in the inflorescence of pineapple called bulbils are also used for vegetative propagation.
- All the above kinds of parts have been used by man in agriculture and horticulture as artificial methods of vegetative propagation.
- Micropropagation by tissue culture enables production of little plants on a large scale.
- Vegetative reproduction is rapid, easy and cheap. The plants produced are genetically identical to the parent plant.

TERMINAL EXERCISES

1. Explain the term isogamy taking *Chlamydomonas* as an example.
2. Describe scalariform conjugation in *Spirogyra*.
3. Differentiate between annuals, biennials and perennial plants.
4. Give significance of pollination.
5. Draw a labelled sketch of a mature ovule.
6. Give a labelled diagram of a mature pollen grain.
7. Mention important characteristics in Anemophilous and Hydrophilous plants.
8. Give the significance of fertilisation.
9. Mention the changes that take place when the fruit ripens.
10. Define the following terms :
    (a) Corm (b) Scion
    (c) Callus (d) Micropropagation
    (e) Vegetative reproduction
11. In what ways do plants reproduce vegetatively without human assistance ?
12. In what ways do plants reproduce vegetatively with human assistance?
13. Define and give an example of each of the following:
    (a) Rhizome (b) Stolon (c) Cutting
    (d) Layering (e) Grafting
14. What are the advantages and disadvantages of vegetative reproduction ?
15. In what way is vegetative reproduction simple ?
16. Write short notes on
    (a) Runner (b) Sucker (c) Bulb (d) Tuber
17. In brief describe the various steps of micropropagation.
19. What is the significance of micropropagation ?
19. If a branch of dasehri mango is grafted on a tree producing desi mango. What type of mangoes will be produced on the grafted branch and on other branches of the tree?

ANSWERS TO INTEX]T QUESTIONS

19.1

1. The process by which living organisms produce their offsprings for the continuity of the species.
2. Offsprings reproduce from a vegetative unit produced by a parent without fusion of gamete. In case of sexual reproduction fusion of male and female reproductive cells produced in male and female reproductive organs, is required.

3. Male and female reproductive cells are known as gametes.
4. Fission, budding, fragmentation.
5. b

19.2
1. Male and female gametes are identical in structure.
2. Zygote
3. Asexual reproduction
4. Anisogamy - *C. braunii*; Oogamy - *C.oogamum* and *C. coccifera*
5. A flagellate thin-walled asexual reproductive unit is called zoospore. If a zoospore loses flagella and becomes, non motile, it is called aplanospore.

19.3
1. Fragmentation
2. Scalariform Conjugation.
3. Diploid nucleus in zygote on return of favourable conditions.
4. Only one filament is involved in lateral conjugation

19.4
1. Annual - Plants which produce flowers and seeds and die within one season.

   Biennial - Plants which complete their life cycle in two seasons. In First season they are in vegetative state and in second season, they reproduce and die.

   Perennial - Plants which live for several years. For first few years they are in vegetative state and later, they flower and produce fruits and seeds every year.
2. Temperature, light - day length
3. *Cannabis* or *Cucumis*
4. Stamens and carpels

19.5
(i) Tapetum
(ii) Pollen sac
(iii) Exine and intine
(iv) Nucellus and integuments

19.6
1. Transfer of pollen grains from anther to stigma of a flower.
2. (i) Cleistogamy

   (ii) Dichogamy

3. (i) Flowers are large, coloured and showy.

   (ii) Some flowers secrete nectar.

19.7

1. Integuments.
2. Ripened ovule.
3. Pea or Gram, Maize grain.
4. Ripened ovary.

   Seed coat
5. Embryo

   Endosperm

   Cotyledons
6. Adventive Polyembryony
7. Cleavage Polyembryony

19.8

1. The process of multiplication in which a portion of the plant body becomes detached and develops into new plants.
2. (a) Ginger (b) Potato (c) Onion (d) Lawn grass (e) mint
3. *Bryophyllum*
4. Rhizomes and Bulbs

19.9

1. (a) Cutting (b) Grafting (c) Layering
2. (a) Runner (b) Tuber (c) Bulb (d) Sucker
3. Desirable varieties of ornamental plants and fruit trees can be multiplied easily.

19.10

1. (a) (i) Croton (ii) Money plant

   (b) (i) Jasmine (ii) Grapevine

   (c) (i) Rose (ii) Mango
2. Micropropagation
3. Orchids, *Chrysanthemum*, *Asparagus*.

20

GROWTH AND DEVELOPMENT IN PLANTS

If you sow a seed in your garden or in a pot, after few days you would find a tiny seedling coming out from the seed. As days pass, the tiny seedling grows in size, the number of leaves increases, and later, it grows into a mature plant and produces flowers and fruits. This is the process of growth and development. Besides growth and development plants also show movement, but it is not as clearly visible as in the case of animals. In this lesson you will learn about growth, development and movements in plants.

OBJECTIVES

After studying this lesson, you will be able to:

- *define the terms growth and development;*
- *differentiate between growth and development and explain growth curve;*
- *list the various stages of cellular growth;*
- *explain the various methods of measurement of plant growth;*
- *describe the factors affecting plant growth and importance of growth regulators;*
- *explain the role of growth regulators in dormancy and germination of seeds;*
- *differentiate among short-day plants, long-day plants and day-neutral plants;*
- *define the terms abscission and senescence;*
- *identify the effects of salt stress and water stress on plants;*
- *define the various types of movement like geotropism, phototropism, nastic and turgor movements.*

20.1 GROWTH AND DEVELOPMENT

You must have noticed that all living organisms grow in size. But have you ever thought how a do they grow? Growth takes place due to cell division, which increases the number of cells in the body. This process continues and we observe increase in weight, size and volume of all plants and animals. This is called **growth.**

> Growth in living organisms may be defined as an irreversible increase in the number and size of a cell, organ or whole organism.

Growth in living organisms is not uniform throughout the life span. Growth takes place at a faster rate till the plants or animals attain maturity. Then it slows down and at a particular time it stops. Later in life death occurs. All these changes that occur in an organism starting from its beginning till its death may collectively be termed as development. Development is associated with **morphogenesis** and **differentiation**. **Morphogenesis** is the process of development of shape and structure of an organism; and **differentiation** is the process of change in cells, tissues or organs to carry out different functions.

Development is the whole series of qualitative and quantitative changes such as growth, differentiation and maturation, which an organism undergoes throughout its life cycle.

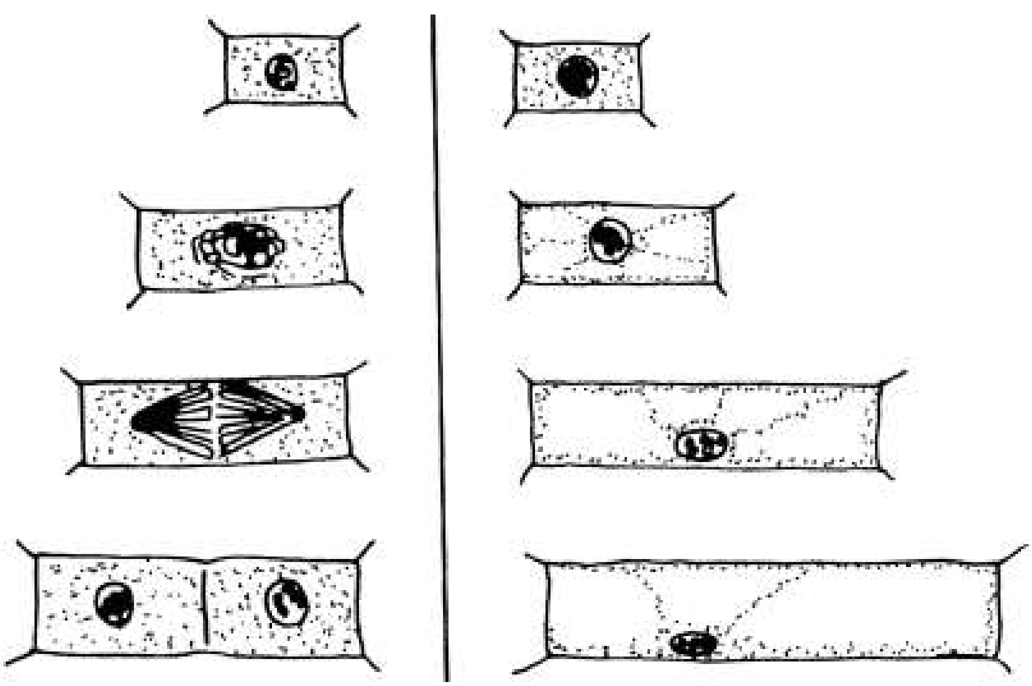
20.2 STAGES OF CELLULAR GROWTH

You have already learnt that growth of an organism is always associated with growth in size and number of cells. The growth of an organ or an organism occurs in three successive stages. They are

(i) Cell division : The number of cells increases due to mitosis (Fig. 20.1a).

(ii) Cell enlargement: The size of individual cell increases after cell division due to increase in the volume of its protoplasm (Fig. 20.1b).

(iii) Cell differentiation: In this stage, structure of the cells changes to perform specific functions. And similar type of cells having same functions form a group, which is known as tissue.



(a) Cell Division (b) Cell Enlargement

Fig. 20.1 Comparison of cell division and cell enlargement

In lower organisms such as bacteria and algae the entire body grows. But in higher organisms like ferns, pine and flowering plants, growth is restricted to the cells present only in the growing regions, like shoot apex and root tip and close to the lateral sides of the stem and root. Growth at the tips leads to elongation of body parts and lateral (side ways) growth leads to increase in the thickness of stem and root.

20.3 GROWTH CURVE

The rate of growth of a plant or plant part is not always the same during its life span. Sometimes it is slow and at other times rapid. If we plot the increase in cell number (growth rate) against time, a typical S-shaped curve is obtained. This is called growth curve or **sigmoid growth curve**. (Fig 20.2)

This curve has three phases of growth.

(i) **Lag Phase** – This is the initial phase of growth when the rate of growth is very slow.

(ii) **Log Phase** – It shows rapid growth and is maximum during the entire life span.

(iii) **Stationary Phase** – Here the rate of growth starts decreasing and finally it stops.

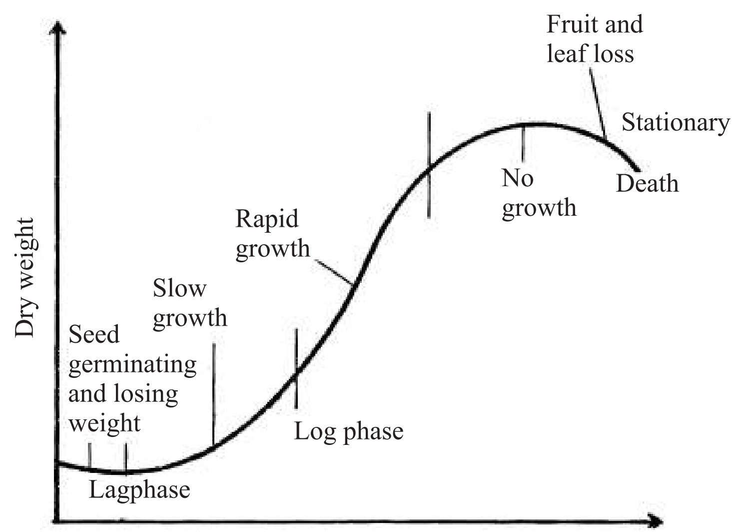


Fig. 20.2 Sigmoid curve

The total time period during which the festest growth of the organ or organism occurs is called **grand period of growth**.

20.4 MEASUREMENT OF GROWTH

After knowing the different phases of growth let us know how to measure growth in plants. Growth in plants being a quantitative phenomenon can be measured in relation to time. It can be measured in terms of

- Increase in length or growth – in case of stem and root;
- Increase in area or volume – in case of leaves and fruits;
- Increase in the number of cells – in algae, yeast and bacteria.

Let us discuss some methods of measuring growth in length.

20.4.1 Direct Method

We know that growth generally takes place at the apical region of plant. So growth in length can be directly measured by means of an ordinary measuring scale at any particular interval of time.

ACTIVITY FOR YOU

Aim

To use an ordinary scale to measure growth in length of the stem of a plant in your garden.

What do you require?

Thread, a piece of stone and a measuring scale.

What to do?

- Tie the stone at one end of the thread;
- Take the length of the stem from above the soil surface with the help of the thread;
- Mark the length of the stem on the thread with the help of a pen;
- Put the thread on the scale and note down the length;
- Record the length citing date of the activity;
- Repeat the procedure and at an interval of one week.

Is there any change in length?

Make a table.

No. of the week	Length in cms.
1	
2	
3	
4	
5	

20.4.2 Auxanometer

For more accurate measurement of length, we can use the specially designed equipment called **auxanometer**. (Fig 20.3). We can use it to measure the rate of growth of shoot length of plants. A thread is tied to the tip of stem of a potted plant and the thread is hung on the pulley of auxanometer. The other end of the thread is tied to a weight. The pulley is fixed with a long needle, which slides over a graduated arc. As the stem grows in length the weight pulls the thread down. The movement of the needle is read on the scale of arc.

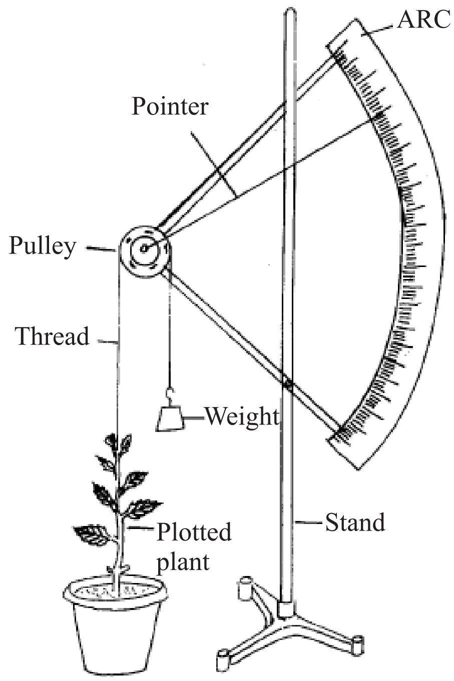


Fig. 20.3 Auxanometer

INTEXT QUESTIONS 20.1

1. Distinguish between growth and development.

   ....

2. What is differentiation?

   ....

3. What role does it play in plant growth and development?

   ....

20.5 FACTORS AFFECTING PLANT GROWTH

Generally plant growth is influenced by a number of factors both external and internal.

20.5.1 External growth factors

External factors are those factors present in the environment that affect the growth of the plants directly or indirectly. These factors are

(i) Light (ii) Temperature (iii) Water (iv) Mineral nutrients

(i) Light

You have already learnt about the necessity of light for the process of photosynthesis. Besides photosynthesis, light is also essential for seed germination, growth of seedling, differentiation of various tissues and organs, and reproduction.

When plants grow in dark, they become tall, yellowish and weak, and the leaves are very small.

(ii) Temperature

Some plants grow in cold climate and some in hot climate. The optimum temperature required for growth of plants ranges between 28-30°C, but it may occur in the temperature range of 4-45°C. All metabolic activities of plants are directly affected by variation of temperature. A very low temperature causes injuries to the plant due to chilling and freezing, and very high temperature stops its growth.

(iii) Water

You have already learnt that a plant absorbs water by its roots, uses it in photosynthesis and other biochemical processes and some of it is lost through transpiration. For proper growth of plants a particular quantity of water is required. Both deficiency and excess of water retards the growth of plants.

(iv) Mineral Nutrients

In the lesson 9 “Plant nutrition” we have already discussed the importance of mineral nutrients for plant growth and development. All metabolic processes require inorganic nutrients. Plant growth is adversely affected by the deficiency of nutrients.

20.5.2 Internal Growth Factors

In addition to the external factors as discussed above, there are some substances produced in the plant body itself, which affects the growth of the plant. These are called **plant hormones** or **phytohormones** or **growth hormones**.

A phytohormone is an organic substance produced in a small quantity in one part of plant body and capable of moving to other parts to influence the growth of that part.

The growth of the plants can also be influenced by certain synthetic chemicals resembling plant hormones both in structure and functions. These are called **growth regulators**. They are not produced by plants naturally.

Growth regulators are chemical substances, other than naturally produced hormones, which promote, inhibit or modify growth and development in plants.

The naturally produced growth hormones are broadly grouped under five major classes. They are

(i) Auxin
(ii) Gibberellins
(iii) Cytokinins
(iv) Ethylene
(v) Abscissic acid

Let us know details about these hormones.

(i) Auxin

Auxin is a growth promoter, generally produced by the growing apex of stem and root of the plants. It helps in the elongation of shoot and root tips behind apical meristem. The naturally produced auxins is Indole-3-Acetic Acid (IAA). They are also produced by chemical synthesis, which show same physiological responses like Auxin. Some of the synthetic auxin are Indole-3-butyric acid (IBA), 2,4-Dichlorophenoxy Acetic Acid (2,4-D), and Naphthalene acetic acid (NAA).

The Greek word **auxein** means "to grow". It was first isolated from human urine.

An experiment was performed by Fritz Went on oat seedling to see the effect of auxins. When tip of oat coleoptile (early shoot) is removed, growth stops. Then the removed tip is placed on a block of agar (gelatinous material from sea weeds) for about an hour. This agar block is then placed on the cut end of the seedling. It was observed that the growth of the seedling started again. It shows that there is something that has passed from the cut tip into the agar block, which helps to restart the growth. This was named **Auxin**, a plant hormone.

Functions of Auxin

(a) It promotes cell elongation;

(b) It suppresses the growth of lateral bud. If the tip of a plant is removed, the lateral branches begin to grow; In most of the plants apical bud suppresses the development of lateral buds. This is called **apical dominance**.

(c) It delays fall of leaves. (leaf abscission)

(d) NAA (Naphthalene acetic acid) is used for preventing fruit drop in apples before they are ripe.

(e) 2, 4-D (2, 4-dichlorophenoxy acetic acid) acts as a dicot weedicide.

(ii) Gibberellin

Gibberellin or Gibberellic Acid (GA) was initially isolated from a fungus *Gibberella fujikuroi*. In plants, it is produced in embryos, roots, and young leaves and it enhances growth.

Functions of Gibberellins

(a) It helps in elongation of stems in genetically dwarf plants. By using gibberellin the height of the dwarf plants can be increased.

(b) It breaks dormancy of seeds and buds.

(c) It induces parthenocarpy. (Formation of seedless fruits without fertilization) or provides stimulus received by pollination.

(iii) Cytokinins : They were extracted from coconut milk.

Cytokinins are synthesized in root apex, endosperm of seeds, and young fruits where cell division takes place continuously.

Functions of Cytokinins

(a) They stimulate cell division, cell enlargement and cell differentiation.

(b) They prevent aging of plant parts.

(c) They inhibit apical dominance and help in growth of lateral buds into branches.

(iv) Ethylene

Ethylene is a gaseous hormone. It is found in ripening fruits, young flowers and young leaves.

Functions of Ethylene

(a) It induces ripening of fruits.

(b) It promotes senescence and abscission of leaf, and flowers.

(c) In cells it only increases the width not the length.

(v) Abscissic acid

Abscissic acid also known as Dormin is a naturally occurring growth inhibitor found in wide variety of plants. It is synthesised in leaves.

Functions of Abscissic acid:

(a) It induces dormancy of buds and seeds as opposed to Gibberellin, which breaks dormancy.

(b) It promotes the senescence of leaf, i.e., fall of leaves happen due to abscissic acid.

(c) It inhibits seed germination and development.

(d) It causes closing of Stomata.

20.6 PRACTICAL APPLICATION OF GROWTH REGULATORS

We have already discussed that by using the various types of growth regulators we can promote, inhibit or modify growth and development in plants. Now-a-days these are widely used by horticulturists to boost their production. Some of the applications are –

(i) With the help of auxins and gibberellins seedless varieties of fruits can be produced. You might have seen seedless grapes and papayas in the market.

(ii) Early flowering in some plants is possible by applying growth regulators.

(iii) With the use of hormones some fruits can be ripened at an early stage.

(iv) Germination in seeds can be possible by applying auxins.

(v) Germination of potatoes and onions can be stopped in storage by application of growth inhibitors.

20.6.1 Differentiation, Dedifferentiation and Redifferentiation

Differentiation: Differentiation in plants is a permanent, localised qualitative change in size, biochemistry, structure and function of cells, tissues or organs. It refers to the processes by which distinct cell types arise from precursor cells and become different from each other. For example:Vascular tissues, xylem and phloem, are differentiated from meristematic cells, procambium, and vascular cambium and mature to perform specific functions. The hormones auxin and cytokinin are essential for vascular tissue differentiation. During differentiation, cells undergo few to major structural changes both in their cell walls and protoplasm. For example, to form a tracheary element, the cells would lose their protoplasm. They also develop a strong, elastic, secondary cell wall to carry water to long distances even under extreme conditions.

Dedifferentiation: It is the reversal of cell development in plants, so that the differentiation that had occurred previously is lost and the cell becomes more generalized in structure. The living differentiated cells that have lost the capacity to divide can regain the capacity of division under certain conditions. This phenomenon is termed **dedifferentiation**. For example, formation of meristems, interfascicular cambium and cork cambium from fully differentiated parenchyma cells.

Redifferentiation: While undergoing dedifferentiation plant cells once again lose their capacity to divide but mature to perform specific functions. This process is called redifferentiation.

INTEXT QUESTIONS 20.2

1. Name the plant hormones concerned with the following:
   (i) Elongation of cell ....
   (ii) Shedding of leaves..
   (iii) Breaking seed dormancy ....
2. Mention two functions of Auxin
   (i) ....
   (ii) ....
3. What is the difference between dedifferentiation and redifferentiation?
   ....
4. Which two hormones are essential for vascular tissue differentiation?
   ....

20.7 DORMANCY AND GERMINATION IN SEEDS

In the previous lesson-7 you have already learnt about formation of seeds in plants. In developed seeds metabolic activities are generally very slow. But at the time of germination, the metabolic activities in seeds increase and they grow into new plants under favourable conditions of growth. This is called **seed germination**.

> **Seed germination** is the return of metabolic activities and growth by the seed tissue to give rise to a new plant by the development of the embryo.

Some seeds do not germinate immediately after dispersal even if suitable conditions of growth are provided. In this period growth of the seeds remains suspended and it is said to be in the rest or dormant stage. This phenomenon is called **dormancy of seeds**. It may occur due to immature embryo**,** hard or impermeable seed coat, and presence of inhibitors like abscissic acid.

20.7.1 Types of Seed Germination

In flowering plants two types of germination are found. They are:

(a) Epigeal germination; and (b) Hypogeal germination.

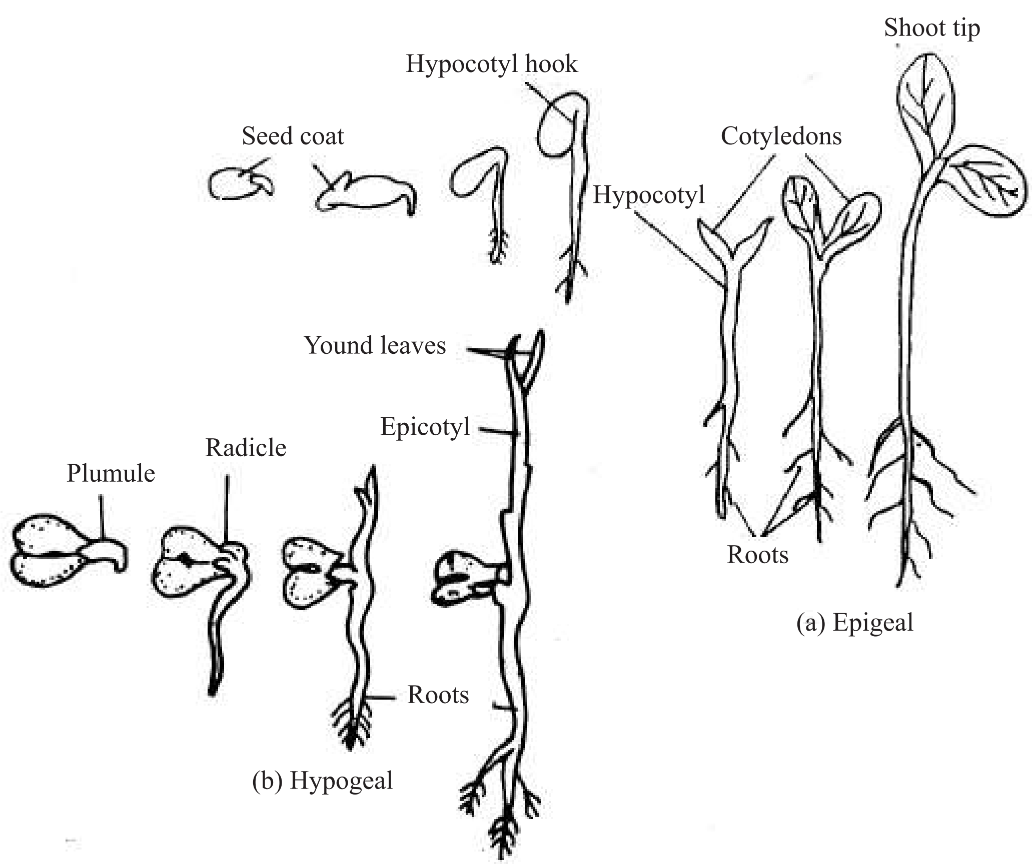


Fig.20.4 Epigeal Germination and Hypogeal Germination
Vivipary (= producing baby plants)

(a) Epigeal Germination

In epigeal (*epi* - above; *geo* - soil)germination hypocotyl elongates and cotyledons come out above the soil surface. Examples : seeds of pumpkin, mustard, tamarind, and french bean.

(b) Hypogeal Germination

In hypogeal (hypo = below, geo = earth) germination the epicotyl elongates and *cotyledons remain below the soil surface*. Examples : Most monocots seed like rice, wheat, maize, and coconut.

> Some plants, which grow in marshy places show a special type of germination called **Vivipary** (Fig. 20.5). Here the seed germinates inside the fruit while it is attached to the parent plant. The weight of the seed increases because of germination and seedling separates from the plant and falls down into the mud. Then roots develop to fix it in the soil. These plants are called viviparous plants. For example, *Rhizophora* and *Sonneratia*.

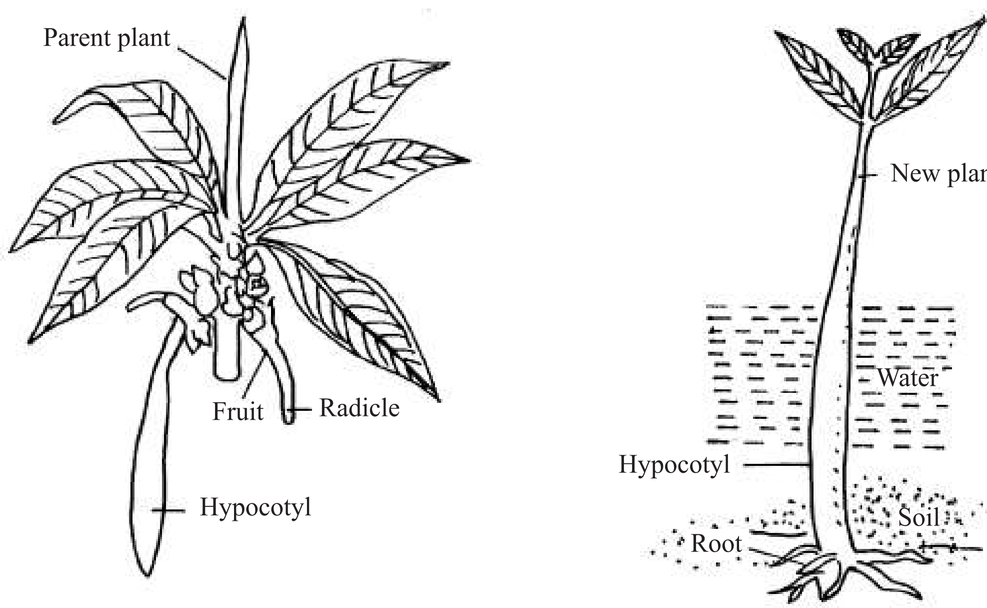


Fig 20.5 Viviparous Germination

20.7.2 Mechanism of Seed Germination

In seed germination, the first step is the imbibition or absorption of water by seed. Then the seed swells and the seed coat ruptures. Through the ruptured seed coat the radicle comes out from one end of embryonic axis. This radicle gives rise to root system. From the other end of embryonic axis the plumule elongates and develops as the shoot of the plant.

20.7.3 Factors Affecting Seed Germination

Seed germination requires five factors : water, temperature, oxygen, light and growth hormones.

(a) **Water :** The seed must swell up to rupture its seed coat. A ripe seed contains very low quantity of water. So for swelling to cause rupture of seed coats supply of adequate water is essential. Biochemical reactions required for growth and development of the seedling require water.

(b) **Temperature :** For germination of seeds a particular temperature is required. The degree of temperature required varies from species to species. Warmth accelerates chemical reactions inside.

(c) **Oxygen :** Oxygen is required in breaking down reserve food of seed and release energy for metabolism of growth of the embryo.

(d) **Light :** In most of the seeds light is not an essential factor for germination. But in some cases like lettuce and tobacco light is absolutely essential.

(e) **Hormone :** Besides the above external factors, hormones also control germination of seeds. Some roles played by hormones are as follows.

- Gibberellins can induce germination in some cases even in complete darkness.
- Auxin, Cytokinins and Ethylene can break dormancy in many seeds and initiate germination.
- In some seeds Abscissic acid inhibits germination process.

20.8 PHOTOPERIODISM – RESPONSES DUE TO LIGHT EXPOSURE DURATION

You must have observed plants like spinach, wheat, etc. which produce flowers in summer; and dahlia, cosmos, etc. flower in winter. Why is it so? Because the plants that flower in summer require longer duration of light per day than those flowering in winter. Thus, we can say that duration of light plays an important role in flowering of plants. **This effect of duration of light on the growth of plants is known as photoperiodism**.

Photoperiodism is the response in growth, transpiration, photosynthesis, and reproduction (flowering) of a plant to the specific duration of light, which falls on it per day.

On the basis of day-length required by the plants for flowering, the plants are classified into the following three categories:

(i) **Short-day Plants (SDP) :** Some plants produce flowers when exposed to a light period shorter than a required day-length. These are called Short-day Plants. Chrysanthemum, Cosmos, Dahlia, Soyabean, are short-day plants.

(ii) **Long-day Plants (LDP) :** They produce flowers when exposed to a light period longer than a fixed day-length. Gulmohar, radish, spinach, are long-day plants.

(iii) **Day-neutral Plants (DNP) :** In these plants flowering is not affected by length of light period i.e. they produce flower in almost all photoperiods.Cucumber, Tomato, and Sunflower, are day-neutral plants.

Though flowering is the best known example of photoperiodism, many other plant processes are also controlled by duration of light. Bud dormancy, bulb formation in onion, and tuber formation in potato are affected by period of light.

20.9 ROLE OF FLORIGEN AND PHYTOCHROME IN FLOWERING

After the discovery of effect of light on flowering, the scientist tried to find out the hormone responsible for flowering in plants. It is hypothesized that a plant hormone called **Florigen** is responsible for initiation of flowering in plants. Florigen is a hypotheticals flowering stimulus synthesized in the leaves under favourable photoperiod, which migrates to shoot apex where flowering occurs.

Have you ever thought how a plant comes to know about the presence or absence of light in its environment? It is due the presence of a particular type of pigment in the plants, called **Phytochrome**. It is also known as light absorbing pigment and it makes the plants sensitive to light and participates in seed germination and flowering. This pigment occurs in two different forms, one Pr and the other, Pfr. While Pr absorbs red light P_{fr} absorbs far-red light (such rays are invisible). Both these forms are inter- convertible. The P_r form absorbs red light and gets converted into P_{fr} form and the P_{fr} form absorbs far-red light and gets converted into P_r form.

$$P_r \underset{\text{Far-red light}}{\overset{\text{Red light}}{\rightleftharpoons}} P_{fr}$$

Fig: 20.6 Inter-conversion of the phytochrome into P_r and P_{fr}

20.10 VERNALISATION—APPLICATION OF LOW TEMPERATURES

You have already learnt that temperature affects growth and development of plants. For flowering in some plants, a particular temperature is required. Studies show that if temperature is reduced to a particular point then flowering occurs at an early stage. For example by applying a temperature ranging between 1-10° C to certain variety of wheat, rice and cotton, growth of seedlings is accelerated and flowering occurs earlier. This method of inducing early flowering in plants at low temperature is called **vernalisation**.

Vernalisation is the process of accelerating the process of flowering by subjecting or exposing the plant to low tempratue.

Practical Utility of Vernalisation

Vernalisation has some practical applications like:

(a) Plants whose life cycle is completed in two seasons (biennials) can produce flower in one season if their seeds are pre-treated to a low temperature.

(b) Crops can be grown and harvested earlier i.e. biennials can be turned into annuals.

20.11 SENESCENCE/AGING OF PLANTS

Like animals, plants also have fixed life span and after completing that perioid, they die. Before death we can observe several degradation processes in their body. You might have noticed yellowing of leaves, and fading of flower colour, in plants. It is due to loss in structure and function of an organ or the whole plant. **The deteriorative processes which ultimately lead to complete loss of organization and functioning of the plant or its parts is known as Senescence**.

Senescence occurs due to the deposition of waste material. In some plants the whole plant dies after flowering and producing seeds. This is called **whole plant senescence.** Example-annual plants like rice, wheat, beans, and tomato. In many other plants, parts above soil die each year and root system stays alive. This is called **organ or shoot-senescence.**

Role of hormones in senescence: Abscissic acid and ethylene promote senescence of leaves but cytokinin delays senescence and helps leaves remain green for long period.

20.12 ABSCISSION – SHEDDING OFF

You might have noticed whenever a leaf becomes old it separates from the plant body and falls down. Again ripe fruits and older flowers also become separated from plants. This detachment of older plant parts or organs from the main plant body is called **abscission**.

In plants, a layer of tissue generally forms an abscission zone at the base of the petiole of a leaf or flower or fruit. The cells of this layer become soft and weak due to destruction of middle lamella and cell wall. So the organ is easily detached by wind or rain fall. Plant hormones like abscissic acid and ethylene promote leaf abscission and auxin prevents it.

20.13 STRESS FACTORS

What happens if you do not supply water to a potted plant for four to five days? You may observe that the leaves bend down and the plant wilts. Here due to lack of water the usual life processes of plant are disturbed. We can say that the plant is facing stress in its life. This may be called as **biological stress**. Not only water, there are a number of factors responsible for causing stress in plants like temperature, salt, shade, light, and pollutants.

Any change in the environmental conditions that may adversely affect the growth or development in plants is called biological stress.

The effect that is produced in plant as a result of stress is called strain. In the above example bending of leaves and wilting of plant are strains.

So the reaction of plant facing the stress is called strain

20.13.1 Types of Stress

There are a variety of stresses to which plants are exposed. Some common stresses are-

(a) Water stress; and (b) Salt stress.

Let us know details about them.

(a) Water Stress

Water stress includes both excess of water (flood) and scarcity of water (drought). Deficiency of water in the plant makes the leaves yellow and they wilt. The various processes in plants like photosynthesis and respiration are reduced, cell enlargement is checked, cell size is deformed and cell rigidity lost due to deficiency of water. Flooding or excess amount of water in soil reduces root and shoot growth, and causes blackening of root tips and yellowing of leaves.

(b) Salt Stress

Salt stress occurs mainly due to the presence of excess amount of calcium and sodium salts in plant body. It causes dehydration of cell, change in shape of cell and disturbance in metabolic processes. Thus cell growth as well as growth and development of plants are retarded.

20.14. PLANT MOVEMENTS

While doing any work our body parts move and also entire body moves from one place to another as per our desire. This is called movement of our body. Plants also show movement. But their movements are completely different from our body movement. Except some unicellular plants, all other higher plants cannot move from place to place as their roots are fixed in the soil. Still they show movement by folding the buds, opening and closing the flowers, and bending towards sun light. These movements in plants are very slow and we have to wait and observe them carefully and patiently to notice these movements. Let us learn about various types of movements shown by plants.

(a) Tropic Movement (directional response or growth movements)

Movement in plants or in any part of the plants towards or away from some environmental factors is known as tropic (trope : turn) movement. You must have observed the movement of plants in the direction of light, the downward movement of roots in the soil, drooping of leaves of some sensitive plants by touch, etc. These are examples of tropic movement.

(i) Phototropism : Induced by light e.g. bending of stems towards light.

(ii) Geotropism : Induced by gravity e.g. growth of roots towards gravity.

(iii) Thigmotropism : Movement caused by contact e.g., twining stem and tendril and the drooping of leaves of sensitive plant by touch.

(iv) Hydrotropism : Induced by water i.e., growth of roots towards source of water.

(b) Nastic Movement

The nastic (nastein : bending) movements are the growth movements resulting due to difference in the rate of growth on **opposite sides of an organ** e.g., opening of petals, coiling of leaves, etc. When upper side of an organ grows faster than the lower side, the movement is called **epinasty**. (e.g., downward curling of leaf, opening of sepals of goldmohur flower. When the lower side grows more rapidly than upper side, it is called as **hyponasty**. (e.g. upward curling of leaf blade)

(c) Turgor Movements

These movements are due to change in the volume of water inside the cell. When more water is present in the cell it is fully expanded and becomes rigid or hard. Such a condition is called turgidity and the cell is said to be **turgid**. When less water is present inside the cell, it is not fully expanded and remains soft. This is called **flaccid** condition. The leaves bend in hot summer due to excessive transpiration on account of loss of turgidity of cells of the leaf.

Some examples of turgor movements are :

(i) Leaves or leaflets of some plants close on the fall of darkness (sleep movement). Example - *Portulaca*, *Acacia*.

(ii) Closing of leaflets and drooping of leaves in response to a strong stimulus of blowing wind or of touch. Example - Sensitive plant (*Mimosa pudica*)

(iii) Closing of leaves of Venus Flytrap to catch a landing insect.

(iv) Seed pods of some plants open on maturity, vigorously expelling their seed. Example - Balsam (Gulmehandi).

INTEXT QUESTIONS 20.3

1. Distinguish between Phototropism and Geotropism

   ....

2. Give two examples of turgor movement

   ....

WHAT YOU HAVE LEARNT

- Growth in living organisms results from increase in the number and size of a cell, organ or whole organism.
- Development is the whole series of qualitative and quantitative changes (growth, differentiation, maturation), which an organism undergoes throughout its life cycle.

- Growth of cells occurs in three successive stages i.e., cell division, cell enlargement, cell differentiation.
- Plants show three phases of growth - Lag Phase, Log Phase, Stationary Phase
- Auxanometer is a specially designed equipment used to measure the rate of growth of shoot length of plants.
- The external factors that affect the growth of the plant are light, temperature, Water and mineral nutrients.
- The internal factors responsible for plant growth are auxin, gibberellins, cytokinins, ethylene, and abscissic acid. These are substances produced in a small quantity in one part of plant body and capable of moving to other parts to influence the growth of that part.
- Seed germination is the return of metabolic activities and growth by the seed tissue to give rise to a new plant. The germination in seeds is mainly affected by factors like Water, temperature, oxygen, light, and hormone. Flowering plants show two types of germination, epigeal germination; and hypogeal germination.
- Photoperiodism is the biological response in growth, reproduction (flowering) of a plant to the duration of light, which falls on it per day.
- Florigen is a hypothetical plant hormone, which is responsible for initiation of flowering in plants.
- The method of accelerating the ability of flowering in plants by keeping them at low temperature for sometime is called vernalisation
- Senescence is a gradual process during which any plant part or the whole plant completely loses its function and ultimately dies.
- The process of detachment of any leaves, fruits, flower or any part of the plant from the main body after getting older is called abscission.
- Any change in the environmental conditions that may adversely affect the growth or development in plants is called biological stress. This stress occurs mainly due to temperature, water, salt, shade, light, and various pollutants.

TERMINAL EXERCISES

1. State the different stages of cellular growth.
2. Distinguish between growth and development.
3. What is a sigmoid growth curve? State the different phases of sigmoid curve.
4. Describe the various external factors that affect the growth of plants.
5. What is vernalisation?
6. Define the term Photoperiodism.
7. What is auxin? What is its role in the growth of plants?
8. State any two functions of Gibberellin?

9. Explain the role of Cytokinins and Ethylene in growth and development of plants.
10. Distinguish between epigeal germination and hypogeal germination.
11. What is meant by seed germination? Describe the various factors responsible for seed germination.
12. What is senescence?
13. State any two practical utilities of growth hormones.
14. What is biological stress? Describe the different types of biological stress.
15. What is apical dominance? Name the hormone responsible for it.
16. What is meant by plant movement? Describe any two types of movement of plants with example.

ANSWERS TO INTEXT QUESTIONS

20.1 1. Growth : Increase in number and size of a cell, organ organism.

Development : Series of qualitative & quantitative changes including growth, differentiation and maturation.

2. Process of change in cells, tissues or organs in order to carry out different functions.

3. Similar cells organise to form a group called tissue to perform a particular function

20.2 1. (i) Auxin, (ii) Ethylene (iii) Abscissic acid

2. (i) Cell elongation (ii) Delays fall of leaves (iii) suppresses growth of lateral bud (any two)

3. *Dedifferentiation:* Process by which precursor cells become distinct cell types to perform a specific function.

Redifferentiation: Process by which the plant cells while undergoing dedifferentiation lose their capacity to divide once again but mature to perform specific functions.

4. Auxin and Cytokinin.

20.3 1. Movement induced by light – Phototropism

Movement induced by gravity – Geotropism

2. (i) Closure of leaves on fall of darkness

(ii) dropping of leaves on touch

(iii) closing leaves of venus fly trap to catch a landing insect (any two)

21

REPRODUCTION AND POPULATION CONTROL

The ability to reproduce is one of the essential characteristics of living beings. It involves the transmission of genetic material from the parental generation to the next generation, thereby ensuring that characteristics not only of the species but also of the parental organisms, are perpetuated. In this process, one generation of living organisms gives rise to another generation. The process by which a living organism produces its own kind is known as **reproduction**.

Organisms reproduce in two ways: (1) gametes are not produced and hence there is no fusion of gametes or fertillisation (asexual reproduction), and (2) by formation and the fusion of gametes (sexual reproduction). In this lesson, types of reproduction, reproduction in sponges, insects and humans are discussed. A section deals with problems of population explosion of humans.

OBJECTIVES

After completing this lesson, you will be able to:

- *define reproduction and differentiate between asexual and sexual reproduction;*
- *describe gemmule formation as one example of asexual reproduction.*
- *describe the organs for sexual reproduction in cockroach.*
- *state functions of each part of male and female reproductive systems in humans;*
- *draw labelled diagrams of male and female reproductive systems;*
- *describe the main events in the process of reproduction in humans starting from the production of gametes to pregnancy and childbirth;*
- *describe the process of exchange of nutrients and respiratory gases across embryo and mother;*
- *explain lactation.*
- *explain how twins are produced;*
- *highlight recent advances in the area of human reproduction;*
- *define the terms—population, demography, birth rate, death rate and growth rate, etc.;*

- *list the factors responsible for rapid rise of population in India;*
- *describe the disadvantages of enormously increasing population;*
- *explain the needs for controlling the population growth;*
- *list various methods of contraception for population control.*

Reproduction: Reproduction is the ability of living organisms by which they produce offspring of their own kind. Organisms reproduce by:

1. **Asexual reproduction** involves the production of an offspring from a single organism without the formation of gametes. It is a common process of reproduction in bacteria, protista, lower plants and lower animals.

2. **Sexual reproduction** is the production of offspring by the formation and subsequent fusion of gametes. At fertilization, the male and the female gametes unite to form a zygote which develops into a mature organism. Most animals and higher plants multiply by sexual reproduction.

Two examples of sexual reproduction are given here (i) insects (ii) in humans

21.1 A SEXUAL REPRODUCTION IN ANIMALS

There are various methods of sexual reproduction in lower animals and one example, is that of production of reproduction bodies called 'gemmules' in sponges (Phylum Porifera)

21.1a Gemmule

Gemmule is a reproductive body for asexual reproduction found in fresh water sponges and some marine sponges (*Gemma* in Greek means bud).

A full grown gemmule (Fig. below) looks like a tiny hard ball containing an inner mass of undifferentiated cells called **archaeocytes**. The archaeocytes are surrounded by a resistant covering which protects the inner cells. The covering is made up of chitin and may be strengthened by spicules. There is a small outlet called micropyle. Gemmules tide over the unfavourable conditions. For example when the pond dries up or during the freezing cold of winter when adult sponges die, it is the gemmules that remain viable. When the favourable conditions return, archaeocytes come out of the micropyle and develop and differentiate into a sponge.

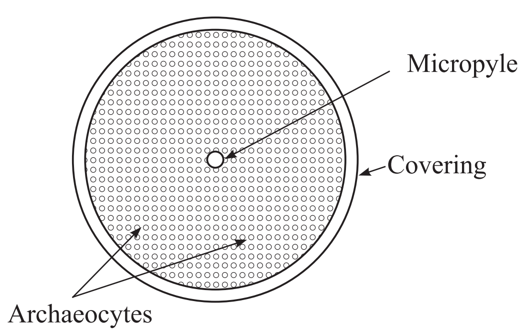


Fig. A gemmule of fresh water sponge *Spongilla*

21.1 REPRODUCTION IN HUMANS

The humans reproduce sexually. Reproduction in humans can be studied in two parts:

(a) Reproductive system, and

(b) Fertilization, pregnancy and development of the embryo.

Human Reproductive System

Maturity of human sex organs begins with puberty the name given to the **changes** that occur in boys and girls as they grow up. Mostly these changes occur between the age of 10 to 14 years, and these are brought about by certain hormones. During puberty the body grows rapidly, and both *primary and secondary reproductive organs* grow and become mature. Along with these changes, *secondary sex characters* also start appearing. It is also to be noted that in males, sexual maturity is attained at the age of 13–14 years and in females, at the age of 11–13 years. Puerty ultimately leads to a stage when the child becomes an adolescent.

Some Basic Facts

What is adolescence?

The term adolescence comes from the Latin verb *adolescere*, meaning '*to grow into maturity*'. In this sense, '*adolescence is a process rather than a time period, a process of achieving the attitudes and beliefs needed for effective participation in society*'. The World Health Organization (WHO) defines adolescence as the period from 10 to 19 years of age characterized by developments and changes in physical, psychological, and social areas.

During adolescance, the secondary sexual charaters that develop are as follows:

In males, these include deepening of voice, widening of shoulders, muscular body, appearance of beard and moustache, growth of axillary and pubic hair, enlargement of external genital organs.

In females, the changes include growth of axillary and pubic hair, widening of pelvis and hip, enlargement of breasts and initiation of the menstrual cycle.

Sexual maturation is a very significant stage in one's life, hence it is necessary to maintain the health and hygiene of the reproductive organs during this stage.

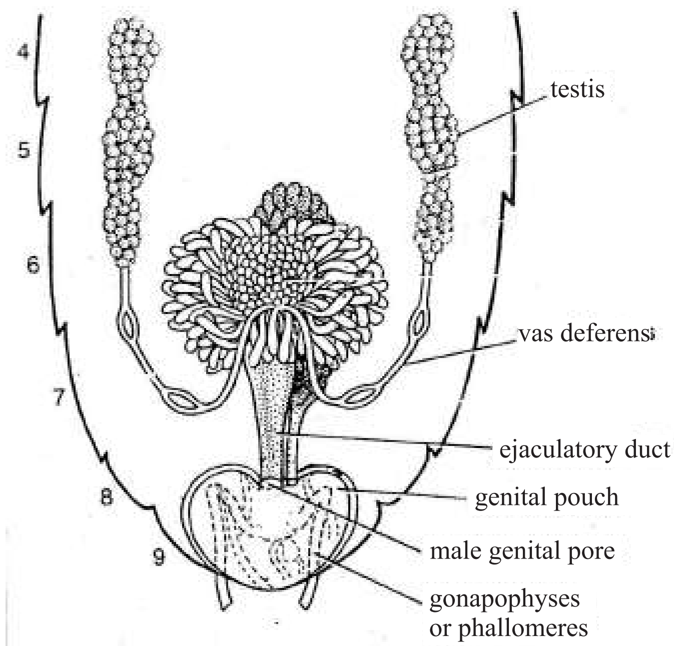
21.2a Reproductive System of Insects

Sexes are separate in most insects and reproduction is usually sexual, although in some groups of insects, eggs sometimes develop parthenogenetically (without fertilization). e.g. in aphids all generations are produced parthenogenetically and are all females.

The reproductive organs of cockroach are described here as a representative of insects.

Male Reproductive System

The male reproductive system consists of a pair of **testis** a pair of delicate ducts called the **vas deferens**, (plural: vasa deferentia) and a single median **ejaculatory duct**. The ejaculatory duct opens into a **genital pouch** through a **male genital pore**. Surrounding the male genital pore are the **gonapophyses** which help in copulation. **Seminal vesicles** are small white sacs at the anterior end of the ejaculatory duct. Seminal vesicles store the sperms. **Mushroom gland** and **phallic** or **conglobate gland** are accessory reproductive glands of male. (See figure below)



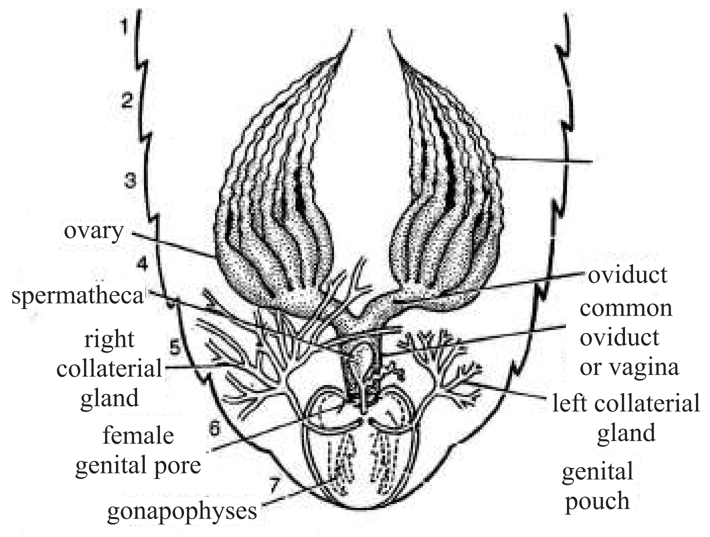
Periplaneta americana. Mate reproductive organs in dorsal view.

Female Reproductive System:

Female reproductive system consists of a pair of **ovaries**, one on either side of the hind gut embedded in the fat bodies. Each ovary consists of blind tubes called **ovarioles.** All the ovarioles unite posteriorly and open into a short lateral oviduct. The two lateral oviducts unite to form a short median **oviduct**. The posterior part of the oviduct is wide and is called the **vagina**. Vagina opens into the **genital pouch** through the female **genital pore** or **vulva**. A **receptaculum seminis** or **spermatheca** opens into the genital pouch. Spermatheca receives the sperms during copulation from the male. Three pairs of **gonapophyses** are present between the female genital pore and anus. They assist in copulation, in laying eggs and in the formation of oötheca (see Fig. below) or egg cover.

A pair of branched accessory glands called the **colleterial glands** open into the genital pouch. The secretion of these glands form the oötheca (hard egg case).

However, different insects may show a variation from this basic plan.



Periplaneta americana. Female reproductive organs in dorsal view.

Human reproductive organs are described and illustrated below.

Male reproductive system

The reproductive system in male consists of the following organs – a pair of **testes**, a pair of epididymis, a pair of vasa deferentia (singular : vas deferens), urethra, penis and accessory glands (Fig. 21.1) (Table 21.1).

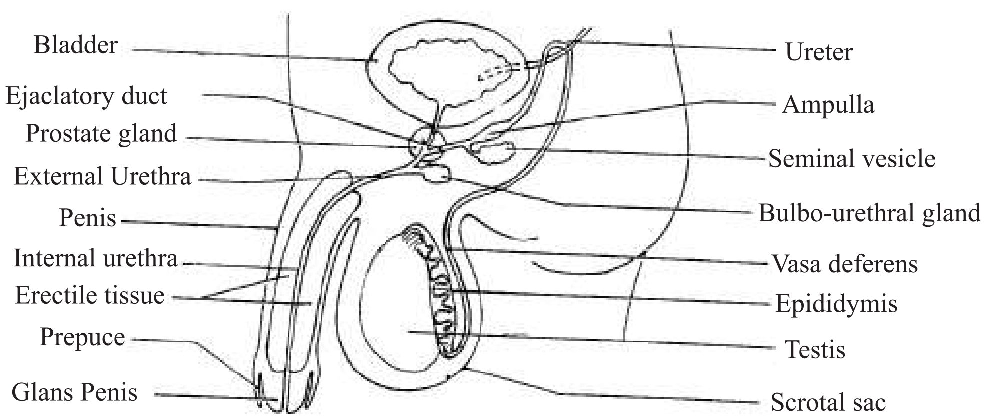


Fig. 21.1 Male Reproductive system

(i) Testes

Testes (singular: testis) as depicted in Fig. 21.2 are the male gonads. In an adult male, each testis is approximately 4-5 cm long and about 12 g in weight. Testes are **extra-abdominal,** that is, present outside the abdomen in a pouch made up of skin and connective tissue called **scrotal sac** or **scrotum** that hangs in the region between the legs.

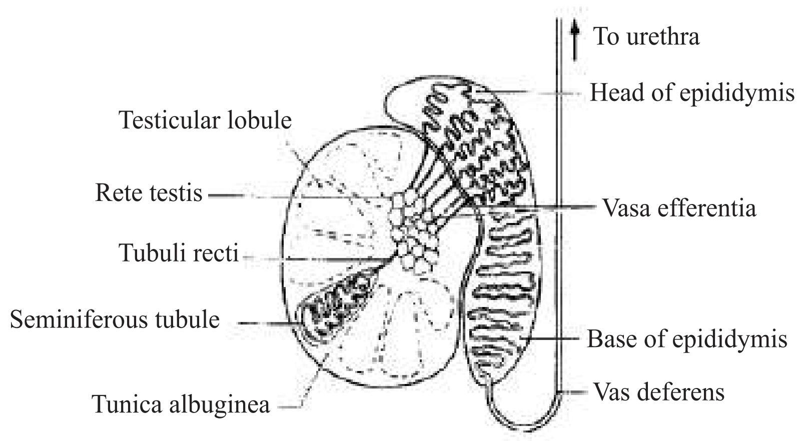


Fig. 21.2 Microscopic Structure of Testis

The scrotum acts as a thermoregulator. It helps in maintaining the temperature of testes at about 2-3°C lower than the body temperature. This temperature is suitable for the development of sperms.

Anatomically, each testis is encased in a capsule of white fibrous connective tissue called tunica albuginea. Each testis has several highly coiled tubules called **seminiferous tubules** (Fig. 21.2) where the sperms are produced. Between the seminiferous tubules is the connective tissue, which contains clumps of interstitial cells, also called **Leydig cells**. These cells secrete **testosterone** the male sex hormone. Testosterone maintains the primary and secondary sexual characteristics in males.

(ii) Epididymis

It is a long highly coiled tube which remains attached to the testis and lies within the scrotal sac. Epididymis stores spermatozoa (sperms) and serves as a passage for their transport from the testis.

(iii) Vas deferens (sperm duct)

Each epididymis continues as **vas deferens**. It enters the abdominal cavity, passes over the urinary bladder and joins the duct of seminal vesicle to form the **ejaculatory duct.** The ejaculatory duct opens into the urethra.

(iv) Urethra

The urethra in males is about 15-20 cm long and is differentiated into three parts— an anterior prostatic part which passes through the prostate gland; a middle membranous part; and a posterior penile part which passes through the copulatory organ, the penis. Urethra functions as a passage for both semen and urine.

(v) Penis

Penis is a cylindrical, spongy, muscular and a highly vascular (supplied with blood vessels) copulatory organ in males. The urethra runs through it centrally and serves as a common passage for urine and semen. During sexual excitement, the spongy tissue gets filled-up with blood, making it erect and stiff. Externally, the penis is covered by skin. The tip of the penis is soft and highly sensitive. It is called **glans penis**. It is covered by a loose fold of skin called prepuce which can be retracted. The functions of various male parts are given in table 21.1.

Table. 21.1 Important functions of male reproductive organs in humans.

Organ	Function
Seminiferous tubules in testes	Produce sperms
Epididymis	Stores sperms in a viable but immobile state
Sperm duct (vas deferens)	Contractions help in the passage of sperms into urethra during ejaculation
Seminal vesicles and prostate gland	Secrete fluid which activates and nourishes sperms
Urethra	Contractions expel semen from penis during ejaculation (urethra also carries urine to exterior)
Penis	Contains spongy tissue and serves as the copulatory organ

21.2 b (iii) Organs associated with human male reproduction system

Accessory glands

The accessory glands include seminal vesicles, prostate glands and Cowper's glands.

Seminal vesicles. A pair of seminal vesicles are present at the base of the urinary bladder. The seminal vesicles store sperms that descend from the testis and secrete seminal fluid. The seminal fluid is a viscous fluid which provides nourishment to the sperms. This secretion forms about 40-80 per cent of the ejaculate (semen thrown out of the penis).

Prostate gland. Prostrate gland surrounds the first part of the urethra. It secretes an alkaline fluid which is discharged into the urethra. This fluid keeps the sperms alive and helps them to swim vigorously. Secretion of prostrate gland forms about 5-30 per cent of the ejaculate.

Cowper's glands or Bulbo-urethral glands. These are paired glands that lie below the prostate gland and join the urethra at a short distance from that of the prostate gland. Cowper's glands secrete a white, viscous, alkaline secretion resembling mucous which acts as a lubricant.

21.2b (iii) Spermatozoa and semen

The process of formation of sperms is termed Spermatogenesis

The spermatozoa are male gametes produced by the testes. Structurally, human sperm has three main parts—head, neck and tail. The tip of a sperm is covered by a cap-like structure, **acrosome**, which helps the sperm to penetrate inside the egg during fertilization. The structure of a human sperm is shown in Fig. 21.3.

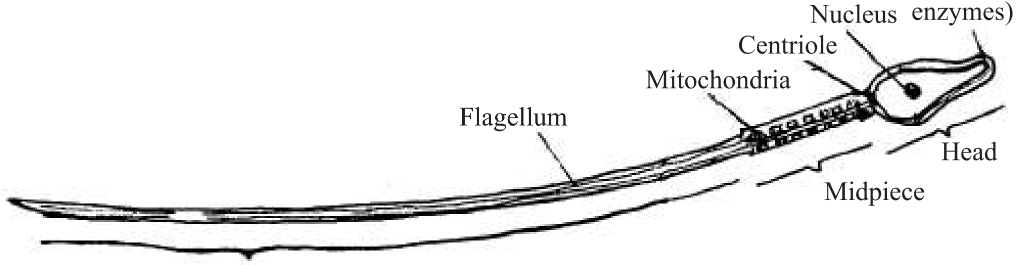


Fig. 21.3 Structure of human sperm.

Spermatozoa are immotile when stored in the epididymis but get activated and motile by the secretions from the accessory reproductive glands in males. The secretions of various accessory glands along with sperms form the **semen**. The sperms are released in millions. In one ejaculation about 200,000,000 (2×10^8) sperms are discharged. Sperms when introduced into the vagina of the female move with the speed of 2 mm/minute in side the body of the female.

Fig. 21.4 shows the course of sperms from their production in the testes to reach the urethra in penis.

Seminiferous tubules in testes produce sperms

↓

Sperms pass to vasa efferents through
network of tubules

↓

Sperms are stored in epididymis in viable but immotile stage

↓

Vas deferens (sperm ducts)

↓

Urethra in penis

Fig. 21.4 The course of sperms in male.

21.2.2 Female reproductive system

The female reproductive system consists of the following organs :

A pair of ovaries, a pair of fallopian tubes, uterus, vagina and external genitalia (Fig. 21.5).

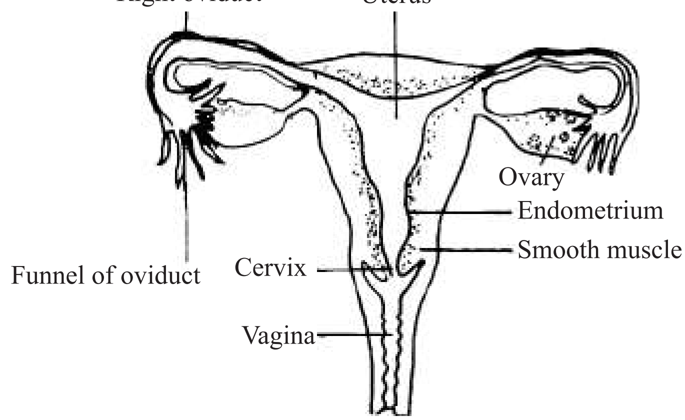


Fig. 21.5 Female reproductive system

(i) Ovaries

There is a pair of ovaries, which lie in the lower part of the abdominal cavity, one on each side of the body. Ovaries produce ova and also secrete female sex hormones, oestrogen and progesterone. The process of formation of egg in the ovary is known as **oogenesis**.

If a section of the ovary is cut, eggs at various stages of maturing can be seen. Each egg begins as a primary follicle. Follicular cells then cover the egg and a cavity called **antrum** is formed. This is the mature egg called **Graffian follicle**. The egg then gets released (ovulation) from the ovary leaving the empty follicle called **corpus luteum** (Fig. 21.6).

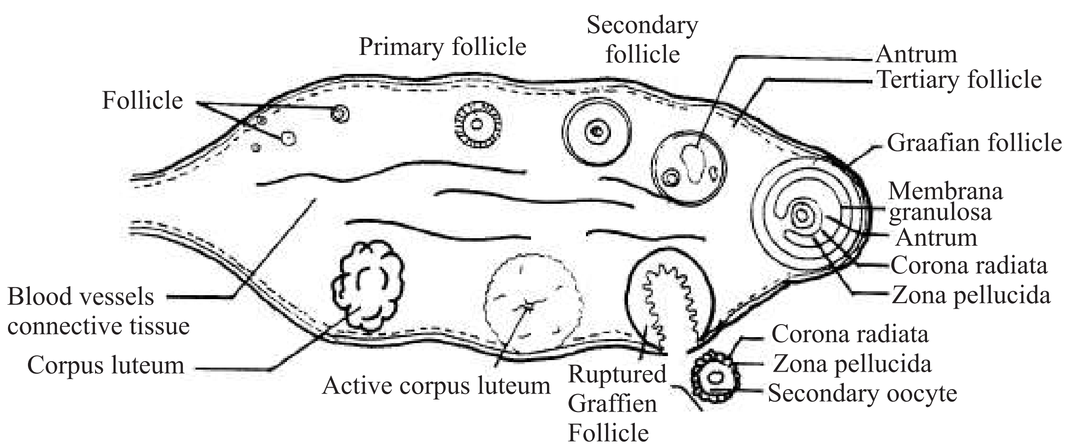


Fig. 21.6 Ovary showing microscopic structure

(ii) Fallopian tubes (oviducts)

There are two oviducts (or Fallopian tubes) in female reproductive system. Each oviduct is about 10-15 cm long. The proximal funnel-shaped end of each oviduct lies near the ovary and is called **infundibulum**. Its margin bears finger-like projections called **fimbrae**. Each infundibulum continues as a thin and coiled tube called oviduct or **Fallopian tube**. Both Fallopian tubes open into the uterus.

(iii) Uterus

The uterus is a pear-shaped, muscular, thick-walled organ. It is about 7 cm long, 5 cm broad, and 2.5 cm thick. The wall of the uterus comprises of three coats—the innermost **endometrium**, middle **myometrium**, and outermost **perimetrium**. The endometrium layer is richly supplied with blood vessels. There is a sphincter muscle that closes the lower end of the uterus where it joins the vagina.

(iv) Vagina

Vagina is the organ where the penis is inserted during coitus (sexual act) for the discharge of semen. It is a muscular tube about 7-10 cm in length. It serves as the birth canal during child birth and also acts as a duct for the passage of uterine secretions and menstrual flow.

The vagina opens to the outside by an opening. The opening of vagina is normally obstructed in a virgin female by a perforated membrane, the **hymen**. In a human female, the urethra and the genital duct have separate openings. Functions of various female reproductive parts are summarised in table 21.2.

Table 21.2. Important functions of female reproductive organs in humans.

Organ	Function
Ovary	Manufactures eggs
Oviduct (or Fallopian tube)	Site of fertilization; transfers fertilized egg/embryo to the uterus
Uterus	Inner lining receives, protects and nourishes embryo; contractions of muscular wall expel baby during birth
Cervix (neck of uterus)	Produces watery mucous that serves as a lubricant for the penis and as medium, in which sperms swim after ejaculation
Vagina	Receives penis during intercourse; passage for baby during birth
Clitoris (external sensual organ)	Equivalent to the male penis;

21.2.3 Menstrual Cycle in Human Females

In a human female, the fertility period extends from the age of puberty, i.e. about 12-13 years up to menopause, i.e. 45-50 years. The stage of puberty is marked by the appearance of secondary sexual characteristics.

Some Basic Facts

Does an irregular menstrual cycle cause any problems?

When a girl begins menstruating, it may take sometime for her periods to become regular. Also, sometimes her menstrual cycle may become irregular, and her periods may be delayed or may occur earlier than the expected date because of illness or mental tension such as stress or depression. Irregularities in the menstrual cycle are quite common among young girls who have just begun to menstruate. However, if one does not menstruate then it is important to consult a doctor or a health worker.

How does one maintain hygiene during the menstrual period?

- Daily bathing along with regular/daily washing of the genital area is essential.
- Sanitary pads and/or cloths used should be changed at least twice a day, if not more frequently.
- It is important to maintain menstrual hygiene in order to reduce the risk of contracting an infection of the female reproductive tract.
- If pads or napkins are not changed frequently, the old blood begins to smell. This may lead to social embarrassment.
- Home-made sanitary napkins should be washed thoroughly with hot water and soap, and should be dried in a sunny and airy place. They should be stored in a clean and dry place.
- Moderate exercise and sufficient rest are also important.

The onset of menstruation in a female is called **menarche**. It starts at an age of about 11-13 years. The permanent stoppage of menstruation in a female is called **menopause**. It occurs at an age of about 45-50 years. At the time of menopause, ovulation and menstruation stop and the reproductive organs decrease in size.

Between puberty and menopause, the female reproductive system passes through a regular monthly sequence of events called the **menstrual cycle**.

During **menstrual cycle** (Fig. 21.7), an ovum is matured and released once every 28 days. However, many a times, due to some reasons this period may increase or decrease. The menstrual cycle starts with the menstrual flow, during which the cellular lining of the uterus, with blood flow, is shed off. This process continues for 3-4 days. From the 5th upto the 13th day of the onset of menstrual cycle, growth and maturation of the Graafian follicle takes place. Graafian follicle is the final stage in the maturation of an ovum inside the ovary. It consists of an ovum and a mass of cells surrounding it. The Graafian follicle also produces a hormone, **oestrogen**, which stimulates the uterus to prepare itself to receive the ovum. The cells lining the uterus grow rapidly and develop a dense network of blood vessels.

Ovulation takes place 13-14 days after the onset of menstruation. The Graafian follicle ruptures to release the ovum. The cells of the ruptured follicle form the **corpus luteum** which secretes the hormone, **progesterone**. The ovum reaches the uterus via the fallopian tube on the 13th or 14th day and remains there up to the 16th day (for 48-72 hours). If the ovum does not receive any sperm during this period it starts degenerating. At the end of the 28th day this ovum is rejected along with the uterine lining. This marks the start of a slow disintegration of the thickened lining of the uterus and the next menstrual cycle.

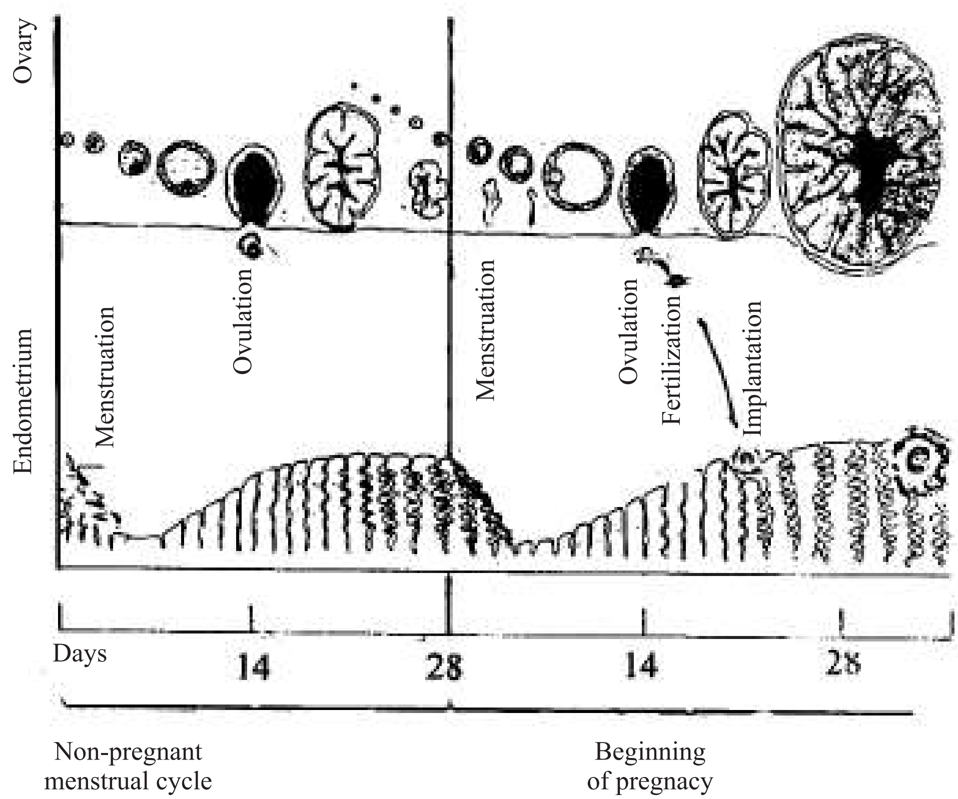


Fig. 21.7 Graphical representation of menstrual cycle

What happens to the menstrual cycle if the ovum receives sperm and fertilization occurs?

If the ovum receives sperm and gets fertilized, menstruation (and ovulation) cease for as long as the woman is pregnant. This is because progesterone is produced continuously first by the corpus luteum (which persists in the ovary) and later by the placenta.

INTEXT QUESTIONS 21.1

1. At what age do human males and females attain puberty?

   ....

2. Name the tubules present in the human testis.

   ....

3. Name the various parts of the following,

   (i) Human male reproductive system

   ....

   (ii) Human female reproductive system

   ....

4. Name the three types of accessory glands found in the human male reproductive system.

   ....

5. State the functions of the following.

   (a) Seminal vesicles ....

   (b) Prostate glands ....

   (c) Uterus ....

6. What is a gemmule? Explain its importance in the life of sponges.

7. State the functions of the following in insects:

   (a) seminal vesicles in male

   (b) spermatheca in female

   (c) testes in males

   (d) ovaries in females

21.2 FERTILIZATION, PREGNANCY AND DEVELOPMENT OF THE EMBRYO

21.2.1 Fertilization and implantation

Spermatoza remain viable in the female genital tract from 24 to 72 hours. For fertilisation, sperms are introduced into the female body. One sperm fuses with the ovum in the fallopian tube.

If the ovum happens to meet a sperm, the two unite to form a **zygote**. 13-14 days after onset of menstruation are most favourable for conception (pregnancy). The zygote immediately begins to divide and passes down the fallopian tube to the uterus and fixes itself to the wall of the uterus. This fixing of the embryo in the wall of the uterus is called **implantation** and the female is said to be pregnant. Implantation takes place about a week after fertilization.

21.2.2 Placenta

Placenta is an association between maternal and foetal tissue meant for some extermely important physiological exchange. The developing embryo is attached to the uterus by a tissue called **placenta** (Fig. 21.8). **Umbilical cord** is a tough structure that serves as the blood vascular connection between the foetus (developing embryo) and uterine wall. From the first few weeks of development, the embryo is enclosed in a sac called **amnion** which is filled with **amniotic fluid**. Amniotic fluid acts as a shock-absorber and helps to protect the embryo from damage.

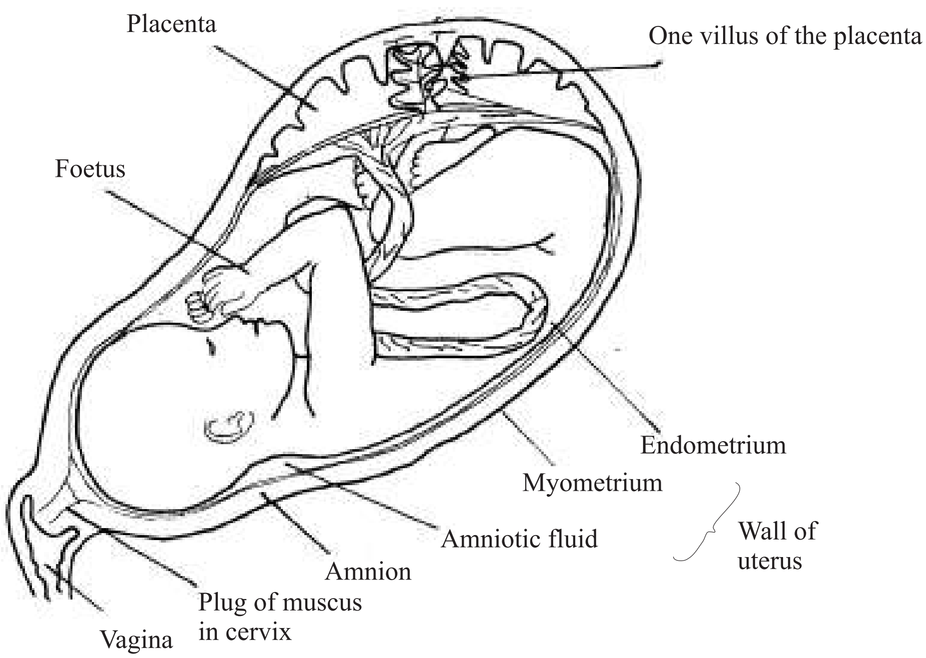


Fig. 21.8 Foetus and placenta

Placenta serves as a tissue through which oxygen and food are supplied from the maternal blood to the foetus. It also transports carbon dioxide and excretory waste from the foetal blood to the maternal blood.

Fig. 21.9 Summarises the steps in fertilisation of human egg, its inplantation and development in the uterus upto birth.

Sperms from male are deposited into the female reproductive system

↓

Egg released from the ovary

↓

Union of the sperm and egg in the fallopian tube

↓

Fertilization and formation of zygote (Day 1)

↓

Repeated division of zygote leading to formation of
a spherical mass of cells called morula (Day 4)

↓

Early embryonic stage is (called blastocyst) formed (Day 5)

↓

Blastocyst attaches to uterine wall
(i.e. Implantation occurs) (Day 6-7)

↓

The developing Embryo about the size
of a pea is formed (4 weeks)

↓

Embryo (now called foetus) with human features, limbs appear.
It floats in amniotic fluid (6 weeks)

↓

Birth of human infant (about 40 weeks)

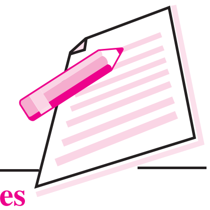
Fig. 21.9 Development of human embryo

Placenta is permeable to respiratory gases, nutrients and antibodies. The membrane prevents harmful material from reaching the embryo. It does not allow the passage of germs from the mother to the foetus. However, if the mother is already infected with HIV, then HIV can pass through the blood to the embryo. Placenta produces the hormone progesterone. Egg-formation (ovulation) and menstruation also stop as pregnancy continues. However, these are resumed after child birth.

The hormone Oxytocin from posterior pituitary is responsible for uterine contractions for child birth.

21.2.3 What happens during childbirth?

- The uterus undergoes occasional contractions (labour).
- The amnion bursts and the amniotic fluid is discharged.
- The uterus contracts vigorously, expelling the baby.
- The baby's lungs start functioning and the baby takes its first breathe.
- The umbilical cord is tied and cut.



Notes

- After birth the placenta gets discharged.
- The breasts start producing milk.

21.2.4 Lactation

The secretion of milk from the mammary glands is called lactation and the period during which the mammary gland secretes milk is called **lactation period**. The first seeretion that comes out from the mammary glands of the mother, just after child birth, is called **colostrum.** It is rich in nutrients, fats and proteins. Colostrum also contains antibodies (Immunoglobulin A-IgA) that provide passive immunity to the new born infant.

The synthesis of milk from the mammary glands is stimulated by the hormone **prolactin** which is secreted by the anterior lobe of the pituitary gland. Another hormone called **oxytocin** secreted by the posterior lobe of pituitary gland stimulates the release of the milk from the mammary glands.

21.2.5 How twins are Produced

Usually, only one ovum is released by an ovary in every reproductive cycle. If this ovum receives sperm and gets fertilized, one baby is born to the mother. But sometimes two eggs may be released and fertilized by two different sperms. Such siblings are called **fraternal twins** who may be brother and sister, or brother-brother, or sister-sister. But in certain cases, only one egg is released and gets fertilized. After this, it divides into two, and the two cells then separate and start developing independently into two separate individuals. They are identical in all respects and called **identical twins**. They are always of the same sex.

Siamese twins

The twins produced from one egg which fail to separate are called Siamese twins. The first case of Siamese twins was of twin boys born to a Chinese mother in Siam, (now Thailand) in 1811. These were joined at the thoracic region. These twins lived up to an age of 65 years.

The Siamese twins can sometimes be surgically separated. However, it depends upon the extent of their joining.

21.3 NEW MEDICAL TECHNIQUES IN REPRODUCTION

There are many new medical techniques in the field of reproduction to help infertile males and females produce babies. Some of these are given here.

Test tube babies

In some women the oviducts (Fallopian tubes) are blocked. This prevents the ova from being fertilized. This problem can be overcome by the **test tube baby technique**. In this technique, one or more ripe ova are sucked from a woman's ovaries using a special syringe. These ova are placed in a dish containing sperms from her male partner under optimum conditions for a few hours. Sperms fertilize the ova which form an embryo. One embryo is then inserted into the woman's uterus where there is a chance it will implant and develop into a baby.

Artificial insemination

Human semen can be rapidly frozen using liquid nitrogen and stored in sperm banks for several years without losing its fertile condition. It is then thawed, and introduced into a woman by means of a syringe at a time when ovulation takes place. This is called **artificial insemination**.

Fertility drugs

In some women ovaries fail to develop the Graafian follicles needed to release ripe ova into their reproductive tract. It is now possible to artificially stimulate follicle production by injecting sterile women with a fertility drug containing FSH (follicle stimulating hormone) obtained from animals.

INTEXT QUESTIONS 21.2

1. State the main function of placenta.

   ....

2. Define the following terms.
   (i) Implantation ....
   (ii) Placenta ....
   (iii) Morula ....
   (iv) Amnion ....

3. Name the fluid surrounding the foetus in the uterus.

   ....

4. Write the function of:
   (a) Prolactin
   (b) Oxytocin

5. The first milk that comes out of the mammary gland of the mother is called .... Why is this first milk important for the child?

21.4 POPULATION–PROBLEMS AND CONTROL

21.4.1 Few terms to remember

- **Human population** : The sum total of human beings on earth.

- **Demography** : The scientific and statistical study of human population. It deals with population growth, its composition (age, sex ratio) and its distribution in space.
- **Population density** : The number of individuals per square kilometre (km^2) at any given time.
- **Birth rate (natality)** : The number of live births per 1000 individuals of population per year.
- **Death rate (mortality)** : The number of deaths per 1000 individuals of population per year.
- **Population growth rate** : The difference between the birth rate and the death rate.
- **Census** : The official data of registered number of people in a selected area.

21.4.2 Population growth in India

Did you know that India is the second most populous country in the world, next to China. India comprises more than 15% of world's total population. The population of India was about 24 crores in the year 1901. Except for a slight fall in 1911-21, the population of India has been steadily increasing for the last 100 years. As per the census of 2001, as on 1st March 2001, the population of India was 1,027,015,247, i.e. about 102.7 crores. This alarming rate of rise in human population is a cause of concern. Now in 2014, the population of India is:

Table 21.3 The population of India during last 100 years

Year	Approximate population (in crores)
1901	23.8
1911	25.2
1921	25.1
1931	27.9
1941	31.8
1951	36.1
1961	43.9
1971	54.8
1981	68.5
1991	84.6
2001	102.7

21.4.3 Factors responsible for population explosion in India

Advancement in agriculture : With the advancement in the agriculture sector, the availability of food has increased leading to less of starvation and malnutrition.

Advancement in medicine : With the advancement in medicine, various diseases can be controlled now. This has led to increase in life span. Thus, more and more people live longer, reach reproductive age and produce more children.

Religious and social customs : Because of prevailing social custom and beliefs many people do not accept family planning measures, leading to rise in population.

Industrialization : Advancement in industrialization helps in better storage and distribution of food, more employment opportunities and more prosperity.

Illiteracy : A sizeable number of our population is educated, and yet a large proportion is still illiterate. They are not aware of the functioning of reproductive system and hence the consequence of overpopulation.

Economic reasons : Children instead of attending school go to work and increase the income of the family.

Desire for a male child : Even after so much emphasis on gender equality, because of patriarchy in many families, the male child is considered to be essential for continuing the name of the family. The parents want to have at least one son and in this process they give birth to many children sometimes.

21.4.4 Problems posed by increasing population

The problems posed by increasing population are of two types:

1. Problems posed to large families, and
2. Problems posed to the Country.

1. Problems for large families

A large family having many children suffers many problems such as

(a) **Poor health of the mother :** Because of frequent pregnancies, the mother may suffer from ill-health.

(b) **Poor housing :** More family members need more space. The family may not be able to afford a good, clean and spacious house.

(c) **Economic pressure :** The large family will need more resources, leading to immense economic pressure on the parents and children affecting the quality of life.

(d) **Poor health :** The family members may not get enough food, leading to malnutrition and deficiency diseases. They will require constant medical support.

Also, because of medical facilities being expensive, it may not be possible to provide everyone adequate medical support.

(e) **Improper education :** Proper educational facilities for children may not be affordable.

Problems Posed to the Country

A high population growth has severe environmental implications like over-crowding, decrease in per capita income, depletion of food, land, fuel and consumer resources. Some such problems are listed below:

(a) **Urbanization and environmental degradation :** Due to increasing population, farmlands in the rural areas can no longer support additional people. Thus, a large number of people migrate to urban areas with the hope of finding jobs and a better life. This leads to an increase in the urban population.

The growth in urban population stresses the urban environment by increasing the number of squatter settlements, and slums with no proper sanitation facilities, thus causing air, water and soil pollution beyond permissible limits.

(b) **Increasing population and transportation :** Increase in population requires a corresponding increase in the means of transport. Increase in the number of automobiles as a consequence of phenomenal growth in population has increased the pollution load (air pollution, water pollution and solid waste pollution).

(c) **Increasing population and education :** Education is most important for economic and social upliftment. Although literacy rate is growing, we still have a very large number of illiterates in the country. The increasing population further adds up to the problems of providing education to all.

(d) **Increasing population, agricultural development and environmental degradation :** In order to meet the food requirement of the ever-increasing population of the country new agricultural techniques have been adopted. Some of these have proved to be detrimental to the environment.

(e) **Increasing population and food requirements :** Increasing population will need more food. For this purpose new agricultural land has to be created. So, forests have been cut down for cultivation. Due to deforestation, excessive irrigation and natural hazards, such as floods are frequent, land is being degraded and wasteland is increasing. The increased use of fertilizers and pesticides to boost agricultural productivity has immense adverse effects on land and water resources of our country. Agricultural land has been extensively polluted due to pollution from fertilizers and pesticides.

(f) **Increasing population and water :** The availability of water is limited. Increasing population needs more water for drinking, bathing, washing etc. Thus, availability of water is becoming scarce.

(g) Increasing population and depletion of mineral reserves : Our mineral reserves are limited, once finished they cannot be replenished (i.e. they are non-renewable). More population means more requirements of minerals, leading to fast depletion of mineral resources.

(h) Increasing population and depleting energy sources : Energy is needed for almost all our day-to-day activities whether for cooking, transportation, factories or at home. Presently we are largely dependent on fossil fuels such as coal and petroleum for energy. At the current rate of consumption, our fossil fuel reserves will be exhausted in a short time.

INTEXT QUESTIONS 21.3

1. List any **four** reasons for population explosion in India.

   ....

2. What is the inter-relationship between population, environment and development?

   ....

3. What is the effect of uncontrolled population growth on us and our nation?

   ....

4. How does population growth influence urbanization and environmental degradation?

   ....

5. Relate the indiscriminate increase in population with the standard of living in our country.

   ....

21.4.5 Population control and family planning

It is very necessary to control the overgrowing population. It is necessary to educate people to accept small family norms and create awareness about population explosion and its impact on the family, society and the nation. The government has taken many measures for providing family planning guidance and support, and family welfare measures.

There are various ways of preventing fertilization and hence to check the increase of population. Some of these are discussed here.

Education

The most effective method for control of population is to impart education to the masses about the consequences of population explosion and make them aware of various ways of fertility control. Education helps to make people aware of the advantages of a small family and the disadvantages of a large family.

Preventive methods for population control and family planning.

Following are some methods of birth control

(i) **Rhythm method –** The period in the menstrual cycle before ovulation phase is termed 'safe period' as no egg is available for fertilization by the sperm. This method, however, is not reliable.

(ii) **Use of condoms in males and diaphragms in females** prevent sperms from meeting the ovulated egg.

(iii) **Intrauterine devices** such as copper T are inserted in the female body so that implantation is not possible. This method requires advice and help from the medical doctor.

(iv) **Oral contraceptive pills** are tablets which have to be taken as per directions from a medical practitioner. These pills interfere with ovulation and in turn prevent fertilization.

(v) **Vasectomy and Tubectomy** are surgical methods. In males, the vas deferens through which sperms travel out of epididymis is ligated (tied) by the surgeon to prevent sperms from going out of the body. This method is temporary and can be reversed by the surgeon if required. For permanently preventing fertilization the vas deferens is cut and the open ends ligatured (tied by thread). Tubectomy is sterilization of the woman by cutting fallopian tubes and ligaturing them so that ovulated egg cannot pass down for fertilisation.

In case preventive measures fail or if the foetus is found to have a defect, the foetus may have to be aborted.

Abortion or Medical Termination of Pregnancy (MTP) is to remove the unwanted foetus from the mother's body. However, it is advised to always seek professional medical help for MTP.

WHAT YOU HAVE LEARNT

- A process by which a living organism is able to produce more of its own kind is known as reproduction.
- In asexual reproduction only one organism is involved, no gametes are produced and no fertilization takes place. Gemmules are reproductive bodies for asexual reproduction in sponges.
- In sexual reproduction both male and female gametes are produced and the process of fertilization takes place. The human reproduce sexually.
- The age of 13-14 years in human males and 11-12 years in human females is called puberty in human beings. At this age, sex organs get matured and several secondary sexual characteristics appear in them.

- The male reproductive system consists of a pair of testes, a pair of epididymis, a pair of vasa differentia, urethra, penis and accessory glands.
- The female reproductive system consists of a pair of ovaries, a pair of Fallopian tubes, uterus, vagina and external genitalia.
- Testes are extra-abdominal in human males.
- The fixing of the embryo in the uterine wall is called implantation.
- Placenta is an association between maternal and foetal tissues meant for exchange of material between pregnant mother and developing foetus.
- Loctation is the production of milk in a mother soon after delivering the baby.
- Twins are of two types—fraternal and identical twins.
- The scientific and statistical study of human population is called demography.
- Advancement in agriculture, medicine, industrialization, religious and social customs, illiteracy, economic reasons and desire for a male child are some factors responsible for the unchecked growth of population in India.
- The enormous increase of the population can be controlled by education, methods.
- In cockroach there are well developed sex organs in males and female as sexes are separate.

TERMINAL EXERCISES

1. Define the following terms.

   (i) Demography (ii) Vasectomy (iii) IUD

2. Mention if the following statements are True (T) or False (F) and rewrite the wrong statements in the correct form.

   (i) Fertilization occurs in vagina.

   (ii) Oxygen and nutrients diffuse from mother's blood into foetus's blood through amnion.

   (iii) Testes produce testosterone hormone.

   (iv) Pregnancy in women can be prevented by the method of vasectomy.

   (v) Tubectomy involves the cutting and tying of the vas deferens in male.

3. Choose the odd one in each of the following.

   (i) ovary; Fallopian tube; ureter; uterus

   (ii) epididymis; urethra; vas deferens; uterus

(iii) Graafian follicle; corpus luteum; Leydig cell

(iv) amnion; corpus luteum; amniotic fluid; umbilical cord

4. Match the terms of Column I with those of Column II and write down the matching pairs.

Column I	Column II
1. Acrosome	(a) Testis
2. Ovulation	(b) Luteinizing hormone
3. Villi	(c) Spermatozoa
4. Fertilization	(d) Progesterone
	(e) Placenta
	(f) Vagina
	(g) Fallopian tube

5. What is reproduction? List tile organs of the human male reproductive system.
6. What is placenta? How is the placenta beneficial to the mother and the foetus?
7. What is the significance of testes being located in scrotal sac outside the abdomen of human males?
8. Write in a sequence the region through which sperm travels from seminiferous tubules up to the urethral opening in human males.
9. How can the knowledge of process of reproduction help in reducing population growth? Give reasons.
10. How does increasing population affect environment?
11. Name the following.

    (i) The organ in which the foetus develops in a human female.

    (ii) The male gamete in humans.

    (iii) The fluid surrounding the developing embryo.

    (iv) Stage when menstruation and ovulation stops in females.

    (v) The surgical method of contraception in human female.

12. Differentiate between the following.

    (i) Implantation and pregnancy

    (ii) Graffian follicle and corpus luteum

    (iii) Identical twins and fraternal twins

(iv) Birth rate and death rate

(v) Vasectomy and tubectomy

13. Draw the outline of the cross section of the male reproductive system.

(i) Label the following parts.

(a) testis (b) epididymis

(c) seminal vesicles (d) vas deferens

(ii) Name the hormone produced by the testis.

(iii) Why are sperms produced in large numbers?

(iv) State the function of the seminal vesicles.

14. Write a note on:

(i) Lactation in humans

(ii) Gemmule (iii) Cockroah ovaries

ANSWERS TO INTEXT QUESTIONS

21.1 1. Male 13-14 years; Female 11-13 years

2. Epididymis

3. (i) Testes, epididymis, vas deferens, urethra, penis

(ii) Ovaries, fallopian tubes, uterus, vagina

4. Seminal vesicles, prostate glands, cowper's glands

5. (a) Stock sperms and provide them nourishment

(b) Secretes an alkaline fluid, thin fluid keeps the sperms alive and helps them to swim vigorously.

(c) Secretes a white viscous, alkaline secretion that acts as a lubricant.

(d) Inner lining receives, protects and nourishes embryo; contraction of muscular wall exits baby during birth.

6. Gemmule is a reproductive body for asexual reproduction in sponges.

Gemmules help sponges overome periods of drought and form new sponges when favourable conditions arise

7. (a) Seminal vesicles store sperms; (b) receives sperms during copulation

(c) generate sperms (d) produce eggs.

21.2 1. supplies oxygen and food from maternal blood to foetus and transports carbon dioxide and excretory waste from foetal blood to the maternal blood.

2. (i) the fixation of morula in the wall of uterus is called implantation

   (ii) Association between maternal and foetal tissue for physiological exchange, developing embryo is attached to the uterus by a tissue called placenta.

   (iii) Morula : The zygote begins to divide and form a mass of cells called morula.

   (iv) Amnion : From the first few stages of development, the embryo is enclosed in a sac called amnion.

3. Amniotic fluid

4. Prolactin stimulates synthesis of milk in mammary glands in women soon after delivering a body.

   Oxytocin stimulates uterine contration for child birth and squeezing of milk in mother for new born infant

5. Colostrum; rich in nutrients, fats and protiens. Provides passive immunity

21.3 1. (i) Advancement in agriculture (ii) Religous and social customs

   (iii) Illiteracy (iv) Desire for a male child

2. See text sub-section 21.4.4

3. See text sub-section 21.4.4

4. See text sub-section 21.4.4

5. See text sub-section 21.4.4

22

PRINCIPLES OF GENETICS

It is a common observation that seeds of mango trees germinate to grow into mango plants, and dogs give birth to puppies only and not into the young ones of any other animal. Humans give birth to human beings. The tendency of offsprings to inherit parental characteristics is termed as '**heredity**' and the study of science of heredity and the reasons governing the variation between the parents and their offsprings, is called '**Genetics**'. Genetics also seeks to answer questions like why two offspring of same parents look different, why some people have dark, and others have fair complexion. In other words, why is there **variation** among individuals of the same kind. This lesson deals with heredity and the reasons behind the variation among individuals of the same species. It also includes diagnostic techniques to find out the bases for types of sex determination, inheritance of blood groups in humans, hereditary disorders and gives an insight up the human genome as amniocentesis.

OBJECTIVES

After completing this lesson, you will be able to :

- *explain the terms heredity and Genetics;*
- *describe Mendel's experiments on garden pea and the principles derived;*
- *define the terms hybridization, alleles, trait, dominance, recessive, homozygous, heterozygous, genotype, phenotype;*
- *explain incomplete dominance, polygenic inheritance, pleiotropy and lethal genes with examples.*
- *explain the chromosome theory of heredity;*
- *define and give examples of linkage, crossing over and cris-cross inheritance;*
- *explain sex determination in honey bees, birds and humans.*
- *justify mitochondrial inheritance as a case of maternal inheritance;*
- *describe the human karyotype;*
- *list and describe the causes and symptoms of some common genetic disorders e.g. Colour blindness, haemophilia, Down's syndrome, Turner's syndrome, Klinefelter's syndrome;*

- *describe the inheritance of Rh factor and explain its significance during pregnancy;*
- *explain inheritance of human blood groups;*
- *explain the diagnostic technique of amniocentesis and give its significance;*
- *give a brief idea of genomics and human genome.*

22.1 HEREDITY AND VARIATION

Whenever an infant is born in a family, the relatives begin to wonder about the resemblance of the infant's eyes, facial features, complexion, colour of hair with those of the parents, siblings and grandparents. The source of such resemblances and differences are in the "genes" that are passed down form parents to children and so on generation after generation. This inheritance of genes is termed '**heredity**' the study of reasons of heredity is '**Genetics**'. New individuals develop features according to the genes inherited by them from their parents.

> **The transmission of characters from one generation to the next, that is from parents to offsprings is known as heredity.**

It is further observed that siblings from same parents are unique and differ from each other except the identical twins. Such differences are termed **variations**.

> **Variation means differences between parents and their offsprings or between offsprings of same parents or between members of the same population.**

Variation in a population is very important. It has survival value for the population. This is because if the environment changes, some individuals (variants) may be able to adapt to new situations and save the population from dying out. Variation arises due to **mutation** or sudden change in the genes. Variation also arises because genes get shifted and exchanged during meiosis at the time of formation of gametes, giving rise to new gene combinations (Recall from lesson 8 on cell and cell division about chiasma formation and lesson no. 20 on reproduction in animals for gamete formation and fertilization). At fertilization, there is random mixing of paternal and maternal chromosomes with different gene combinations. Such a source of variation which is most common is called genetic **recombination**.

> **Heritable Variations generally arise because of mutation and recombination.**

22.2 MENDEL'S EXPERIMENTS ON THE GARDEN PEA AND PRINCIPLES OF INHERITANCE

Sir Gregor Johann Mendel (1822 to 1884) was Austrian monk who used garden pea (*Pisum sativum*) for his experiments on plant breeding and published his results in 1865. His work, however, was independently rediscovered in 1900, long after Mendel's death, by Tschermak, Correns and DeVries. But since Mendel was the first to suggest principles underlying inheritance he is regarded as the founder or **father of genetics**.

22.2.1 Mendel's Experiments

Mendel designed his experiments in such a way that a pure tall variety of pea plants could be crossed to a pure dwarf variety. The anthers from flowers of tall plants were removed and their stigmas dusted with pollen from flowers of dwarf plants. The reverse experiment was also carried out, that is anthers of flowes borne on dwarf plants were removed and their stigmas were dusted by pollen from flowers of tall plants.

In the following spring, seeds from the new plants were collected and sown. Mendel found that all the plants of this generation called **first filial generation** or F_1 grew to be tall plants. He allowed them to self pollinate. Again he collected the seeds. The following year, after the seeds had been sown, he found that three quarters of these plants were tall and the rest dwarf. He repeated the experiment several times and found that the ratio of tall to dwarf plants was 3 : 1 (Fig. 22.1).

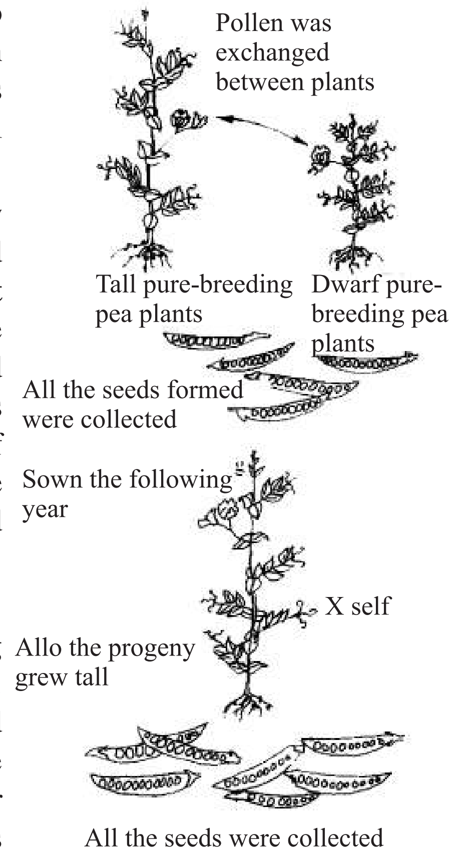


Fig. 22.1 Mendel's experiment with tall and dwarf plants.

In this way he tried to cross pea plants differing in seven such contrasting characters or **traits**. These were 1. red flowered and white flowered plants; 2. axillary flowered (flower arising in the axial of the leaf) and terminal flowered (flower arising at tip of stalk); 3. yellow seeded versus green seeded; 4. round seeded versus wrinkled seeded; 5. green pod versus yellow pod 6. plants with inflated pods versus those with constricted pod and 7. pure tall plants versus pure dwarf plants. Plants with these contrasting characters existed in varieties that were 'self pollinating' so that generation after generation they expressed only one type of feature (Fig. 22.2).

Crosses involving plants differing in the inheritance of **one contrasting feature only** are called **monohybrid crosses**. Mendel also tried crosses involving two contrasting features, such as tall and red flowered plants crossed with dwarf and white flowered plants. Such crosses are termed **dihybrid crosses**.

22.2.2 Mendel's Principles (laws) of inheritance

Based on the results of his experiments, Mendel postulated the following laws of heredity.

1. **Law of segregation or purity of gametes.** At formation of gametes, the two chromosomes of each pair separate (segregate) into two different cell which form the gametes. This is a universal law and always during gamete formation in all sexually reproducing organisms, the two factors of a pair pass into different gametes. Each gamete receives one member of a pair of factors and the gametes are pure.

   Mendel's factors later came to be known as genes.

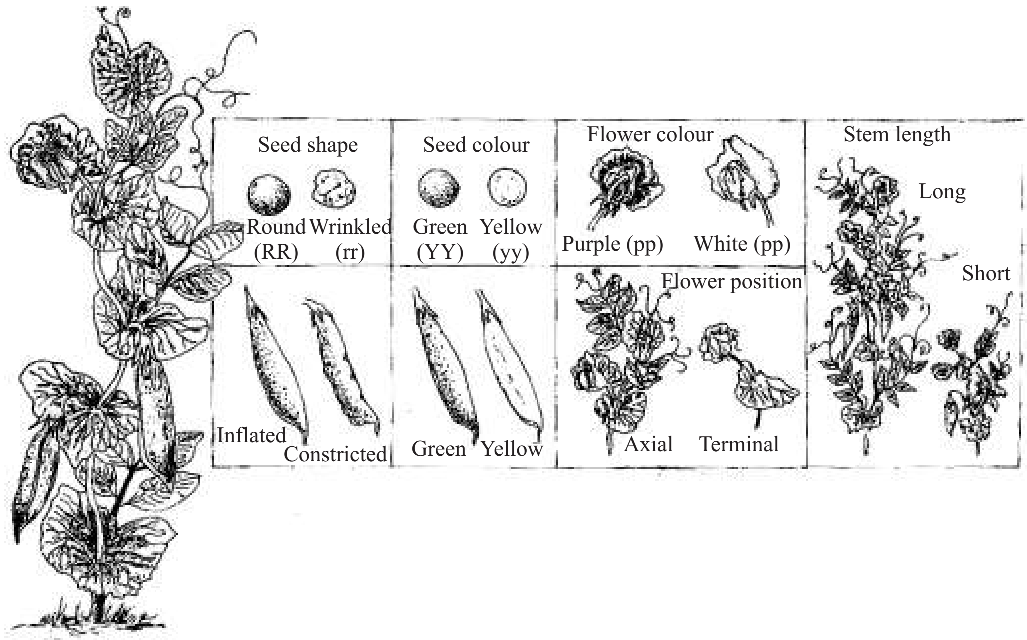


Fig. 22.2 Seven traits studied by Mendel

2. **Law of dominance.** During inheritance of many traits (e.g. eye colour, flower colour, seed shape) is controlled by **one pair of genes**. When the two genes of a pair are of the same kind (e.g. brown colour of eyes, red colour of flower) the condition is termed as **homozygous**. When a pair of chromosomes has the gene controlling the same feature (flower colour) in two different forms (red flower gene on one chromosome and white flower gene on another member of the pair (termed its **homologue**) the condition is termed **heterozygous.** The factors or genes for red and white flower olour are alternative forms of the same gene, that is, the gene for flower colour. Suh alternative forms of the same gene are termed as **Alleles**.

   The second law of inheritance maintains that when the two genes of a pair, represent contrasting characters **the expression of one is dominant over that of the other**. Thus if both genes of an allele are for tallness (represented as TT) that is **homozygous** or one gene is for tallness and another for dwarfness (Tt), that is **heterozygous**, the pea plants will be tall. The opposite of dominant gene is termed **recessive gene**. The recessive feature (e.g. dwarfness of the plant) is expressed only when both the genes of allele are in the homozygous condition (tt).

The law of dominance was found to be true in both monohybrid and dihybrid crosses in cases of all the seven characteristics studied by Mendel in the garden pea.

3. **Law of independent assortment** meaning whereby that in the inheritance of two features (each feature controlled by a pair of genes), genes for the two different features are passed down into the offspring **independently** (Fig. 22.3) i.e. the segregation of one pair of factors is independent of the segregation of the factors belonging to any other pair of factors or allelic pair.

	Red Tall		White Dwarf	
Parents	TTRR	×	ttrr	
gametes	TR		tr	
F_1	Tt		Rr	Tall, red (self)

F_2 progeny worked out below.

Genes in male and female gametes	TR	Tr	tR	tr
TR	TTRR Tall red	TTRr Tall red	TtRR Tall red	TtRr Tall red
Tr	TTRr Tall red	TTrr Tall white	TtRr Tall red	Ttrr Tall white
tR	TtRR Tall red	TtRr Tall red	ttRR Dwarf red	ttRr Dwarf red
tr	TtRr Tall red	TtRr Tall white	ttRr Dwarf red	ttrr Dwarf red

Fig. 22.3 Dihybrid phenotypic ratio
9 Tall Red : 3 Tall White : 3 Dwarf red : 1 Dwarf white

In Fig. 22.3 results show independent assortment in two pairs of genes. R stands for red flower colour, r for white flower colour, T for tallness and t for dwarfness.

You would have noticed that the composition of genes termed **genotype** controls the outside expression which we can see, that is the **phenotype**. The ratio of progeny in the crosses is therefore, the **phenotypic ratio**.

However, as more and more scientists began to devise genetic experiments, it became clear that Mendel's laws do not hold true in all cases. We shall learn about the deviations from Mendel's laws such as incomplete dominance, codominance and polygenic inheritance.

22.2.3 Reasons for Mendel's success

1. **Mendel succeeded in postulating laws of inheritane because of his choice of experimental plant** garden pea which has a short life cycle, has self pollinated bisexual flowers so that cross-pollination is not allowed and the true breeding behaviour of parents could be maintained. Because of the property of self pollination in garden pea plants, a large number of pure line of plants with several pairs of contrasting characters could be obtained in the same field.

2. **His selection of traits :** All the seven pairs of contrasting characters of pea plants considered by Mendel in his experiments showed complete dominance that helped Mendel to postulate the law of dominance and the law of segregation.

3. The factors for all the seven traits selected by Mendel for his experiments were either present on separate homologous chromosomes or if they were present on the same chromosome, they were apart so that the factors segregated independently & were not inherited together so that Mendal failed to discover linkage and crossing over.

4. **Mendel's methodology:** His technique of experimentation also helped him in discovering the Laws of Heredity :

   (i) Homozygous pure line plants with contrasting characters were crossed.

   (ii) Self pollination was prevented by removing stamens to bring about cross-pollination between the desired parents.

   (iii) Female plants were dusted with pollen grains from another plant with the contrasting feature and were tied in a bag to prevent any further pollination.

   (iv) Seeds were collected from plants of different generations and sown in time.

   (v) The results of different generations were maintained, and analysed statistically, by counting the individuals exhibiting different traits.

   (vi) He considered the inheritance of one character at a time, then he considered inheritance involving individuals differing in two contrasting characters.

   (vii) He performed reciprocal crosses and test crosses to confirm the results. (see section 22.3 for definition of these terms), and formulated the basic laws of heredity.

22.3 IMPORTANT TERMS IN GENETICS

- **Factor :** The unit of inheritance and expression of a particular character is controlled by inheritable units called factor (gene) which are present in pairs in parental cells and singly in the gametes.

- **Gene :** A segment of DNA molecule which determines the unit of inheritance and expression of a particular character.

- **Alleles or Allelomorphs :** Two or more alternative forms of a gene are called **alleles**. For example in pea plant, the gene for producing seed shape may occur in two alternative forms: smooth (S) and wrinkled (s). Genes for smooth wrinkled seeds are alleles of each other, and occupy same locus on homologous chromosomes.
- **Trait :** is the morphologically or physiologically visible character, e.g. colour of flower, and shape of seed.
- **Dominant trait :** Out of the two alleles or allelorrorphs of a trait, the one which expresses itself in a heterogygous organism in the F_1 hybrid is called the dominant trait (dominant allele) and the one that remains masked in F_1 individual but gets expressed in the next generation (F_2), is called **recessive**. Thus, if the allelic combination in an organism is Tt, and T (tallness) expresses itself but t (dwarfness) cannot, so T is the dominant allele, and tallness is dominant on dwarfness represented by "t'.
- **Recessive trait :** Out of the two alleles for a trait, the one which is suppressed (does not express) in the F_1 hybrid is called the recessive trait (recessive allele). But the Recessive allele does express itself only in the homozygous state (e.g. tt).
- **Genotype :** A class of individuals recognised based on its genetic constitution and breeding behaviour is called the genotype, e.g., the genotype of pure smooth seeded parent pea plant is SS and it will always breed true for smooth-seeded character, but plants having Ss on selfing would give rise to a population represented by 3 : 1 ratio for smooth seeded plants and wrinkled seeded plants.
- **Phenotype :** A class of individuals recognised based on outward appearance of a trait in an individual is the phenotype, e.g. Smooth-seeded shape or wrinkled shape of seeds represent two different phenotypes.
- **Homozygous :** An individual possessing identical alleles for a trait is termed homozygous e.g. SS is homozygous condition for smooth seeded character in garden-pea.
- **Heterozygous :** An individual with dissimilar alleles for a trait is termed heterozygous for e.g. Ss represents the heterozygous condition for smooth seeded character in garden pea.
- **Parent generations :** The parents used for the first cross represent the parent (or P_1) generation.
- **F_1 generation :** The progeny produced from a cross between two parents (P_1) is called **First filial** or **F_1 generation**.
- **F_2 generation :** The progeny resulting from self pollination or inbreeding of F_1 individuals is called **Second Filial** or F_2 generation.
- **Monohybrid cross :** The cross between two parents differing in a single pair of contrasting characters is called monohybrid cross and the F_1 offspring is the

Monohybrid. The phenotypic ratio of 3 dominants : 1 recessive obtained in the F_2 generation from the monohybrid crosses by Mendel was mentioned as 3:1 **monohybrid ratio**.

- **Dihybrid cross :** The cross in which two parents differing in two pairs of contrasting characters are considered simultaneously for the inheritance pattern is called dihybrid cross. The phenotypic ratio obtained in the F_2 generation from a dihybrid cross is called Mendelian dihybrid ratio (9 : 3 : 3 : 1), and the F_1-individual is called dihybrid (Ss Tt).
- **Hybridisation :** Crossing organisms belonging to different species for getting desirable qualities in the offspring.
- **Test cross :** is the Crossing of the F_1 progeny with the homozygous recessive parent. If F_1 progeny is heterozygous, then test cross always yields the ratio of 1 : 1 between its different genotypes and phenotypes.
- **Reciprocal cross :** Is the cross in which the sex of the parents is reversed. That is if in the first cross father was dwarf and mother tall, then in the reciprocal cross, dwarf parent will be female and tall parent male.

INTEXT QUESTIONS 22.1

1. Name the founder of genetics and state why he is called so.

   ....

2. State one difference between

   (i) homozygous and heterozygous individuals

   ....

   (ii) dominant and recessive traits

   ....

   (iii) genotype and phenotype

   ....

   (iv) monohybrid and dihybrid crosses.

   ....

3. Define heredity and Genetics.

   ....

4. Give the monohybrid and dihybrid phenotypic ratios for Mendelian inheritancce.

   ....

5. Mention two sources of variation.

   ....

22.3 DEVIATION FROM MENDEL'S LAWS INCOMPLETE DOMINANCE

In the four O'clock plant *Mirabilis jalapa* and Snapdragon or *Antirrhinum* law of dominance does not hold good. Thus when a homozygous red flowered plant (RR) is crossed to a homozygous white flowered plant (rr), all flowers in the F_1 are pink while when F_1 plants are self pollinated, the phenotypic ratio in the next generation is found to be 1 : 2 : 1.

Parents	RR × rr
Gametes	R, R × r, r
F_1	Rr Pink
F_2	1 Red : 2 Pink : 1 White
	1 RR : 2 Rr : 1 rr

You will find that the heterozygous (Rr) plants have an intermediate colour pink. You must have also noticed that the genotypic ratio 1 RR : 2 Rr : 1 rr and phenotypic ratio 1 Red : 2 Pink : 1 white are the same, that is, 1 : 2 : 1.

Multiple alleles and codominance

Height and flower colour in peas and eye colour of humans have only two **alleles** (T and t; R and r; B and b (alleles for Brown blue eyes in humans). Most genes, however, may have more than two alleles or **multiple alleles**, controlling the same Trait. An example of multiple alleles is inheritance of blood group in man.

The four blood groups of humans are determined by combination of different alleles. The alleles I^A for A group, I^B for B blood group are both dominant. Therefore person with alleles I^A and I^B have the blood group AB as both the genes I^A and I^B are **co-dominant**. The gene i^o when homozygous (i^oi^o) gives the blood group O. Genotype and phenotype of blood groups in humans are given in Table 22.1.

Table 22.1 Genotypes and Phenotypes of human blood groups

Genotype	Blood group
I^AI^A and $I^A\ i^o$	A
$I^B\ I^B$ and $I^B\ i^o$	B
$I^A\ I^B$	AB
i^oi^o	O

Lethal genes

Have you ever seen a yellow mouse? Probably not. The yellow coat colour in mice is due to the presence of the gene (y) which is also responsible for killing the mouse in homozygous (yy) condition at the zygotic stage indicating thereby that the mice homozygons for dominant "Y" allele (that is, true breeding for yellow oat colour) are never borne. Such a combination of genes (y) are termed **lethal genes**, and the phenomenon is called **lethality**. Some lethal genes kill an individual only in the homozygous condition and are **recessive lethals.** .

Pleiotropy

While a gene may have multiple alleles and thus give multiple genotypes, one gene may control several phenotypes. For example the recessive gene for white eye in *Drosophila* when present in the homozygous condition affects several other features such as wing shape and shape of abdomen. Thus, a white eyed *Drosophila* is also born with vestigeal wings and curled abdomen.

Polygenic or quantitative inheritance

When a trait (feature or character) is controlled by a single gene representing an allelic pair it is termed **monogenic inheritance**. However, many traits or features are controlled by a number of different genes present at different loci on the same chromosome or different chromosomes. For example, the height and skin colour of humans and the kernel colour of wheat results from the combined effect of several genes, none of which are singly dominant. Polygenes affecting a particular trait are found on different locion many chromosomes. Each of these genes has equal contribution and cumulative effect. Three to four genes contribute towards formation of the pigment in the skin of humans. So there is a continuous variation in skin colour from very fair to very dark. Such an inheritance controlled by many genes having additive or cumulative effect in terms of expression of the phenotypic character, is termed as **quantitative inheritance** or **polygenic** (poly meaning or due to many genes) **inheritance**.

INTEXT QUESTIONS 22.2

1. Define :

   (i) An allele ....

   (ii) Codominance ....

   (iii) Polygenes ....

   (iv) Lethal genes ....

2. Name the kind of inheritance in terms of expression of

   (i) blood groups of humans ....
   ....
   ....
   ....

(ii) wheat kernel colour ....
....
(iii) human skin colour? ....
....

3. State the phenotypic monohybrid ratio in case of incomplete dominance.
....

22.4 CHROMOSOMAL THEORY OF INHERITANCE

Sutton and Boveri in **1902** observed that

> Chromosomes from two parents come together in the zygote as a result of the fusion of two gametes and again separate out during meiosis at the time of formation of gametes. You have already learnt that chromosomes are filamentous bodies present in the nucleus and seen only during cell division. Gametes have half (n) number of chromosomes or are haploid and zygote is diploid or has (2n) or double the number of chromosomes when compared to chromosome number in the gametes.

The observations proved that there is a remarkable similarity between the behaviour of Mendelian factors or genes during inheritance and that of chromosomes during meiosis.

This led Sutton and Boveri to propose '**chromosomal theory of inheritance**' and its salient features are as follows.

1. The somatic or body cells of an organism, which are derived by the repeated division of zygote have **two identical sets of chromosomes** i.e. they are **diploid.** Out of these, one set of chromosomes is received from the mother (maternal chromosomes) and one set from the father (paternal chromosomes). Two chromosomes of one type (carrying genes controlling the same set of characters) constitute a **homologous pair**. Humans have 23 pairs of chromosomes.
2. The chromosomes of homologous pair separate out during meiosis at the time of gamete formation.
3. The behaviour of chromosomes during meiosis indicates that Mendelian factors or **genes are located linearly on the chromosomes.** With progress in molecular biology it is now known that a **chromosome is made of a molecule of DNA and specific sets of segments of DNA are the genes.**

22.5 LINKAGE AND CROSSING OVER

Bateson and Punnett performed a dihybrid cross with true breeding varieties of sweet pea (*Lathyrus sativus*) and instead of 9 : 3 : 3 : 1 ratio in F_2 generation they got the ratio 7 : 1 :1 : 7. It means that the characters controlled by the two genes chosen for the experiment do not follow the principle of independent assortment as postulated by Mendel. Instead they tend to be inherited together or are **linked** together. Thus genes present on the same chromosome tend to be inherited together and are said to be **linked**. This phenomenon is called **linkage**.

All the genes present on the same pair of chromosomes and with a tendency to be inherited together forms a linkage group.

In the above experiment some recombinant type of individuals were also produced. How did that happen ? They are produced by another phenomenon called **crossing over**.

Crossing over is the physical exchange of parts of the non sister chromatids of the chromosomes of a homologous pair (Fig. 22.4).

Crossing over occurs during prophase I at meiosis I of the time of gamete formation. The point where crossing over occurs is called **chiasma**. (plural : chiasmata) See Fig. 22.3. Linked genes get separated from each other by crossing over.

Because of linkage and crossing over a heterozygous individual can produce four types of gametes as shown in Fig. 22.4. The figure 22.4 shows linked genes of the parents and **recombinants** due to crossing over.

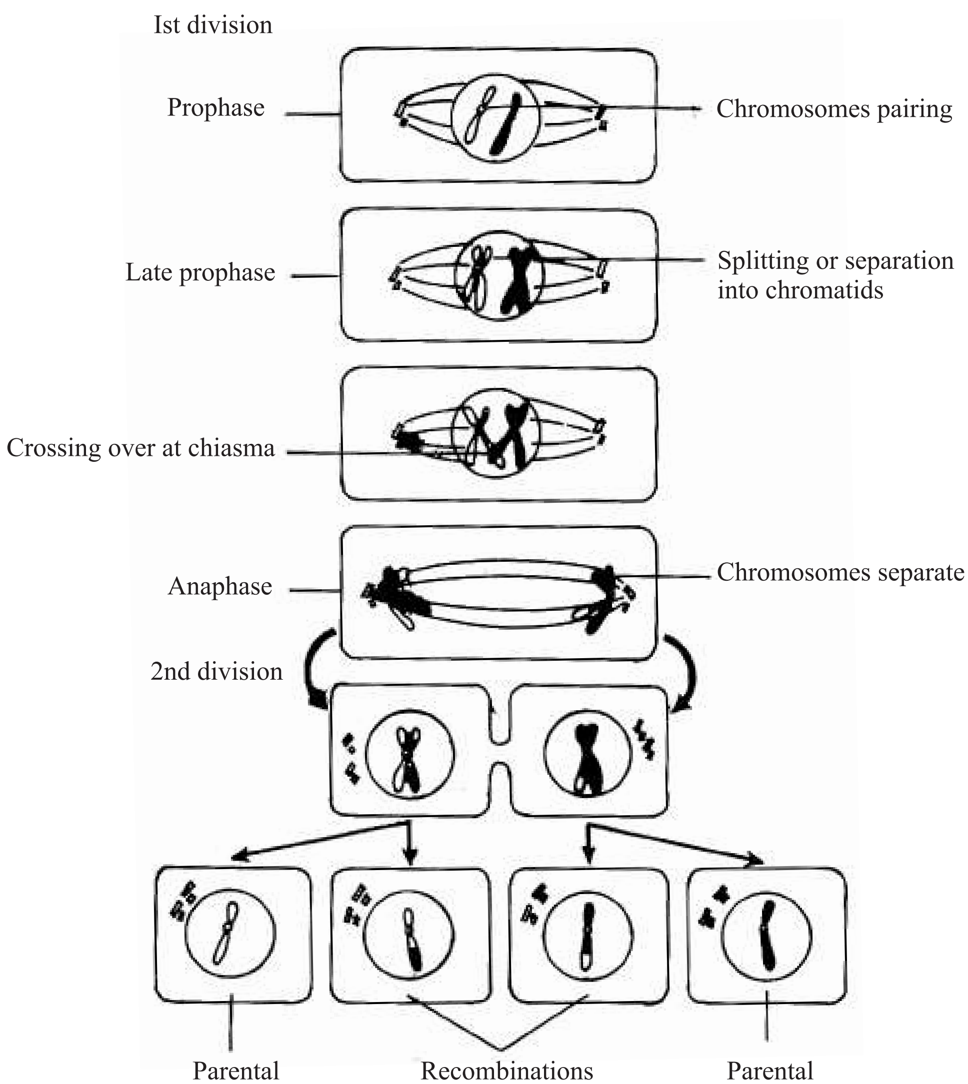


Fig. 22.4 Schematic diagram showing recombination by crossing over

22.6 CHROMOSOMES AND SEX DETERMINATION

Sex of the unborn individuals is determined in different ways in different kinds of organisms. You will learn about sex determination in humans, birds and honey bees in this section.

In some diploid organisms, specific chromosomes have a role in sex determination. Such chromosomes are called **sex chromosomes** and the rest of the chromosomes of a set are called **autosomes**.

- If sex chromosomes are morphologically similar (i.e. XX) in an individual, the individual is termed **homogametic**. Such individuals, produce only one kind of gametes (containing X). For example : all eggs of the human female contain an X chromosome and autosomes. So human female is termed as homogametic.

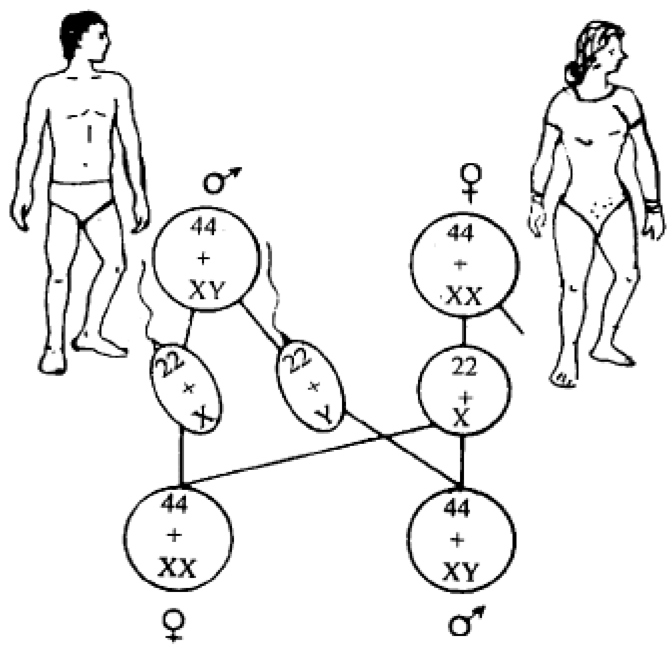


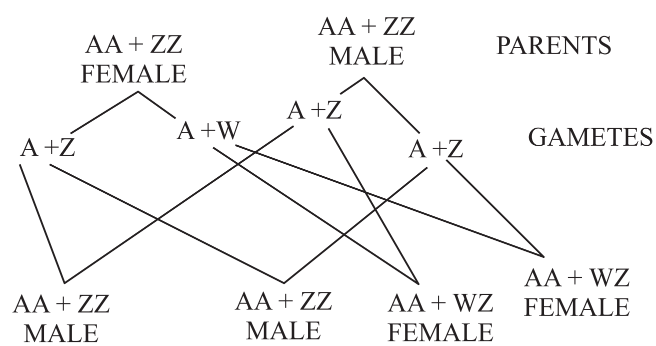
Fig. 22.5 Chromosomal basis of sex determination in humans.

22.6.1 Sex Determination in Human

- Sex chromosomes in males are morphologically dissimilar (i.e. XY). Such individuals produce two types of gametes (one containing X and the other containing Y) and are called heterogametic. For example : human male produces two kinds of sperms, X bearing and Y bearing sperms. When the human egg is fertilised by an X bearing sperm a girl is born, and if human egg is fertilized by a sperm having "Y" chromosome, a boy is born (Fig. 22.6). Whether the unborn will be a male or female is purely a matter of chance and no parent can be blamed for the sex of the progeny.

22.6.2 Sex Determination in Birds

You have just studied the XX-XY type of sex determination in humans. This type of sex determination is found in other mammals and most insects. However, the method of sex determination in birds is a little different. In birds both sexes (male and female) possess two sex chromosomes but unlike human beings the female has the heteromorphic morphologically different sex chromosomes (ZW) while the males bear homomorphic (condition, the sex chromosomes (ZZ). Thus, the females are heterogametic and produce two types of eggs: A+Z and A+W ('A' stands for autosomes). The male gamete is only of one type: A+Z. This type of sex determination is called ZW-ZZ type or WZ-ZZ type of sex determination. The letters Z and W are used to distinguish these types of sex chromosomes from X and Y chromosomes found in the X-Y type of sex determination.



ZW - ZZ Type of Sex Determination in birds AA - Autosomes

22.6.3 Sex Determination in Honey Bees

Honey bees have a unique method of sex determination. In honey bees, fertilised eggs emerge as females and unfertilised eggs develop into males. Since fertilised eggs and also females are diploid and unfertilised eggs and males haploid, sex determination in honey bees is referred to as **haplodiploidy**-sometimes also called **arrhenotoky**.

The sex is determined by the number of sets of chromosomes an individual receives. The male, which is called a drone, is produced from **unfertilized haploid eggs**. And thus, male honeybees contain a single set of chromosomes. The female honeybees, which are worker bees and queen bees, are produced from fertilized eggs and therefore are diploid. They contain two sets of chromosomes. In this case, only females are produced by sexual reproduction.

It is very interesting in honey bees that males have no father and cannot have sons but have a grandfather and can have grandsons.

22.7 CRIS-CROSS INHERITANCE X-LINKED INHERITANCE

We already know that genes are located on chromosomes. The genes which are located on X chromosome (sex chromosome), are called **sex linked genes**. These genes show cris-cross inheritance as shown in Fig. 22.6.

When a male has a defective sex linked gene located on **X** chromosome he transmits the defective **X** chromosome to his **daughter only during reproduction,** . The female who has this gene transmits it to her son and daughter both in equal probability. So the male passes on his recessive sex linked trait to 50% of his grandsons through his daughter. The sex linked trait being recessive is not expressed in female but is expressed in males. Therefore males suffer from the genetic defect due to the presence of faulty gene on the single X-chromosome while females are only **carriers** of these defective genes as they have the other X which masks the effet of faulty gene. The trait shows up in females only both X chromosomes from mother and father have faulty gene.

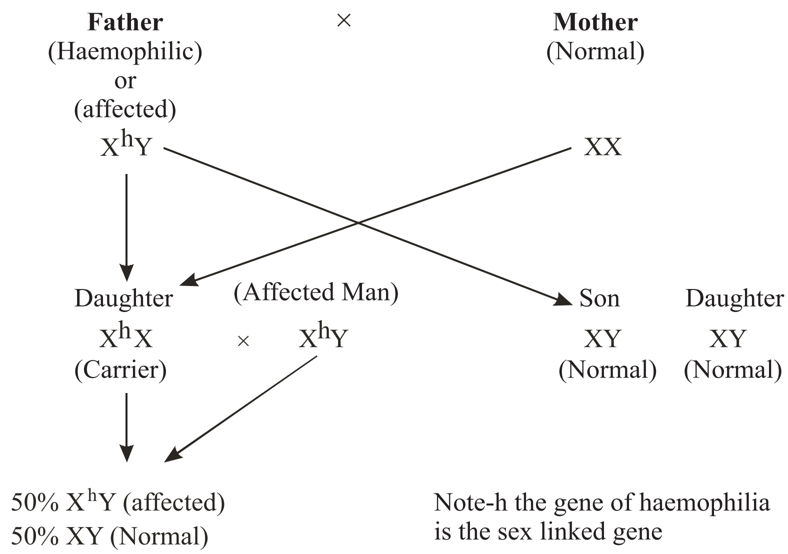
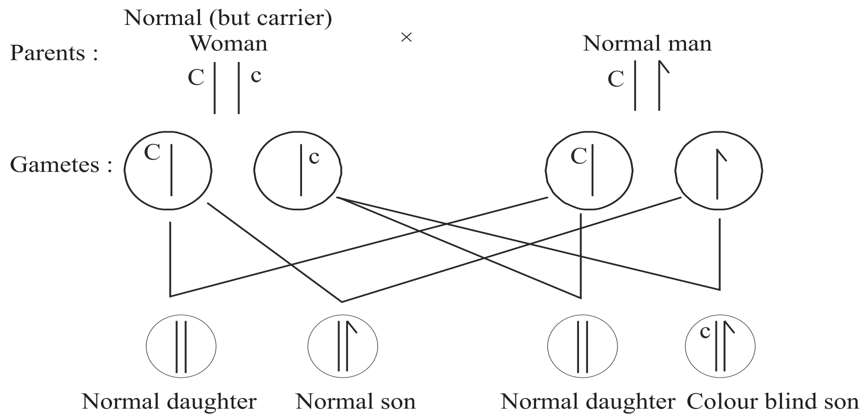


Fig. 22.6 Criss cross inheritance or X-linked sex linked inheritance

> This type of inheritance of recessive sex linked character from father to daughter and then from the daughter to her sons is known as **cris-cross inheritance or sex linked or X-linked inheritance.**

Criss Cross Inheritance in humans : Red green colour blindness and Haemophilia are examples of sex linked inheritance in humans. The defective gene is located on **X** chromosome. Thus a single defective gene causes disease in male while two defective genes (homozygous condition) only can cause the disease in female. Females in heterozygous condition are apparently normal but actually the carriers of the disease. Carrier females pass this defective gene to 50% of her sons. The disease is expressed only in males because male does not have the partners of the genes on **Y** Chromosome to mask the effect of the faulty gene. See Fig. 22.7 (a), and (b).



(C = gene for normal colour vision and c = gene for colour blindness)

Fig. 22.7 (a) Progeny of carrier female for colour blindness and a man with normal colour vision.

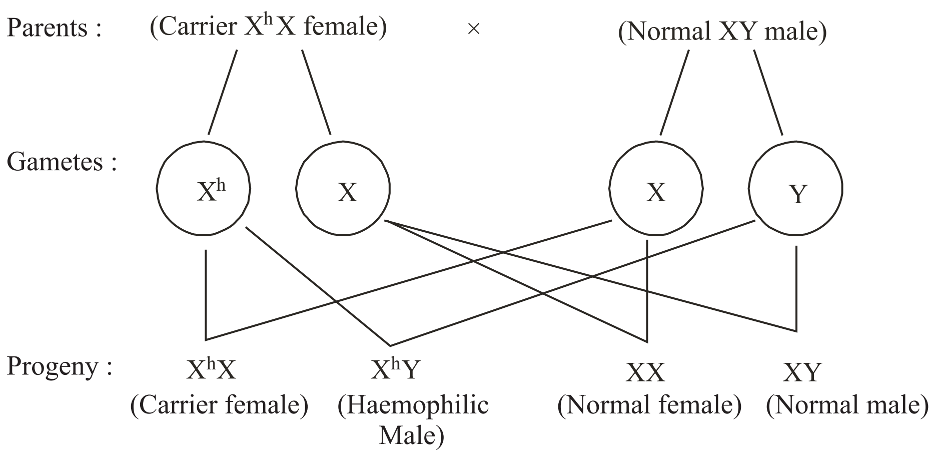


Fig. 22.7 (b) Progeny of a haemophilic carrier female and normal male

INTEXT QUESTIONS 22.3

1. What are genes and where are they located?

   ....

2. State the names of the scientists who proposed the chromosomal theory of inheritance.

   ....

3. Define (i) linkage and (ii) crossing over.

   ....

4. When does gene exchange through chiasma formation occur between homologous chromosomes?

   ....

5. Why is the human female called the homogametic sex?

6. A colour blind man married a normal woman whose father and mother both had normal colour vision. Will any of their sons be colour blind? If not why not.

7. With the help of flow chart explain the difference in sex determination in birds and mammals.

8. Name an insect in which all males are produced parthenogenetically.

9. In honey bees "males have no father and cannot have sons but have a grandfather". Justify the statement.

10. Which sex in birds is heterogametic?

11. Why is sex determination in honeybees called haplodiploidy

22.8 MITOCHONDRIAL INHERITANCE AS A CASE OF MATERNAL INHERITANCE

Apart from the nucleus, mitochondria and chloroplasts also possess DNA and you have just learnt that genes are segments of DNA. Till now you have studied that genes are present on the chromosomes present in the nucleus. Since mitochondria come into the zygote from the egg, inheritance of mitochondrial DNA is said to be a case of **maternal inheritance**.

In fact, certain diseases and therefore the genes responsible for them are due to defects in mitochondrial DNA and can be traced to the mother's family.

22.9 HUMAN KARYOTYPE

Human karyotype is the arrangement of human chromosomes in seven groups according to the types of chromosomes and their size. It is prepared by arranging chromosomes seen at mitotic metaphase in descending order with the longest pair of chromosomes drawn first, and the sex chromosomes are drawn the last :

(i) Total no. of chromosomes or 2n = 46 (23 pairs).

(ii) Number of autosomes = 44 (22 pairs).

(iii) Sex chromosomes 2 = X and Y

(iv) Depending on size, location of centromere, and bands obtained by special staining methods, human chromosomes are grouped into 7 groups, A to G as shown in Fig. 22.8.

Notes

Sex determination in humans, as you have already learnt is as follows :

Normal male has 22 pairs of autosomes + one X chromosome and one Y chromosome

Normal female has 22 pairs of autosomes + two X chromosomes

Presence of Y is necessary for maleness.

Absence of Y chromosomes, makes the individual a female with some defective characters.

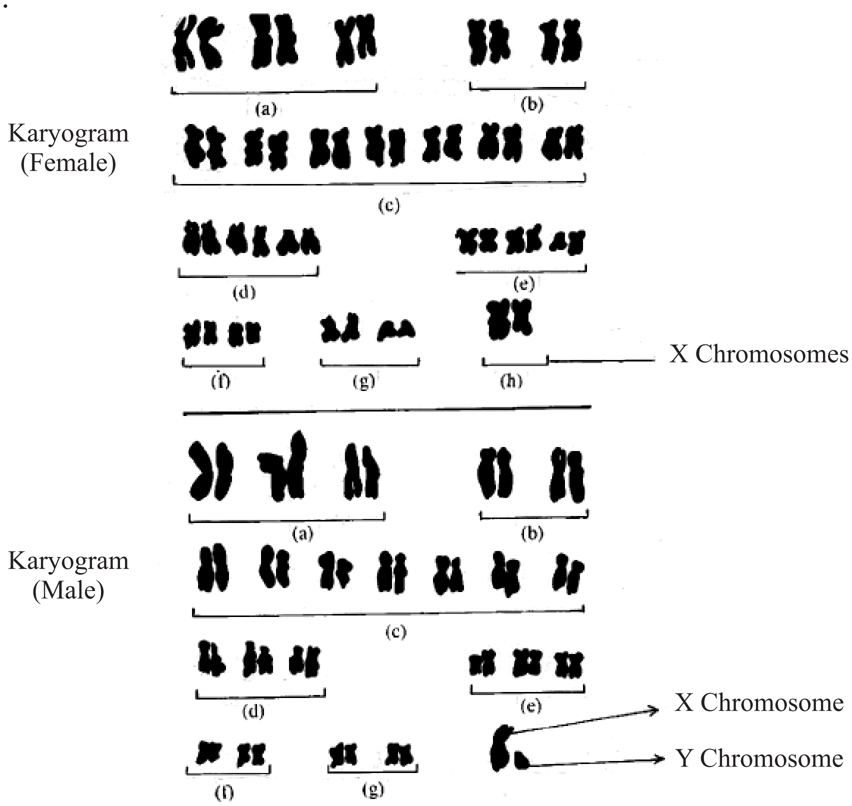


Fig. 22.8 Karyotype showing chromosomes of normal male. Female has the same autosomes but two X-chromosomes instead of XY

22.10 CHROMOSOMAL ABNORMALITIES AND GENETIC DISORDERS IN HUMANS

Any change from the normal number or structure of chromosomes causes abnormalities. Following are some examples of human genetic disorders :

1. Mongolism or Down's syndrome

The individual has 47 chromosomes because of one extra chromosome in the 21st pair (Trisomy of chromosome 21). The outcome of this defect are the following characters or features :

- mentally retarded
- have a thick tongue
- and a drooping (false expression of pleasure) face. Fig. 22.9.

The possibility of giving birth to a mongolian child is far greater in pregnant mothers above the age of forty.

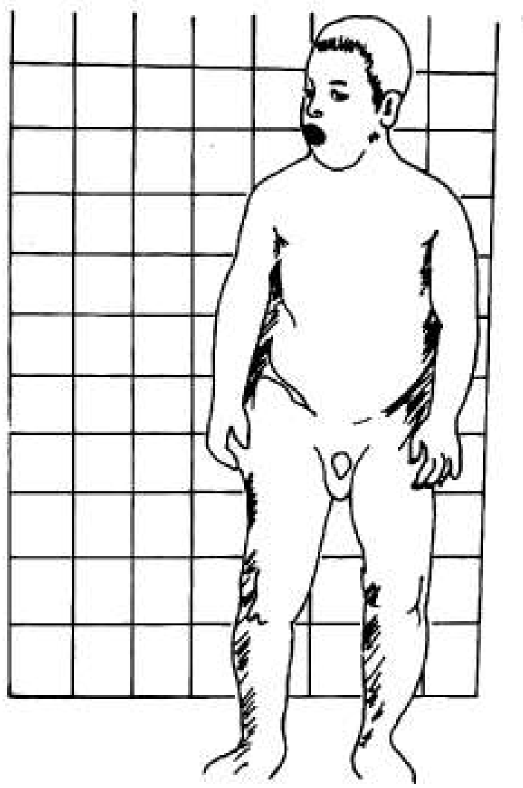


Fig. 22.9 Mongolism or Down's syndrome

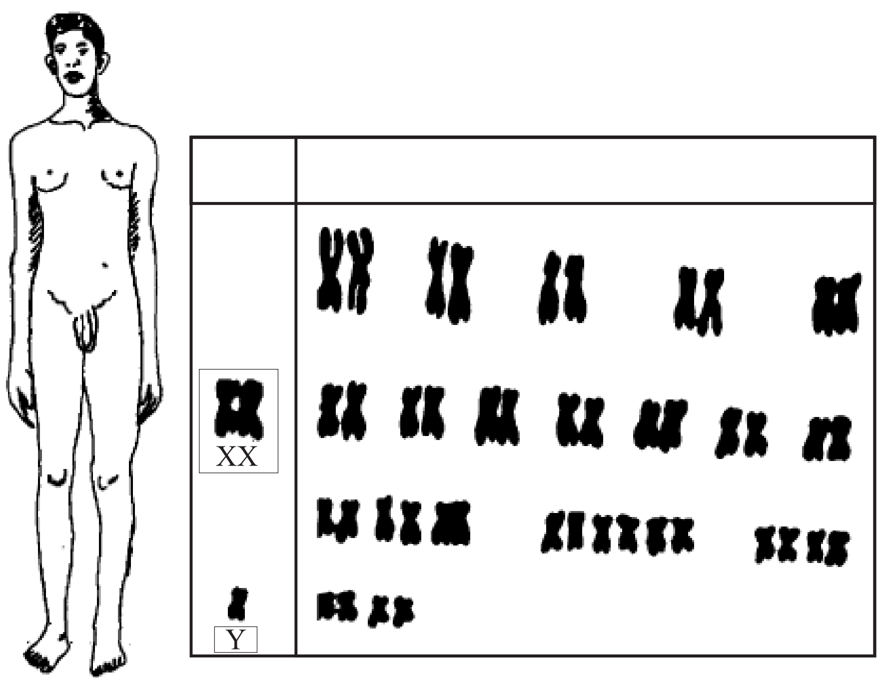


Fig. 22.10 Man showing Klinefelter's syndrome

2. Klinefelter's syndrome

Individual is a male with 47 chromosome with one extra X chromosome. (44 autosomes + XXY). Typical features of Klinefelter's syndrome are :

- Tall, mentally retarded male;
- Sterile and shows breast development or **gynaecomastia** (gynae : female; massere : mammary glands). Fig. 22.10.

3. Turner's syndrome

Individual is a female with 45 chromosomes and with only one X, chromosome (22 pairs of autosomes +XO). The characteristic features of this syndrome are

- Mentally retarded
- web like skin on neck.
- incompletely developed breasts. Fig. 22.11.

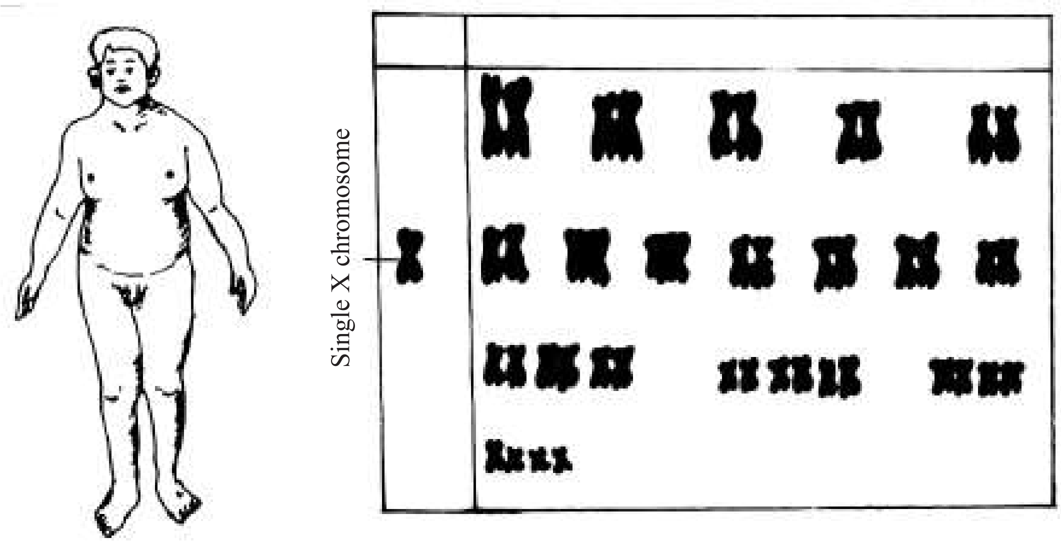
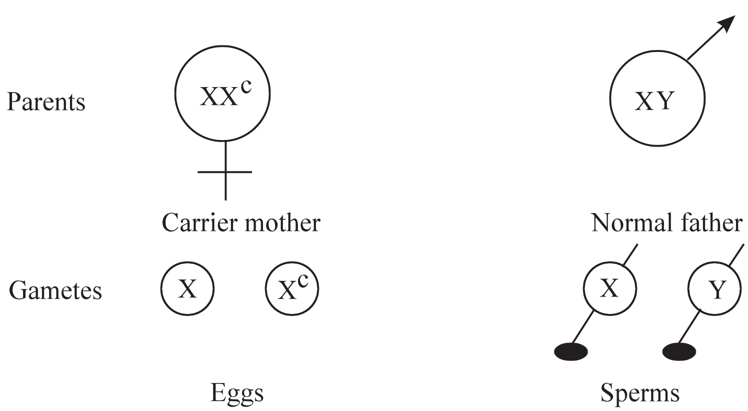


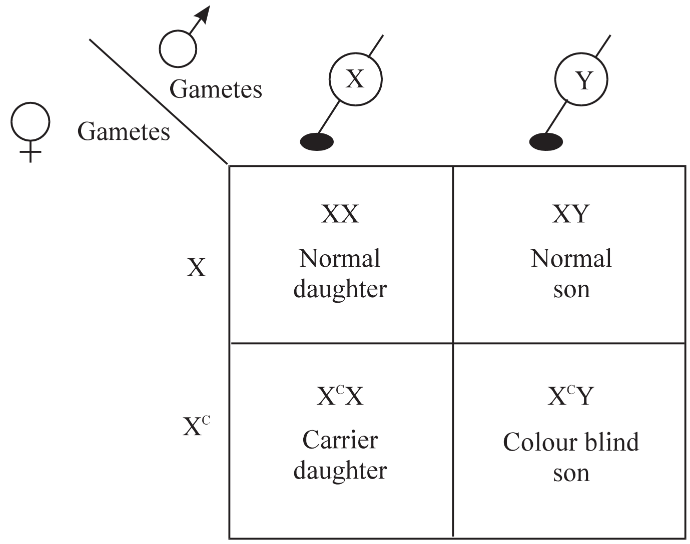
Fig. 22.11 A woman suffering from Turner's syndrome.

4. Colour blindness and Haemophilia (Bleeder's diseases)

Both these defects are sex linked disorders. (See figures 22.6 and 22.7)



The inheritance is as follows :



Note : X = *normal allele*; X^C = *recessive mutant*

Fig. 22.12 Inheritance of colour blindness

See also 22.7

In male, the single X-chromosome is received from the mother.

Hence a defective, gene (for colour blindness or haemophilia) on X chromosome of the mother, is passed on to the son and expressed as a defect.

The daughter receives one X-chromosome from the mother and the other X from the father. In a carrier daughter the defective gene received from the mother is masked chromosome received from normal father by normal allele on the other X (Fig. 22.12).

Colour blind males are unable to distinguish between red-green colours. In haemophilia afflicted male, blood does not clot easily and the patient may bleed to death. Its mode of inheritance is exactly like that of colour blindness.

5. Thalassemia

It is an autosomal disorder in which normal haemoglobin is not synthesised. So, frequent blood transfusions are required for survival.

The defective gene is recessive and present on an autosome in the heterozygous Parents may not show the disorder. The child who gets the defective genes ‘from both the parents (homozygous recessive) suffers from Thalassemia.

6. Sickle Cell Anemia

This is another hereditary abnormality due to mutation of a single autosomal gene in which red blood corpuscles lose their shape and become sickle shaped because of defective Haemoglobin. Individuals possessing two defective genes (homozygous recessive), cannot survive. In the heterozygous individuals, one gene is normal and so half the number of total red blood corpuscles are normal containing normal haemoglobin while the others are defective. For heterozygous individuals with sickle cell gene, it is a boon in disguise against malaria for children with one defective haemoglobin gene can survive as they are less affected by malarial because the malarial parasite cannot thrive inside the defective RBCs.

7. Rh factor

Rh factor is an antigen (a protein) present on the surface of red blood corpuscles. About 15% of all women do not have the gene for Rh antigen. They are Rh-negative. Men can also be Rh-negative. But the problem which this trait creates is in Rh-negative women.

A pregnant Rh-negative woman whose husband is Rh + may bear a the child who may have inherited the Rh + gene from the father. If the foetal blood of the Rh + foetus enters mother's body stream, her immune system produces antibodies against Rh antigen which may cause minor problems in first pregnancy. Antibodies remain in the mother's blood and in the subsequent pregnancies, the mother's antibodies against foetal Rh antigen may enter the foetal blood stream and destroy its red blood corpuscles causing severe anemia which may even be fatal (erythroblastosis foetalis) for the foetus.

Now-a-days Rh-negative mother of a Rh-positive foetus is treated immediately after delivery, to destroy Rh antigens in her blood stream. (Fig. 22.13)

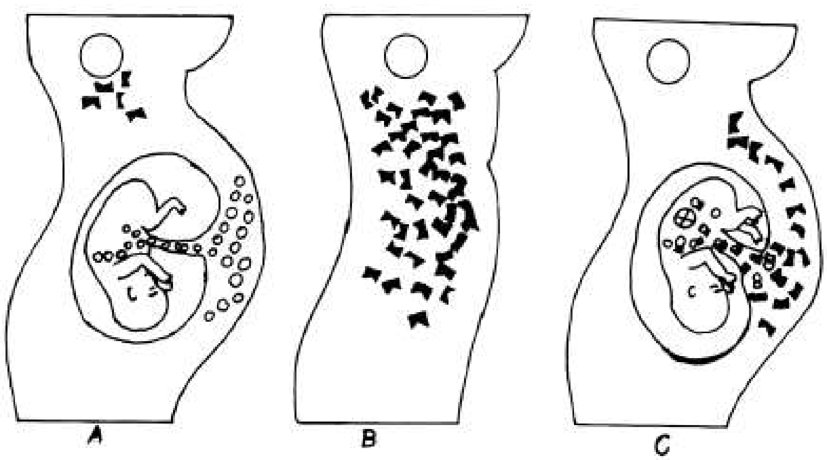


Fig. 22.13 The mechanism of Rh inheritance

(a) shows the first pregnancy where the mother is Rh (-) and foetus Rh (+). Antigens (empty circles) of the foetus stimulate the production of anti bodies (black blocks) in the mother's blood.

(b) shows the retention of anti bodies in the mother's body.

(c) shows the Rh (+) foetus in the womb of the same mother during the second pregnancy. The anti factors from the mother's body destroy the infant's red blood cells.

22.11 AMNIOCENTESIS

Amniocentesis in a technique by which hereditary disorders due to defects in genes can be detected. In this technique (Fig. 22.14)

(i) a small sample of amniotic fluid which surrounds the foetus is syringed out.

(ii) This fluid has cells which break off from the skin of the foetus.

(iii) Foetal cells are picked up and cultured.

(iv) Chromosomes in the dividing cells are analysed for genetic defects.

If incurable genetic defects are detected, pregnancy can be terminated.

It is illegal to use amniocentesis for detecting the sex of the unborn.

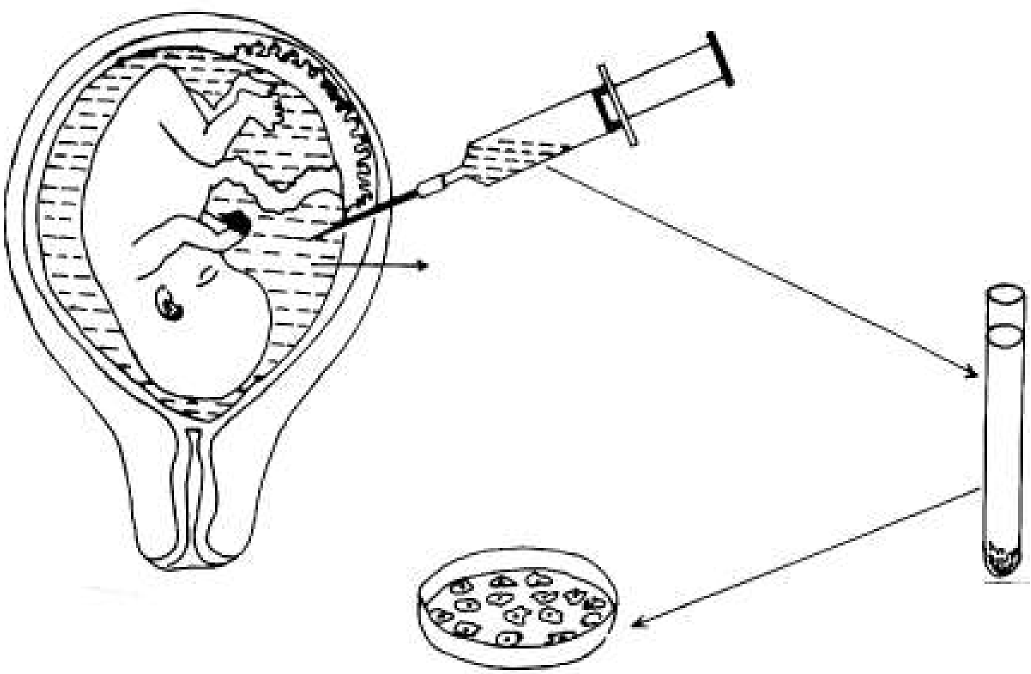


Fig. 22.14 Techniques of Amniocentesis

22.12 THE HUMAN GENOME

In the last over hundred years genetics and molecular biology have gone far ahead and the progress has been very rapid.

You have just read about genetic disorders and today there is hope for cure through gene therapy. This is because in 2003, most of the genes on human chromosomes have been mapped or located on the 23(n) chromosomes. The genes responsible for inheritance of various structural features, that control various enzymes that catalyse the various biochemical reactions in the body, and genes responsible for genetic disorders have been located. **Genome means genes of a particular organism on its haploid set of chromosomes and study of genome is Genomics**. Since genes are present in pairs (one inherited from mother and other from the father), all kinds of genes present in a particular type of organism are present in its haploid set (n). Thus human genome may be defined as all the genes present in the haploid set of chromosomes in humans. There are an estimated 20,000 to 25,000 genes and 3 billion base pairs in the total human DNA. Each human chromosome has apart from protein coding genes, regulating base sequences, non coding DNA, promoter sequences (TATA box) in between genes that code for proteins. There are genes that code for the production of ribosomal RNA and the many tRNAs.

It is estimated that only 1.5% of the human genome has protein coding sequences.

INTEXT QUESTIONS 22.4

1. Why is mitochondrial inheritance treated as a case of maternal inheritance?

   ....

2. Into how many groups have human chromosomes been grouped in the human karyotype?

   ....

3. State the chromosomal abnormality in Klinefelters, Turners syndrome and in Mongolism.

   ....

WHAT YOU HAVE LEARNT

- Heredity means the transmission of characters from parents to offsprings.
- Variation pertains to differences between siblings or members of same species.
- Mendel was the first to explain that heredity involves transmission of certain factors from reproductive cells of parents to offsprings.
- Hugo de Vries, Correns and Tschermach rediscovered Mendel's Laws of inheritance nearly 35 years after Mendel's death.
- Mendel selected seven varieties of garden pea differing in seven pairs of contrasting characters.
- According to his 'law of segregation' the factors segregate at the time of gamete formation, and come together after fertilization.
- Mendel's 'law of dominance' states when partents differing in a pair of contrasting characters are crossed, the factor that expresses itself in the F-1 is called **dominant**, and the factor which is masked by **dominant** factor, is called **recessive**.
- Law of independent assortment states that the inheritance of factors controlling one character does not depend on inheritance of any other factor controlling any other character.

- There are deviations from Mendelian inheritance and these patterns of inheritance are incomplete dominance, codominanace, multiple alleles, polygenic inheritance and pleiotropy.
- Sutton and Boveri (1902) proposed the chromosome theory of heredity. It states that Mendelian factors or genes are located on chromosomes.
- Genes are located on chromosomes in a linear fashion and are held together in linkage group. Linked genes get segregated through chiasma formation or crossing over.
- Organisms with separate sexes have a pair of sex chromosomes called sex chromosomes. In humans, XX are responsible for homogametic female and XY for heterogametic male. In birds it is the opposite—male is ZZ or homogametic and female is ZW or heterogametic.
- In honey bees, males arise from unfertilised eggs and are therefore, haploid or with half the number of chromusomes while females develop from fertilised eggs and are diploid.
- Human males inherit an X chromosome from female parent and Y from the male parents. Y chromosome bears genes for maleness.
- Females receive two X chromosomes one each from either of the two parents.
- Any change in normal number and structure of chromosomes of an individual causes abnormalities.
- A normal karyotype shows 23 pairs of humans chromosomes bearing thousands of genes, controlling different characters.
- Down's syndrome patients have 47 chromosomes exhibitting tri-somy of chromosome 21.
- Klinefelter's syndrome patient has 44 autosomes and XXY.
- Turner's syndrome, has 44 autosomes + XO
- Colour blindness and Haemophilia are X-linked and sex-linked disorders.
- Thallessemia and Sickle cell anaemia are due to a single autosomal defective gene.
- Rh +ve foetus in a Rh negative mother poses problems in which antibodies are produced in mother's blood against antigens of the foetus.
- The human genome has been mapped.
- Amniocentesis is a technique for detecting genetic disorder in foetus.

TERMINAL EXERCISES

1. State the three Mendel's laws of inheritance. Which one of these laws is universal?

2. Consider a hypothetical case of a cross between a tall plant (TT) and a dwarf plant (tt). Work out the phenotypic and genotypic ratios of the F_2 progeny if the cross were to show
   (a) dominance (b) incomplete dominance
3. What will be the blood group of the progeny of parents with AB and O groups.
4. Write notes on :
   (a) recessive lethal genes (b) pleiotropy
   (c) linkage groups (d) mitochondrial inheritance
   (e) human karyotype (f) human genome
5. Why do we find so many different complexions among humans?
6. State the chromosome theory of inheritance.
7. Work out the following crosses and mention the phenotypic ratio of their progeny.
   (a) A colour blind man marries a carrier woman
   (b) A man with normal colour vision marries a carrier woman.
8. Why is X-linked inheritance termed cris-cross inheritance?
9. Give an account of genetic disorders caused by abnormal chromosomal number.
10. What is amniocentesis? How and for what is it carried out?
11. In what way is chromosomal sex determination of humans different from that of birds?
12. From which kind of eggs do males and females of honeybees emerge.

ANSWERS TO INTEXT QUESTIONS

22.1 1. Gregor John Mendel, was the first to suggest principles underlying heredity

2. (i) homozygous = bearing identical alleles controlling a trait; heterozygous = bearing dissimilar alleles controlling a trait.

   (ii) Dominant allele = expressing in both heterozygous and homozygous conditions.

   Recessive = expressing only in homozygous condition.

   (iii) Genotype = genetic constitution of an individual, represented with the help of symbols.

   Phenotype = class of individuals recognised based on externally/ internally visible characters.

(iv) monohybrid = cross between two parents differing in a single pair of contrasting character; dihybrid corss = cross of two parents differing in two pairs of contrasting characters.

3. Heredity : is the study of transmission of characters from one generation to next generation.

   Variation: Differences between individuals of same species.

4. Monohybrid ratio = 3 : 1, Dihybrid ratio = 9 : 3 : 3 : 1.

5. Mutation, Recombination.

22.2 1. (i) Alleles are diffrerent forms of a gene.

(ii) Both alleles express as dominant phenotype.

(iii) Many genes controlling same trait.

(iv) Presence of which kind of genes in an individual proves to be fatal?

2. (i) Codominance and multiple alleles

(ii) Incomplete dominance

(iii) Polygenic inheritance

(iv) Polygenic inheritance

3. 1 : 2 : 1

22.3 1. Genes are segments of DNA. They are located in chromosomes.

2. Sutton and Boveri

3. (i) Linkage is the tendency of genes residing on the same chromosome to be inherited together.

   (ii) Breakage and exchange of genes between two chromatids of a homologous pair is termed crossing over.

4. During prophase I of meiosis

5. Human female produces only one kind of gametes (homo = same)

6. No. Because gene for color blindness on X chromocomes is a recessive gene so it gets marked by renual gene from mother.

7. Female

8. Because males develop from unfertilised or haploid eggs and females from fertilised or diploid eggs.

22.4 1. Because mitochondia are inherited from the mother through the ovum.

2. Seven

3. Kline felter : 2n = 47; XXY

   Turner : 2n = 45; XO

   Mongolism : 2n = 47; Trisomy of chromosome 21

23

MOLECULAR INHERITANCE AND GENE EXPRESSION

A cell contains the nucleus. Nucleus contains chromosomes, Chromosomes bear genes. Genes carry the hereditary information. A zygote has the information for development and differentiation of the embryo in its genes. Cells of an individual have the genes for maintaining their structure and function. What are these genes and how do they function? Genes are made of segments of the DNA. This lesson deals with the study of DNA as the genetic material, its structure and functioning at the molecular level.

OBJECTIVES

After completing this lesson, you will be able to :

- *discuss the concept of one gene one enzyme hypothesis;*
- *give the history of discovery of DNA as geneticc material;*
- *describe the general structure of DNA by referring to the terms nucleotides, nucleosides, purincs and pyrimidines;*
- *list the differences between DNA and RNA;*
- *mention the various categories of RNA and explain their functions;*
- *describe the modes of gene transfer, transformation, transduction and conjugation;*
- *explain the steps of DNA replication;*
- *explain the concept of central dogma;*
- *describe the sequence of steps during transcription and translation during protein sysnthcsis;*
- *trace the major steps in regulation of gene expression;*
- *define house-keeping genes and explain their role;*
- *categorise various types of mutations;*
- *define mutagen and list their different categories;*
- *highlight the useful and harmful effects of mutation.*

23.1 THE CONCEPT OF THE ONE GENE ONE ENZYME HYPOTHESIS

The British biochemist and physician Archibald Garrod had mentioned in his book named "Inborn errors of metabolism" that there are inherited genetic disorders such as **phenylketonuria** and **alkaptonuria** which are caused by the absence of particular enzymes. Beadle and Tatum working with the mutants of the fungus *Neurospora* showed that the absence of a gene in a mutant leads to absence of an enzyme in a metabolic pathway (chain of biochemical reactions) midway. Thus was proposed that **one gene was responsible for the production of one enzyme** and this was called the **one gene one enzyme hypothesis**. Later, it was found that an enzyme (a protein) may be made of more than one polypeptide and one gene controlled production of one polypeptide (chain of amino acids in a protein).

In the following sections you will learn about the nature of the genetic material, DNA, and its role in the synthesis of proteins. You will also learn about gene mutation because of which a normal protein is not manufactured in the body and results in genetic disorders.

23.2 DISCOVERY OF DNA AS THE GENETIC (HEREDITARY) MATERIAL

That genes, located on chromosomes, are the hereditary material was known to scientists in the early twentieth century. That genes are segments of DNA became evident from the work of Griffith on **bacterial transformation.**

Bacterial transformation

The bacterium *Streptococcus pneumoniae* when grown in the lab forms smooth colonies and when injected into mice kill them. A mutant of this bacterium forms rough colonies and is harmless to mice. In 1928, Frederick Griffith found that if the *smooth virulent* form of *Streptococcus* is killed and mixed with the *harmless rough* form of *Streptococcus* the latter becomes virulent (killer). This change (or transformation) of the bacteria from harmless to virulent is termed **bacterial transformation.** (Fig. 23.1).

In 1944, Avery, Mcleod and McCarty extracted DNA from the virulent smooth *Streptococcus* and mixed it with the non-virulent rough variety. The non-rough variety became *virulent* and had a *smooth coat*. This did not happen when DNA of the virulent form was digested with the enzyme DNase and then mixed. Thus it became clear that **DNA was the transforming principle.**

Later Hershey and Chase in 1952 used T_2 bacteriophage, a virus which infects bacteria for their experiments. They labelled the protein coat of the virus with radioactive isotope of sulphur ^{35}S. When the virus was introduced into the bacteria, no radioactivity was found inside the bacteria as the viral coat was left outside. When they labelled viral DNA with $^{52}P_{32}$ or radioactive phosphorus, radioactivity was found inside the bacteria. It bacame clear that new generations of the virus were reproduced inside bacteria because of viral DNA (Fig. 23.2).

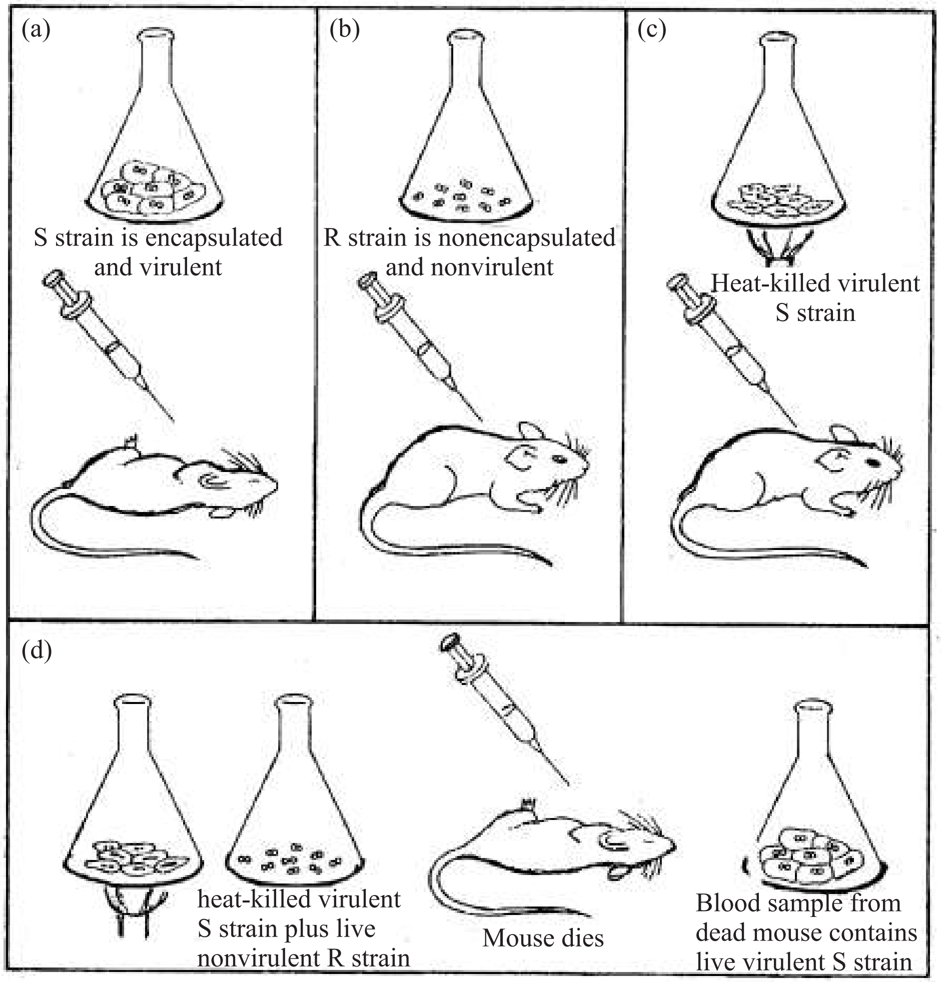


Fig. 23.1 Griffith's bacterial transformation experiment.

These experiments confirmed that DNA is the genetic material and genes are made of Deoxyribonucleic Acid or DNA.

23.3 STRUCTURE OF DNA, THE GENETIC (HEREDITARY) MATERIAL

23.3.1 Chemical nature of DNA or Deoxyribonucleic acid

DNA is a polynucleotide, a macromolecule (macro = large) made of units called **nucleotides.**

Each nucleotide consists of three subunits.

(i) a pentose (5 carbon) sugar called **deoxyribose**

(ii) 4 nitrogenous bases Adenine (A), and Guanine (G) are purine bases and Thymine (T) and Cytosine (C) are pyrimidine bases

(iii) a phosphate group (PO_4) positioned on the sugar (Fig. 23.3)

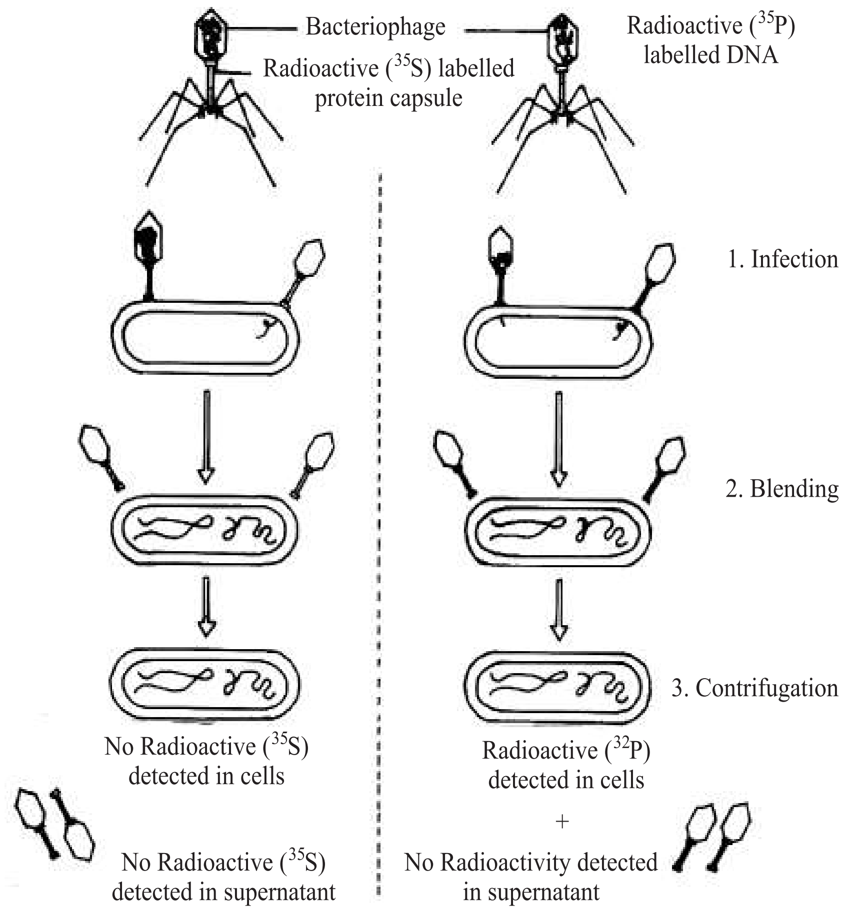
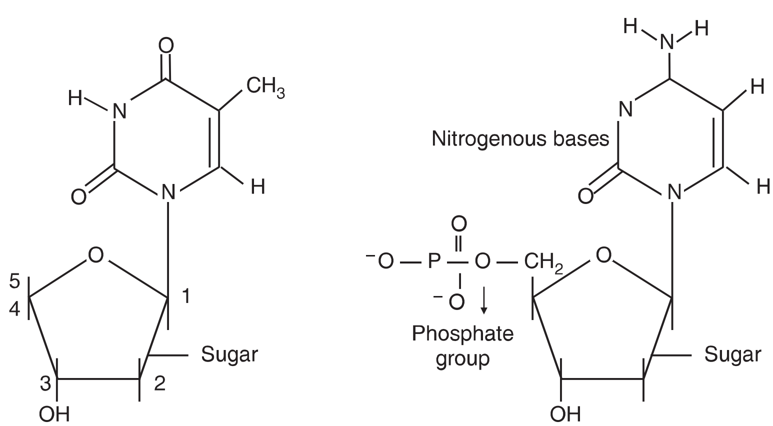


Fig. 23.2 The Hershey Chase experiment



(a) (Base + Sugar = Nucleoside)

(b) (Base + Sugar + Phosphate = Nucleotide)

Fig. 23.3 Component of nucleoside and nucleotide

A base and a sugar combine to form a nucleoside, while it becomes a **nucleotide** when a phosphate group gets attached to the **nucleoside**.

Base + sugar = nucleoside

Base + sugar + Phosphate = nucleotide

So there are **four nucleotides** in DNA formed of sugar and nitrogenous base and phosphate.

Chargaff's rule

The four nucleotides are not present in equal amounts in a DNA molecule. But the amount of purines (A + G) and that of pyrimidines (T + C) is always equal. In other words, A = T and G = C. This is called Chargaff's rule.

23.3.2 Physical structure of DNA– The DNA double helix

A DNA molecule is **three dimensional** and made of **two strands** helically coiled around each other. Franklin and Wilkins first showed through X-ray diffraction studies of DNA that it is a double helix.

In 1953, James Watson and Francis Crick were awarded the Nobel Prize for working out the structure of DNA.

According to the Watson and Crick model

- DNA molecule is a **double helix** consisting of two strands of DNA
- The arrangement of the two strands is **antiparallel**, which means that the sequence of nucleotides goes up in 5′ to 3′ direction in one strand and other strand comes down in 3′ to 5′ direction. (3′ and 5′ refer to the carbon atom to which the phosphate group is attached) see Fig. 23.4.

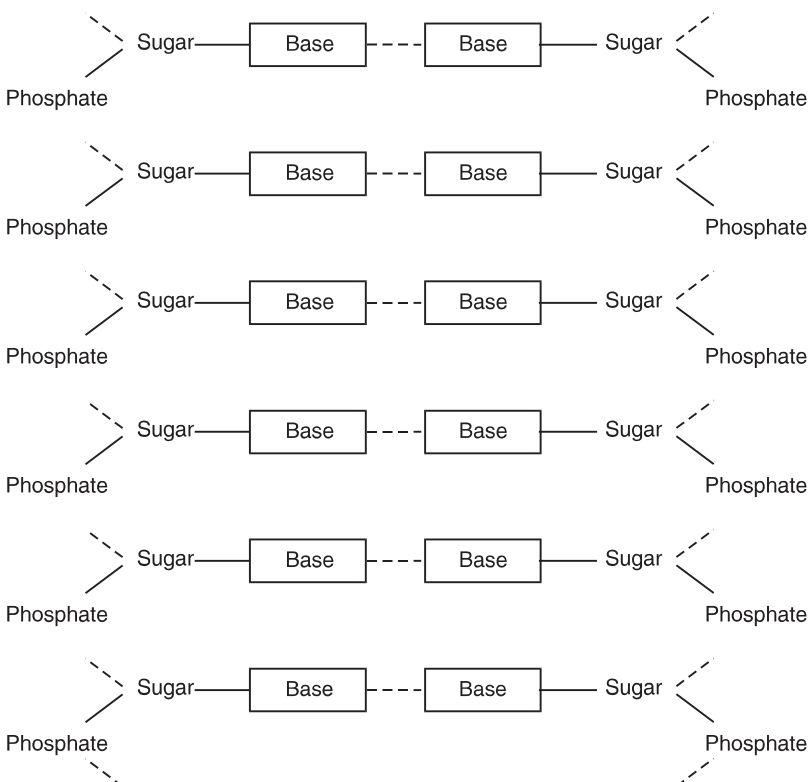


Fig. 23.4a Components of a DNA double helix

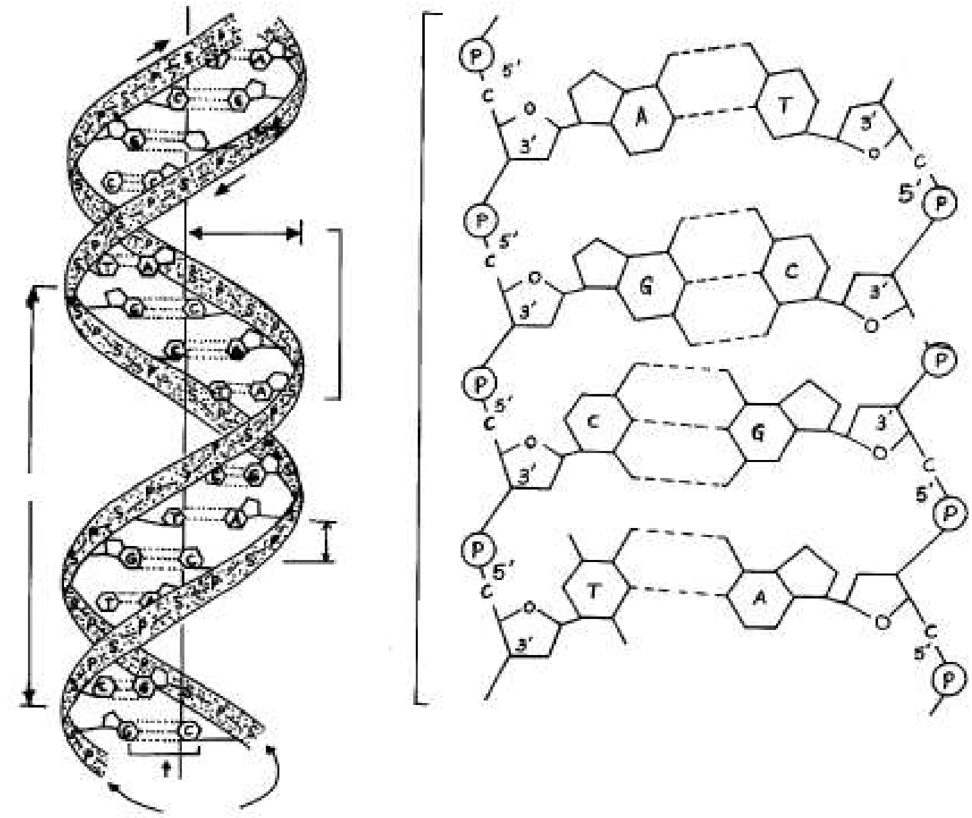


Fig. 23.4b-c DNA double helix

- The **backbone** of the helix is made of **sugar and phosphate.** Nitrogenous bases are linked to the **sugar**. (Fig. 23.4a and 23.4b)
- The bases of the two strands are linked by hydrogen bonds.
- Base pairing is very specific as per Chargaff's rule. Adenine, a purine base always pairs with thymine, a pyrimdine base. The purine base Guanine pairs with the pyrimidine, Cytosine. These pairs of bases are called **complementary bases.**

There are **two** hydrogen bonds between A and T and **three** hydrogen bonds between G and C. A and T are complementary bases and so are G and C.

In the DNA helix, a complete helical turn occurs after 3.4 nm (or 34Å). This complete turn encloses 10 base pairs. Each base pair lies 0.34 nm (3.4 Å) apart. The diameter of the double helical DNA molecule is 2.0 nm (Fig. 23.4c).

Watson and Crick model explains well how the two strands of a DNA molecule may separate at replication and transcription and then rewind.

The hereditary material must be capable of (i) replication (ii) storage of information (iii) transmission of information (iv) expression of information and (v) regulation of gene expression.

Packaging of DNA in Eukaryotic chromosome

In the bacteria (prokaryotes), ***only one double stranded DNA molecule*** constitutes the chromosome. Eukaryotes have many chromosomes and also many genes. One chromosome, however, is made up of one long double stranded DNA molecule. So how does this long molecule get accommodated in the chromosome seen as small mircoscopic entities during cell division? Fig. 23.5 shows how a long DNA molecule is packaged.

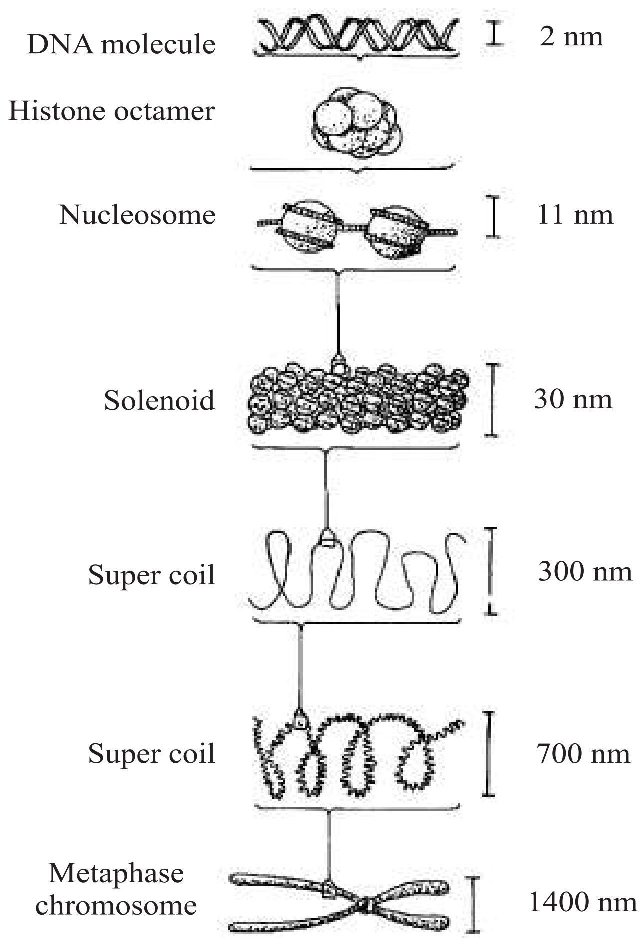


Fig. 23.5 Packaging of the DNA molecule.

- At intervals DNA molecule is coiled around a "core particle" which is an **octamer**, that is made of 8 histone proteins forming a ball like structure.
- Each core particle with DNA around it is called a **nucleosome.** Under the electron microscope the eukaryotic chromosome looks like a string of beads (string being the DNA molecule and beads the nucleosomes).
- The string is then coiled to form a **solenoid** and the solenoid is coiled again (**supercoiling**) ultimately to form the chromosome.
- In this way the long DNA molecule becomes thicker and thicker and shorter and shorter as shown in the figure.

23.4 RNA OR RIBONUCLEIC ACID

Apart from DNA, RNA or Ribonucleic acid is the other important nucleic acid present inside the cell. Table 23.1 gives the differences between DNA and RNA.

Table 23.1 Differences between DNA and RNA

DNA	RNA
1. *Double* stranded molecule	1. Single stranded molecule
2. Contains **deoxyribose** sugar	2. contains **ribose** sugar.
3. Pyrimidine base complementary to Adenine is **Thymine**	3. Pyrimiine base complementary to adenine is **Uracil** No thymine in RNA
4. DNA has only one function, that is to bear hereditary in formation	4. Many species of RNA such as mRNA, tRNA, rRNA with different functions. RNA is the genetic material in retroviruses.
5. DNA can duplicate **on its own**	5. RNA is synthesized **on a DNA template**

Functions of various type of RNA

mRNA or messenger RNA

mRNA or messenger RNA is transcribed in the nucleus to carry information for the protein to be synthesized, from DNA to site of protein synthesis in the cytoplasm.

mRNA is transcribed as a strand of complementary bases of one of the DNA strands and carries the information for the synthesis of a particular protein or polypeptide.

tRNA or transfer RNA

tRNA or transfer RNA, also called soluble RNA has a clover leaf structure (Fig. 23.6) with loops. One loop recognises the ribosome, the top loop has an ‘anticodon’ to recognise the codon (triplet nucleotide sequence coding for an amino acids) on mRNA. tRNA “transfers” the amino acids to their respective positions during synthesis of protein.

There are many t-RNAs which differ in their anticodon. Each tRNA is specific for an amino acid and can carry that amino acid to the ribosome during protein synthesis.

The 3’ end of every t RNA ends in the bases CCA and the 5’ end of the tRNA end in G. Amino acid is carried at 5’ end.

tRNA contains unusual bases like inosine, dihydrouridine etc.

rRNA or ribosomal RNA

rRNA is a component of ribosome which are ribonucleoprotein particles containing RNA and proteins. rRNA is synthesized from the information in ribosomal genes in a chromosome. rRNA has a role in protein synthesis

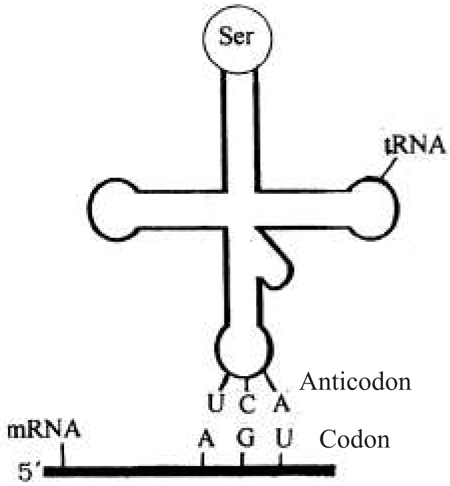


Fig. 23.6 RNA showing anti codon and codon pairing.

23.5 MECHANISMS OF DNA TRANSFER IN BACTERIA

Bacteria are prokaryotes and possess a single DNA molecule as their single chromosome. The DNA molecule is double stranded and helically coiled. Among bacteria, genes may be transferred from one bacterium to the other. DNA transfer or gene transfer can occur among bacteria by any one of the three processes, 1. Conjugation, 2. Transformation and 3. Transduction

Conjugation

Two bacteria may come together for **conjugation**. In conjugation, a plasmid containing a few genes passes from one bacterium into the other. The transfer (also called horizontal gene transfer) may also happen through a break in the single strand of the chromosome of **donor bacterium** and then that broken one strand is transferred to the **recipient bacterium**. The single strand left behind in the donor as well as the single strand donated to the recipient cell then become double stranded by adding a strand with complementary bases. The transferred DNA gets integrated into recipient chromosome. This is called **recombination.** Conjugation occurs between two strains of bacteria F^+ and F^-. The transferred DNA is from F^+ called F factor. Since F factor from F^+ is integrated into bacterial chromosome, there is high frequency of recombination, hence the strain is now known as H fr strain.

Transformation

Recall from the earlier part of this lesson (21.2) that DNA from one bacterium may integrate into DNA of another bacterium as in case of *Streptococcus pneumoniae*. Transformation is defined as the **ability of extracellular DNA to enter a bacterial cell** and recombine with the bacterial genome. The bacterial genome acquires new properties on account of the foreign DNA that had entered.

Transduction

Transduction refers to transfer of DNA from one bacterial cell into another bacterium through the agency of a virus (bacteriophage). A phage may undergo **lysogeny**, that

Notes

is the virus enters the bacterium and divides along with bacterial genome. So a number of viral particles can form. Meanwhile viral DNA integrates and becomes part of bacterial DNA which is now a new **recombinant DNA**. Sometimes the viral genome may become independent and carry host bacterial genes to another new host bacterium and recombine into its genome. This process of gene transfer is called **transduction.**

INTEXT QUESTIONS 23.1

1. Expand the abbreviation DNA.

   ....

2. Name the scientists who confirmed that DNA was the genetic material in bacterial transformation.

   ....

3. Name the sugar and the nitrogenous bases found in DNA

   ....

23.6 DNA REPLICATION

DNA duplicates itself with complete fidelity for passing on genetic information to the next generation of cells. Replication may thus be defined as a mechanism for transmission of genetic information generation after generation.

You have learnt in the lesson on 'cell' that the cell passes through the cell cycle and DNA replication or DNA duplication takes place during S-phase.

Mechanism of replicaiton

Replication occurs through the following steps :

1. Unwinding of DNA double helix

The two strands of the replicating DNA molecule separate by the action of the enzyme **Helicase. Topoisomerase** enzyme keeps it open. The opened part is the replicaiton fork as shown in Fig. 23.7a.

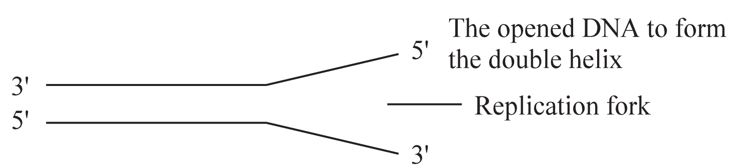


Fig. 23.7a Replication fork

2. Synthesis of the primer

Primer is a short RNA molecule of about 5 to 10 bases. It is formed in the presence of the enzyme **primase**. The primer provides a 3'-OH group for attachment of the new DNA strand.

3. Synthesis of new DNA strand

The opened strands of DNA form the template. New strands complementary to template get synthesized. At the replication fork, a new DNA strand begins to synthesise, attaching itself to the primer, in the presence of the enzyme **DNA polymerase**. It begins synthesis from its 5' end and a DNA strand complementary to one of the unwound parental DNA strand gets synthesized. The new strand of DNA **continues to be synthesized uninterrupted** and is termed as the **leading strand.**

Synthesis of the other new DNA strand

DNA synthesis always takes place along 5' to 3' direction. Therefore, the other new DNA strand gets synthesised in the direction opposite to the leading strand. This new strand called **Lagging strand** builds up in small pieces as shown in the figure, in the presence of enzyme **DNA polymerase**. Thus, the synthesis of the lagging strand is **discontinuous** (Fig. 23.7b). The new pieces of DNA are termed **Okazaki fragments**. In the presence of the enzyme **ligase** and the energy source ATP, the okazaki pieces get joined together to form a DNA strand

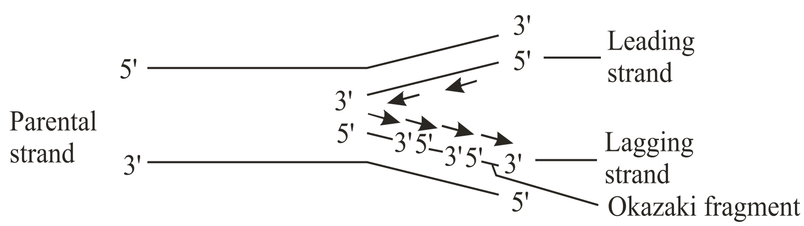


Fig. 23.7b Formation of new DNA strands

- DNA replication is remarkably accurate so that the parental DNA molecule gets an exact duplicate copy. Any mistake gets chipped and repaired. This is at the end of DNA replication and is called DNA **proof reading**.
- After **DNA replication,** two identical DNA molecules are formed which are identical to the parent molecule.
- DNA replication is thus **semidiscontinuous**, that is, one strand of the new DNA molecule builds up continuously and the other in pieces.
- DNA replication is **semiconservative**, since in the two new molecules formed, one parental strand is conserved and the other strand is newly synthesised The semiconservative mode of DNA replication was experimentally proven by Messelson and Stahl.

INTEXT QUESTIONS 23.2

1. In which direction does DNA polymerase proceed to catalyse DNA replicaiton 5′ to 3′ or 3′ to 5′?

   ....

Notes

2. What is a primer .... a DNA molecule or an RNA molecule?

 ....

3. Name the four enzymes needed for DNA replication.

 ....

4. Which enzyme joins the okazaki pieces to form a complete DNA strand?

 ....

23.7 GENES AND PROTEIN SYNTHESIS

The genes of an individual is the **genotype**, and the expression of genes results in the **phenotype**. This you have already learnt in the previous lesson. There are different **structural proteins** e.g. Haemoglobin in blood, enzymes e.g. pepsin, almost all of which are proteins. There are **carrier proteins** in the cell membrane about which you have learnt in lesson 1, on cell. So there are various proteins and the information for the formation of these proteins is present in the genes, which you know are sequences of bases in the DNA molecule.

For the study of protein synthesis you have to first understand the following

1. Central dogma
2. Genetic code

23.7.1 Central Dogma

Genes are in the nucleus and proteins are synthesised in the cytoplasm of the cell. **The transfer of information from genes to the site of protein synthesis constitutes the Central Dogma.** The central dogma operates in the following sequence. Information flows from DNA (particular gene) to the particular protein through RNA.

$$\text{DNA} \xrightarrow{\text{Transcription}} \text{RNA} \xrightarrow{\text{Translation}} \text{Protein}$$

For protein synthesis, first the information coded in DNA is copied as a complementary messenger RNA molecule. This is termed as **Transcription**. Messenger RNA carrying information moves out of nucleus into the cytoplasm, attaches to the ribosomes to translate the information in the form of a protein. This is termed **Translation** as shown.

In retroviruses, the genetic material is RNA. Therefore, during protein synthesis it is first ‘transcribed into a DNA molecule in the presence of the enzyme **Reverse Transcriptase** and then the path of central dogma is followed as shown below.

$$\text{RNA} \xrightarrow[\text{transcription}]{\text{Reverse}} \text{DNA} \longrightarrow \text{mRNA} \longrightarrow \text{Protein}$$

(genetic material
of retrovirus)

23.7.2 Genetic Code

The information for the synthesis of proteins is present in the DNA in a sequence of nucleotides. This coded information was discovered by Nirenberg, Mathais and Ochoa.

The genetic code refers to the information in DNA responsible for the amino acid sequence of a particular protein to be synthesised. The information is coded as sequence of nitrogen bases in the DNA molecule. The particular gene or fragment of DNA which carries the code for synthesis of a complete polypeptide (protein) is termed a **cistron**.

The genetic code has the following characteristics:

1. Genetic code is a **triplet** code. This means that sequence of 3 bases called **codon** has the information of a particular amino acid. The **sequence of** codons determine the sequence of amino acids in a protein.
2. Genetic code is **unambiguous,** that is a particular codon can code for only one amino acid.
3. Genetic code is **commaless** and **non-overlapping**. This means that it is read continuously from beginning to end.
4. Genetic code is **degenerate**. There are 20 amino acids only that form the various proteins of living beings. But if 3 out of 4 nucleotides (each containing one of the four bases) form a codon, there can be $4^3 = 64$ codons. Hence more than one codon codes for a particular amino acid that is, the code is degenerate. In fact as you can see from the table 23.1 first two bases of the codons for the same amino acid are common and the third one changes or wobbles. This is called **Wobble hypothesis**.
5. The genetic code is read on the transcribed mRNA during protein synthesis.
6. AUG codon, codes for Methionine and is the **initiation** codon as it is the first one to be transcribed from a cistron.
7. UAA, UAG and UGA are stop codons and anticodons of one of these three codons is present at the end of every cistron to terminate protein synthesis.
8. Genetic code is universal and common for almost all organisms on earth. (Table 23.1).

23.7.3 Transcription in Prokaryotes (Bacteria)

The flow of genetic information from cistronic DNA to mRNA is called Transcription. It occurs in the following steps–

1. Cistronic DNA which carries the information for the protein to be synthesised unwinds in the presence of enzymes helicase and topoisomerase.

2. RNA polymerase begins to catalyse synthesis of mRNA signalled by a protein called **sigma** factor.

3. mRNA is synthesised complementary to cistronic DNA and a Rho factor signals RNA polymerase to complete transcription.

4. The strand of DNA which bears the code for transcription of the specific protein is called **sense strand of DNA** opposed to the **antisense strand** which is not transcribed. (Fig 23.8)

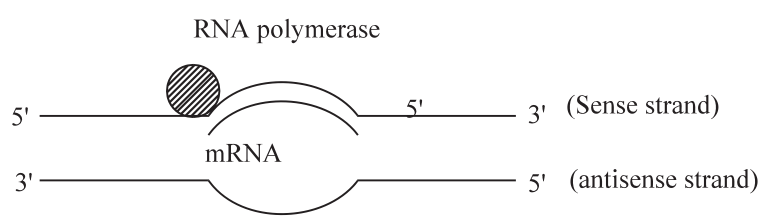


Fig. 23.8 Transcription in prokaryotes

In Eukaryotes a large molecule of RNA called hn RNA is synthesised in the nucleus when its sense strand is exposed. Catalysed by enzyme RNA polymerase, hn RNA is processed to form mRNA which gets a cap at 5' end and a poly A tail, before leaving the nucleus.

Processsing of mRNA

hnRNA is large because eukaryotic genes contain coding sequences called **exons** and non coding sequences called introns (I) in between exons. Both introns and exons (E) are transcribed in mRNA. During processing of mRNA, introns are cut off and exons join to form mRNA.

- A nucleoside (recall from section 23.3) called methyl guanosine comes and attaches at the 5' end of mRNA. This is called capping.
- A small piece of RNA having only nucleotides containing the base Adenine is attached at the 3' end. This is called the poly A tail.
- The m RNA with cap and tail moves out of the pores in the nuclear membrane.

The process of formation of functional mRNA from hnRNA is termed **RNA processing** (Figs. 23.9)

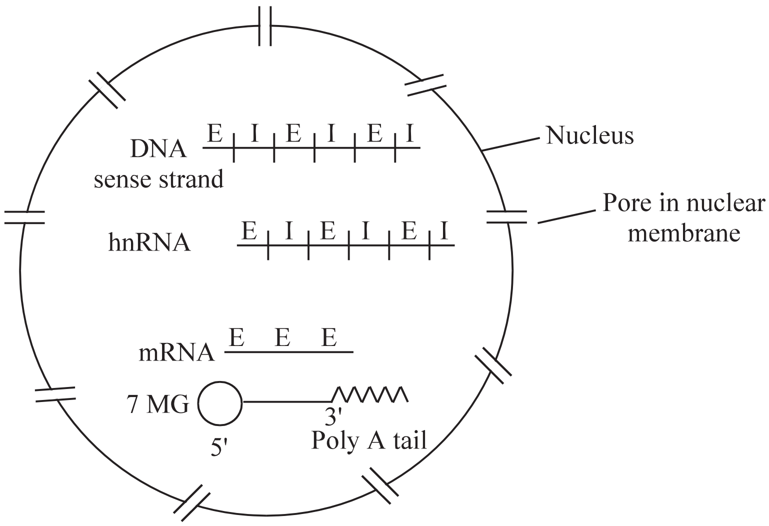


Fig. 23.9 Schematic drawing showing transcription and processing of hnRNA in eukaryotes

23.7.4 Translation

A series of events follows transcription in which the language of nucleotides transcribed (copied) in mRNA is **translated** into the language of amino acids to form a protein. These events are

1. Activation of amino acid
2. Formation of mRNA ribosome complex and chain initiation
3. Chain elongation
4. Chain termination

Activation of amino acid

A specific t RNA attaches to specific amino acid in the presence of the enzyme **amino acyl-tRNA synthetase** in two steps given below. This requires energy

$$\text{Amino acid} + \text{ATP} \xrightarrow[\text{tRNA synthetase}]{\text{aminoacyl}} \underset{\text{(Amino acyl adenylate)}}{\text{aa} \sim \text{AMP}} + \underset{\text{(Inorganic phosphate)}}{\text{Pi}}$$

$$\text{aa}\sim\text{AMP} + \text{tRNA} \xrightarrow[\text{tRNA synthetase}]{\text{aminoacyl}} \underset{\text{(Amino acid attached to its tRNA)}}{\text{aa} \sim \text{tRNA}} + \text{AMP}$$

Formation of mRNA ribosome complex and chain initiation

- mRNA binds to small ribosomal subunit

- Larger subunit of ribosome attaches to complete the ribosome.
- The mRNA ribosomal complex contains two codons so that at a time two amino acids can be accommodated in the ribosome.
- In the presence of some proteins called **initiation factors** methionine (an amino acid is carried to the mRNA ribosome complex and enters at the A site in the large subunit of ribosome. Recall that tRNA has an **anticodon** a sequence of three bases complementary to the codon for methionine.

Chain elongation

The second amino acid is carried by its tRNA to the ribosome according to the second codon on at the P site in large ribosomal unit. Peptidyl transferase enzyme then helps to establish a bond between the first two amino acids. The first amino acid loses its tRNA which moves out. Ribosome then moves over the m-RNA towards 3' end. The dipeptide made of the two amino acids shifts towards 5' end such that the second amino acid occupies the A site with methionine attahed to it. The third amino acid then enters through P site carried by its tRNA according to third codon. In the presence of peptidyl transferase, a peptide bond is formed between second and third amino acids and tRNA of second amino acid becomes free. In this way the peptide chain is synthesized. (Fig. 23.10).

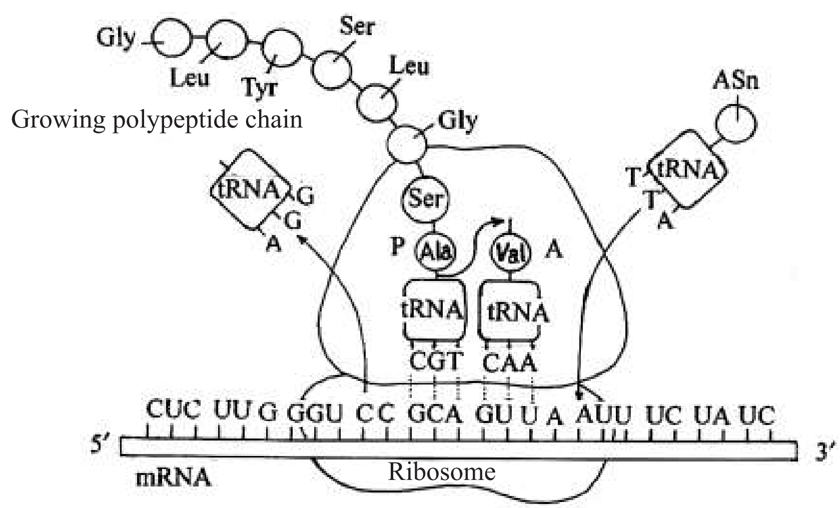


Fig. 23.10 Translation of mRNA Polysome assembly

- **Polysome assembly**

  When mRNA has shifted ahead such that about ten amino acid long peptide is synthesised, a second ribosome attaches to form ribosome mRNa complex. Thus at one point of time a number of ribosomes are seen attached to mRNA one molecule of the polypeptide continues synthesis in each ribosome till the termination codon is reached (Fig. 23.10).

Chain termination

When the stop codon on mRNA is reached, the polypeptide is synthesised. It leaves the ribosome and the ribosome dissociates into its two subunits.

INTEXT QUESTIONS 23.3

1. What is central dogma in molecular Biology?

   ....

2. Which molecule is synthesised during transcription?

   ....

3. What is a codon? What is meant by 'code is degenerate'?

   ....

4. Where in the cell does translation occur?

   ....

5. Name the three types of RNA that participate in protein synthesis.

   ....

23.8 HOUSE KEEPING GENES

In multicellular organisms, all cells contain all genes but only those genes function which are required to be active. In other words the expression of genes is regulated by switching on and switching off genes when required.

Certain genes, however, bear the code for proteins needed in the cell all the time. These are the genes needed for survival and maintenance of the cells and need to be expressed all the time. Such genes which are expressed all the time in all cells are termed **housekeeping genes. Inducible genes** are the genes which are switched on when a particular substance is present in the environment. **Repressible genes** are those which are shut off in the presence of a specific substance in the environment.

23.9 REGULATION OF GENE EXPRESSION

In Prokaryotes, the Lac-operon is an excellent example of control of gene expression in prokaryotes (bacteria). It is an inducible system and is switched on in the presence of the substrate **lactose**. Enzymes for metabolising lactose are galactosidase, permease and transacetylase and genes that code for them get switched on. In the absence of lactose, they remain switched off.

Jacob and Monod received the Nobel prize for showing that bacterium *Escherichia coli* has a set of genes forming an "operon" which regulate expression of genes coding for enzymes needed to breakdown lactose. The operon includes certain genes lying close together on the chromosome next to the regulator gene i, and includes promoter gene p which RNA polymerase identifies at the time of transcription; operator gene, o which switches on structural genes z, y, a coding for the enzymes, Galactosidase, Permease and Transacetylase.

The working of the operon system is given in Fig. 23.11a-b.

In absence of the substrate lactose

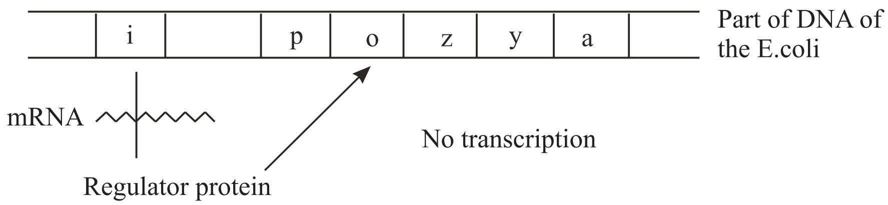


Fig. 23.11a Lac operon switched off

Regulator protein blocks o, RNA polymerase cannot find p and z, y, a remain switched off.

In the presence of lactose

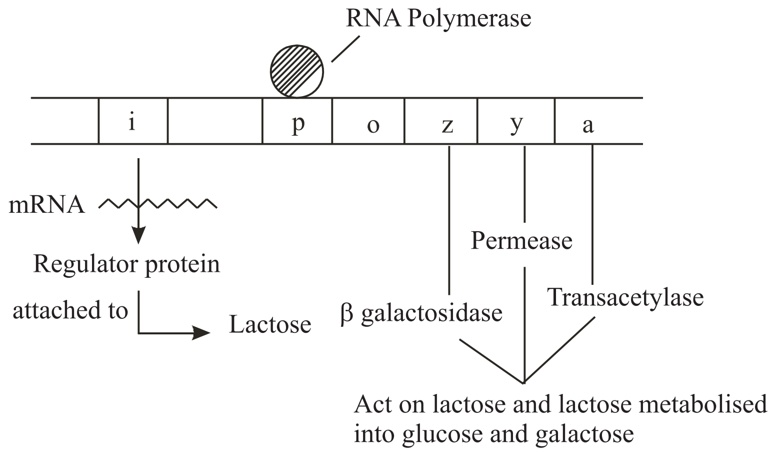


Fig. 23.11b Lac operon switched on

Regulator protein is attracted to lactose, o site opens; RNA polymerase finds promoter; genes z, y, a switched on, transcription begins and the three enzymes are synthesized inside the cell.

The above is an example of inducible system. Repressible systems are also found in prokaryotes.

Gene regulation in eukaryotes is more complex, Gene expression can be regulated at level of transcription or processing of hnRNA into mRNA or at translation or post translation. (Fig. 23.12).

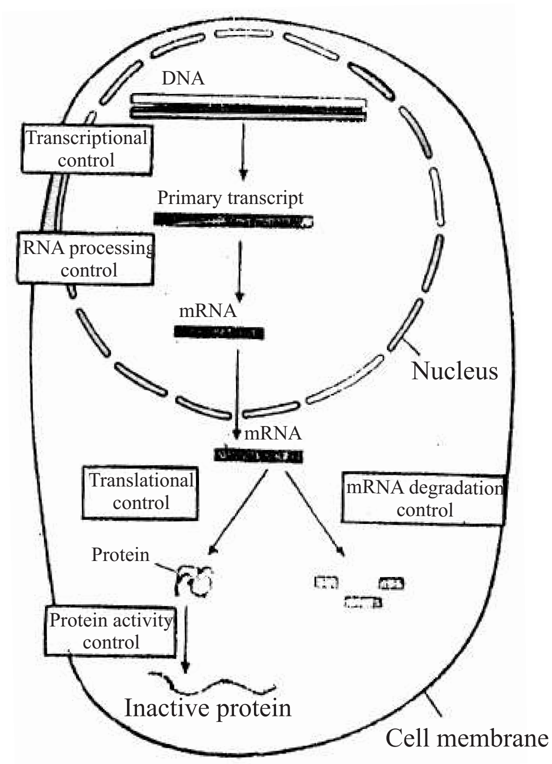


Fig. 23.12 Levels of gene control in eukaryotes

A heritable change in the structure, content and organization of the genetic material that can be passed down to the next generation is termed **mutation**. Mutation may occur in **one gene** when it is termed **point mutation** or may affect a number of genes on a part of chromosome when it is termed **chromosomal mutation**.

Chromosomal mutation

Involves a number of genes. It is of two types, (1) Change in number of chromosomes and (2) Change in structure of chromosomes.

The number of chromosomes in individuals of a species is fixed. For example humans have 2n = 46 chromosomes. But sometimes one or more chromosomes may be lost or added and such a change in number is termed **Aneuploidy** when 2n = 45 or 2n = 47 is found is an individual. Sometimes the whole set of chromosomes may be duplicated so that instead of 2n, an individual way possess 3n or 4n chromosomes. This is **polyplocdy**.

Chromosomal change in structure is also termed as **chromosomal aberration**. It is of four types 1. **Deletion**, in which a piece of a chromosome may be lost. 2. **Inversion**, a piece of a chromosome breaks off and rejoins in the reverse direction. 3. **Duplication** A part of the chromosome may get represented twice and 4. **Translocation** a piece from another chromosome may get attached.

Genes mutation or Point Mutation

A change which affects only one gene is called gene mutation or point mutation. You already know that gene is a segment of DNA and is made of a sequence of nucleotides. Whenever one nucleotide is changed within a gene, it may cause a change in the phenotype.

Gene mutation is of the following types :

1. Transition : When a purine base is replaced by another purine base or a pyrimidine base by another pyrimidine

   ATGCATGC ⟶ A**G**GC AGGC

2. Transversion : When a purine base is replaced by pyrimidine base and similarly a pyrimidine base by a purine

   ATGC ATGC ⟶ ATG**T** ATGC

3. Frameshift : Sometimes due to loss or gain of one nucleotide the reading frame of the genetic code for an entire protien changes

   CAT CAT CAT CAT ⟶ CAT ATC ATC ATC

   when C gets lost after CAT

4. Missense : A change in the genetic code due to replacement of a nucleotide (base) may give rise to a different protein e.g. sickle cell haemoglobin.

5. Nonsense : If a genetic code changes such that it becomes a stop codon mid way, no protein is formed e.g.

   GAAGAAGAA ⟶ GAA**UAA**AA

   synthesis stops as UAA in stop condon

6. Silent : When the changed nucleotide does not bring about any phenotypic change because it also codes for same amino acid.

Mutagens

Agents that cause mutation in the genetic material are called **mutagens**. Mutagens belong to two categories

1. Radiations : x-ray, UV rays, α radiations.
2. Chemical : Mustard gas, Actinomycin D

INTEXT QUESTIONS 23.4

1. Name the components of an operon.

   ....

2. What is mutation? When is a mutation called a transition mutation?

   ....

3. Why is "silent mutation" called so?

....

4. What are mutagens?

....

5. Name a chemical which causes mutation in the heredity material.

....

WHAT YOU HAVE LEARNT

- One gene was found to be responsible for the production of one enzyme, and this was called one gene one enzyme hypothesis.
- The transformation of the bacteria from harmless to virulent is termed bacterial transformation.
- DNA is a polynucleotide, made up of nucleotides. Each nucleotide consists of three subunits (i) deoxyribose sugar (ii) any one of 4 nitrogenous bases (Adenine, Guanine, Thymine and cytosine (iii) a phosphate group.
- RNA is the other important nucleic acid present inside the cell. RNA has pentose sugar ribose and base uracil instead of cytosine. Many species of RNA such as mRNA, tRNA, rRNA have different functions.
- Transformation means the ability of extracellular DNA to enter a bacterial cell and recombine with the bacterial genome.
- Transduction refers to transfer of DNA from one bacterial cell into another bacterium through the agency of a virus.
- Replication may be defined as a mechanism for transmission of genetic information generation after generation.
- The transfer of information from genes to the site of protein synthesis constitutes the central dogma.
- The information for genetic coded was discovered by Nirenberg, Mathair and Ochoa.
- The flow of genetic information from cistronic DNA to mRNA is called transcription.
- A single triplet (three bases) is called codon.
- Mutation is a sudden change in genes or chromosomes resulting in alteration of protien/phenotype.

TERMINAL EXERCISES

1. How did Hershey and Chase prove that DNA is the hereditary material?
2. Explain (i) Transduction and (2) Lysogeny
3. Describe the Watson and Crick model of DNA.
4. Explain how replication takes place.
5. Write a note on Central Dogma
6. State the properties of the genetic code.
7. Explain transcription in Eukaryotes and processing of hnRNA.
8. What do you mean by regulation of genes?
9. Explain how the lac operon gets switched on in the presence of lactose in *E.coli*.
10. Name three levels at which regulation takes place in a eukaryotic cell.
11. Write notes on :
    (i) Types of mutations
    (ii) Okazaki fragments
    (iii) Chain termination during translation.

ANSWERS TO INTEXT QUESTIONS

23.1
1. Deoxyribonucleic acdi
2. Avery, Mcleod and McCarty
3. Deoxyribose, Adenine, Guanine, Thymine, Cytosine

23.2
1. In 5’-3’ direction
2. RNA molecule
3. Helicase, DNA polymerase, DNA ligase, Topoisomerase
4. DNA ligase

23.3
1. The transfer of information from genes to the site of protein synthesis constitutes the central dogma.
2. Cistronic DNA
3. Sequence of three bases in the genes.
4. Nucleus
5. mRNA, tRNA, hnRNA

23.4
2. A heritable change in the structure, content and organization of genetic material when in a DNA sequence a purine is replaced by purine and pyrimidine is replaced by pyrimidine.
3. A silent mutation ina gene does not bring about a change in the synthesis of the coded protien.

24

GENETICS AND SOCIETY

You have already learnt that genetics is the science of heredity and variation. After Mendel's work was rediscovered in 1900, genetics progressed very rapidly in the 20th century. Today we find many applications of the knowledge of genetics in the fields of agriculture, medicine and forensic science. Some technologies related to genetics such as gene cloning, recombinant DNA technology, DNA fingerprinting, raising genetically modified crops will be dealt with in this lesson. Biopiracy, biosafety and biopatents related to GMOs and Bt crops have also been touched upon

OBJECTIVES

After completing this lesson, you will be able to :

- *highlight human curiosity and consciousness for healthy progeny;*
- *define the term gene cloning;*
- *explain the usefulness of gene bank;*
- *enumerate the various steps of recombinant DNA technology in a sequence;*
- *define genetic engineering and mention its utility;*
- *define transgenic organism, explain the steps in its production and cite examples of transgenic animals, plants and microbes;*
- *critically evaluate the advantages* and disadvantages of growing Bt crops;
- *describe steps of polymerase chain reaction and mention its (PCQ) use;*
- *list the steps of DNA fingerprinting and mention its usefulness;*
- *explain the term genomics;*
- *justify the importance of genetic counselling.*
- *express concern regarding biosafety and awareness regarding biopiracy and biopatents*

24.1 GENETICS THROUGH AGES

The history of genetics can be traced to prehistoric times and can be classified into three eras as given below :

Early ideas

Primitive art such as drawings in ancient tombs and caves, bones and skulls show that human activities included selecting, breeding and domesticating plants and animals. Between 8000 and 1000 BC, horses, camels oxen and dogs had been domesticated. Between 7000 to 5000 BC corn, rice, wheat and datepalm were being cultivated.

Between the 17th and 19th century many theories regarding inheritance had been proposed but could not be proved. These were **epigenesis, preformationism, blending inheritance** and **pangenesis**. But this clearly shows that humans were always curious to know how traits are passed down the generations.

Modern Genetics

Gregor Johann Mendel, whose principles (laws) of inheritance you have learnt in earlier lessons of the unit is regarded as the founder of modern genetics. Between 1902 and 1904, the **chromosome theory of inheritance** was accepted and chromosomes, which could actually be seen under the microscope during cell division were regarded as the 'bearers of hereditary characters (genes)'. **Mutations** were recognised as source of **genetic variation.**

With the acceptance of Darwin's theory of natural selection, geneticists studied the inheritance of traits in populations (**Population genetics**).

Molecular Genetics

By the mid 20th century, **DNA** was established as the genetic material and structure and chemical nature of DNA was understood [recall the double helical structure of DNA as proposed by J. Watson and F. Crick]

The **central dogma** of molecular biology holds that genetic information resides in DNA, but its expression is in the form of proteins which are synthesized according to genetic information carried by mRNA from DNA.

In the last two decades of the twentieth century more has been understood about the **nucleic acid molecules** and **protein molecules** and also about the **genetics of bacteria**. The knowledge gained has led to the invention of technologies of **genetic engineering, gene cloning, organismal cloning, DNA finger printing**. Even more recent are the fields of **genomics** and **bioinformatics**. The entire genetic make up (genome) of an organism can now be cloned, sequenced and functions of the various genes explored. Knowing the human genome has opened up the possibilities for handling genetic disorders through **gene therapy.**

24.2 GENE CLONING AND GENE BANK

The term **clone** is a collective term for **genetically identical** individuals. You have probably heard about the sheep named "Dolly", which possessed the same genes as did her mother as she was cloned from her mother.

> In the Roslin Institute in Scotland, Ian Wilmut cloned "Dolly" the sheep from Dolly's mother in 1996. The nucleus from a cell from Dolly's mother's udder (mammary glands) was introduced into the egg of another ewe (female sheep) whose nucleus was removed. This cell divided to give more cells which formed an embryo that could be implanted into the uterus of another ewe (surrogate mother).

The production of large quantities of identical genes is called **gene cloning**. Since any gene is a segment of DNA having a **particular sequence** of the four nitrogen bases (A, T, G, C), multiple copies of a particular gene may be obtained by means of **recombinant DNA technology**, popularly known as **genetic engineering**. You will learn more about genetic engineering later in this lesson.

Gene bank

Various clones of bacteria carrying the **desired genes** in their DNA can be stored and preserved at very low temperatures for their future use, in a gene bank. A gene bank or a gene library or a DNA library is, thus, a collection of bacterial or bacteriophage (virus) clones. Each clone carries specific DNA segment (gene) from another organism. For example, human gene coding for the hormone insulin may be inserted through genetic engineering into a bacterium. When the bacterium multiplies it forms a clone of bacteria carrying the gene for insulin and may be preserved in the '**gene bank**'. Thus, clones from a gene bank may be used for producing large quantities of certain enzymes, hormones and vaccines.

INTEXT QUESTIONS 24.1

1. Name any two recent techniques in genetics.

   ....

2. Define gene cloning

   ....

3. What is a gene bank ?

   ....

24.3 RECOMBINANT DNA TECHNOLOGY

One of the major applications of genetics is in "genetic engineering" which is also called recombinant DNA technology. In this technique the desired gene which is a DNA segment carrying a particular sequence of nucleotides, is added to the DNA of another organism (usually a bacterium) with the help of a transferring agent or **vector**. The modified DNA molecule carrying DNA from two different sources is called **recombinant DNA** or **rDNA.** The joining of two pieces of DNA is termed **DNA splicing** (Splicing in Latin means marriage).

The steps in the production of rDNA is as follows (Fig. 24.1) :

- The desired piece of DNA is cut from the cells (e.g. human cells) with the help of enzymes called **restriction endonucleases** or restriction enzymes. These enzymes are found in different bacteria. They recognise **specific nucleotide sequences** in a DNA molecule and cleave (cut) them.
- The same restriction enzyme cuts the same specific nucleotide sequence in a plasmid. A plasmid is a ring shaped DNA molecule present in a bacterium. It is **not** part of the chromosome of the bacterium. It is used as a vector for transferring the foreign DNA into the host cell.
- The desired DNA fragments are then mixed with the cleaved plasmids. These plasmids pick up the foreign DNA pieces with the same base sequence to replace their lost parts. These become the recombinant plastids and the DNA is rDNA or **recombinant DNA**
- The recombinant plasmids are now introduced into or mixed with their bacteria which pick up the recombinant plasmids.
- The r-plasmids in the bacteria multiply along with the host bacteria. Soon a **clone of bacteria with** rDNA is obtained. Such a bacterial clone containing copies of the desired gene can be preserved for future use. For example, as already mentioned, human insulin gene can be inserted into bacterial plasmid and insulin obtained from the bacterial clone when needed.

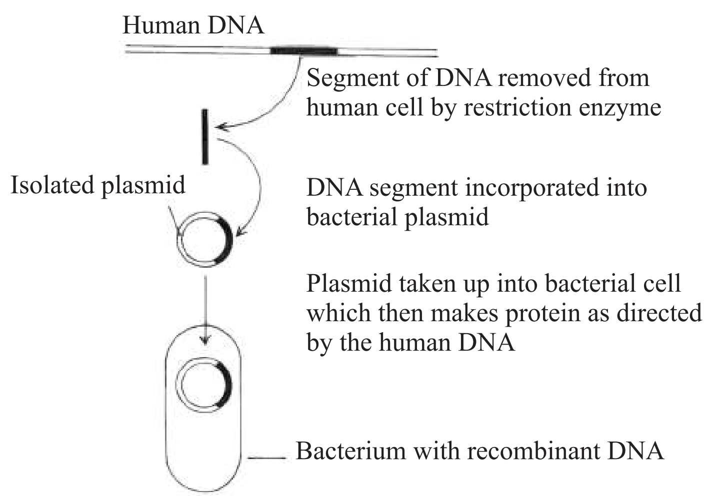


Fig. 24.1 Major steps in genetic engineering.

24.4 IMPORTANCE OF GENETIC ENGINEERING

Genetic engineering or rDNA technology can be used for various purposes:

- To manufacture important compounds like vaccines, hormones, vitamins, antibodies etc. The production of these substances is by inserting genes responsible for them in the bacteria and then getting clones of these bacteria to produce the desired substances.
- To manufacture enzymes used for making cheese.
- To breakdown pollutants through recombinant bacteria (bioremediation).
- To clone particular genes with the help of rDNA technology and build up a gene bank or a gene library.
- To use rDNA for gene therapy for curing genetic disorders.
- To raise useful plants (transgenic plants) resistant to herbicides (chemicals used to kill weeds) or insect pests by inserting genes in the plants through rDNA technology.

INTEXT QUESTIONS 24.2

1. What is the popular term for recombinant DNA technology?

   ....

2. What is meant by DNA splicing?

   ....

3. What is a plasmid and why is it called a vector for genetic engineering?

   ....

24.5 TRANSGENIC MICROBES, PLANTS AND ANIMALS

Also called genetically modified organisms (GM organisms), transgenic organisms contain in their genetic make up, foreign genes, that is, genes from another species or another kind of organism. **Transgenics are raised through recombinant DNA technology.**

24.5.1 Transgenic microbes

Bacteria are easiest to be genetically modified by adding foreign gene into their plasmids through rDNA technology as you have already learnt in this lesson. Transgenic bacteria with insulin gene and human growth hormone gene have been cloned to provide these hormones for human use.

Other uses of transgenic bacteria are in decomposing pollutants and extracting metals such as copper and gold.

24.5.2 Transgenic plants

Some genetically modified plants are herbicide and pest resistant. A genetically modified tobacco plant contains a gene from the firefly and emits green light.

Bt CROPS

Bt crops are genetically modified crops and are therefore also called **transgenic crops**. The name Bt crops is because the transgene or the foreign gene is transferred into the crop by the soil bacterium *Bacillus thuringiensis* (Bt).

The transferred gene or transgene is not harmful to the host crop into whose genotype the gene has been added. It codes for a protein called ***cry* protein**.

The bacteria Bt lives in the soil. In its genotype there is a gene called *cry* gene which produces an insecticidal (insect killing) protein. A Bt crop produces this protein. When an insect pest eats the Bt crop, cry protein is converted into a toxic substance by the enzyme present in the stomach of the pest. This toxic substance kills the pest.

The cry gene has been isolated and transferred into many crops, eg cotton, maize, brinjal, tomato and tobacco and tested in the fields. They are resistant to insect attacks. Use of Bt crops reduces the need for spraying insecticides to kill insect pests. Insecticides are harmful to humans and other animals.

However, Bt crops can only be cultivated after permission from Government of India, under Environment Protection Act (EPA). This is because entomologists worry that:

- Since Bt crops make the toxin throughout their growing season, pests may evolve which are Bt resistant
- Non-target species like the butterflies may die if they feed on Bt pollen.
- Genetically modified crops may be harmful for the environment as they may pass the gene into a close relative plant which may be useless for humans but perpetuate as super weeds.

24.5.3 Transgenic animals

The gene for growth hormone from cattle have been inserted through genetic engineering to produce large fish, pigs and some other animals.

Transgenic goats can produce a blood clotting protein in their milk. This may be useful for children suffering from disorders such as haemophilia in which blood does not clot.

> Genetic engineering offers a wide scope for transferring genes from one organism to another, such as plants to microbes, animals to microbes. Such gene transfers are not possible by other techniques like hybridisation. However, rDNA technology is not without problems. One danger is that accidentally or intentionally pathogens may be produced and misused as in biological warfare. Hence strict guidelines have been laid down for research in genetic engineering.

24.5.4 Biosafety

There is public concern about possible hazards of using genetically modified (GM) organisms as food. You already know that a GM organism is one that contains genes from another species. For example, Bt brinjal, a GM brinjal has genes added to genome of brinjal from another species by genetic engineering which helps it to protect itself from one of its pests. The salmon fish has been genetically modified by adding a more active salmon growth hormone gene.

But the concern is about safety of GM foods to humans and other animals and also to the environment. Hence, in early 2000, several countries agreed to a Biosafety protocol by which the safety of using GM foods is first ascertained before using them. In our country, Department of Biotechnology, in compliance with rules of Environment Protection Act (EPA) has to be consulted granting permission for research and use of any GM organism only after testing its safety to humans, other animals and the environment.

24.5.5 Biopiracy

Piracy means theft. Biopiracy means patenting or exploiting a biological resource of another country without being authorised or giving adequate compensation. For example, a rich developed country may patent a bioresource such as medicinal plant or traditional knowledge regarding a bioresource of a developing country. Sometimes a useful biomolecule extracted from a plant growing in another country may be patented and used for commercial benefits. Even genes from foreign plants and animals may be patented, eg U.S granted a patent for the germplasm of basmati rice grown in India.

24.5.6 Biopatent

A patent is an official document. Possession of this document permits the holder to use or sell his/her invention. The duration of a patent is 20 years and the patent holder has to obtain a license on certain reasonable terms and conditions. The Indian Patent Act (1970) provides patents for invention to be used as food, medicine/ drugs, alloys, semiconductors etc. In India, duration of patent is for 14 years except for food and pharmaceuticals which is only for 7 years.

The patent is granted to the inventor so that the invention is not used by others for commercial purposes. A patent may be granted for (i) an invention or discovery (ii) improvement of an earlier invention (iii) process of generating a patent (iv) a concept or design.

INTEXT QUESTIONS 24.3

1. Use the example of Bt crops to state importance of transgenic crops.

   ....

2. What is a cry protein?

   ....

3. Exploiting a biological resource of another country without being authorised is called ....
4. When and why was the biopatent act adopted in India?
   ....
5. What is the duration of a patent for pharmaceutical products in India?
   ....

24.6 POLYMERASE CHAIN REACTION

You have learnt in the lesson no 22, that DNA polymerase is the enzyme responsible for DNA replication or making a copy of a DNA molecule.

In the technique called **polymerase chain reaction (PCR),** DNA polymerase enzyme is used repeatedly for making many copies of a small fragment of DNA. Thus polymerase chain reaction or PCR helps in making many copies of a small amount of DNA.

The steps in PCR are,

- Double helical DNA molecule is heated so that it breaks up into two strands
- Primers are added and the DNA is cooled.
- DNA polymerase is added and in its presence the two single strands acquire complementary strands and so two molecules of the DNA are formed. (Fig. 24.2).

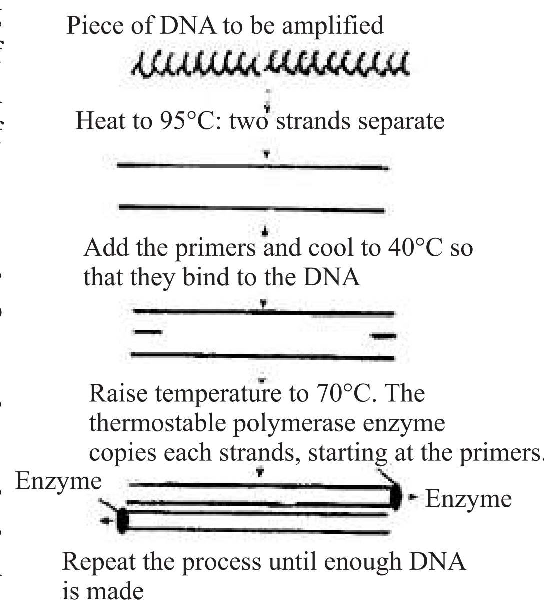


Fig. 24.2 Polymerase chain reaction

These steps are repeated to get multiple copies of DNA. These days DNA polymerase from a bacterium living in hot springs called Taq polymerase is used in PCR machines. DNA amplified by PCR can be used for various techniques.

24.7 DNA FINGER PRINTING

Like our fingerprints, the repeated sequences in our DNA are unique. You must have heard that the police lifts fingerprints from the scene of crime to identify the culprit in case of rape, theft or murder.

In 1984, Alec Jeffreys, a geneticist invented a technique which could distinguish the DNA of a person from that of another and called this technique **genetic fingerprinting** or **DNA fingerprinting**. This technique is now used for scientific investigation of crime. For example identifying correctly the accused in rape or murder or to solve paternity disputes (find out who the actual father of a child is).

DNA fingerprinting can be done from very small amounts of DNA which are taken out of a tiny drop of blood, semen, hair follicle, tooth pulp etc. picked up from the scene of crime. The steps in the technique are:

- DNA is isolated from blood, semen etc.
- Its quantity is increased through PCR
- The lengths of these DNA pieces vary from person to person because of certain repeated sequences of nucleotides in DNA which vary.
- The DNA pieces are separated from each other according to size and charge with the help of a technique called **electrophoresis.**
- The pattern as you can see in the figure given below is unique for each person.

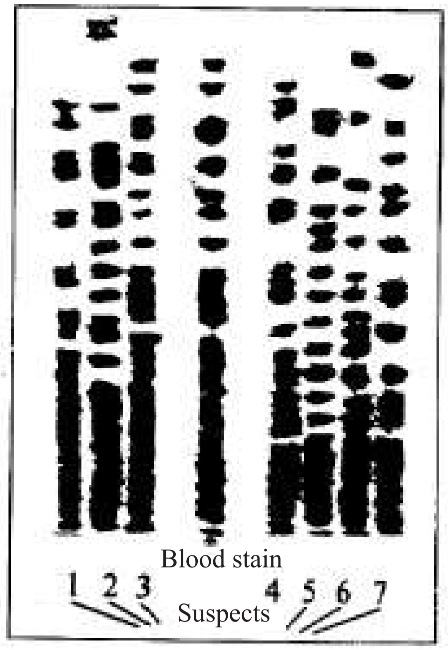


Fig. 24.3 DNA fingerprinting (Match and see that culprit is suspect No : 3)

In a crime, there may be three or four suspects. Their DNA fingerprinting is carried out and compared with that of the DNA picked up from the scene of crime. The one that matches the DNA print of one of the suspects is the actual culprit. (Fig. 24.3).

24.8 GENOMICS

Genome is a collective term for a full set of genes in an organism. Genes are paired and so genome means all the genes present in a haploid (n) set of chromosomes. Genomics is the analysis of the genome data, that is, finding out the functional nucleotide sequences (genes) in the DNA of an organism.

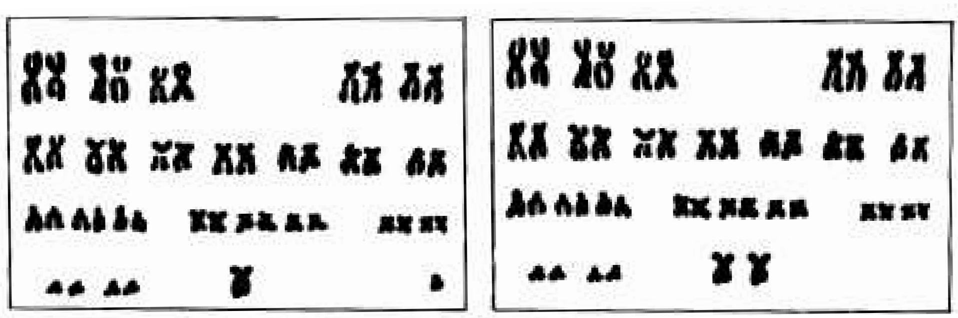


Fig. 24.4 Karyotypes showing Chromosomes of (a) male, and (b) female humans

The genome of *E. coli* bacterium, the yeast **Saccharomyces** and some other kinds of organisms is already known *e.g. Arabidopsis Drosophila.*

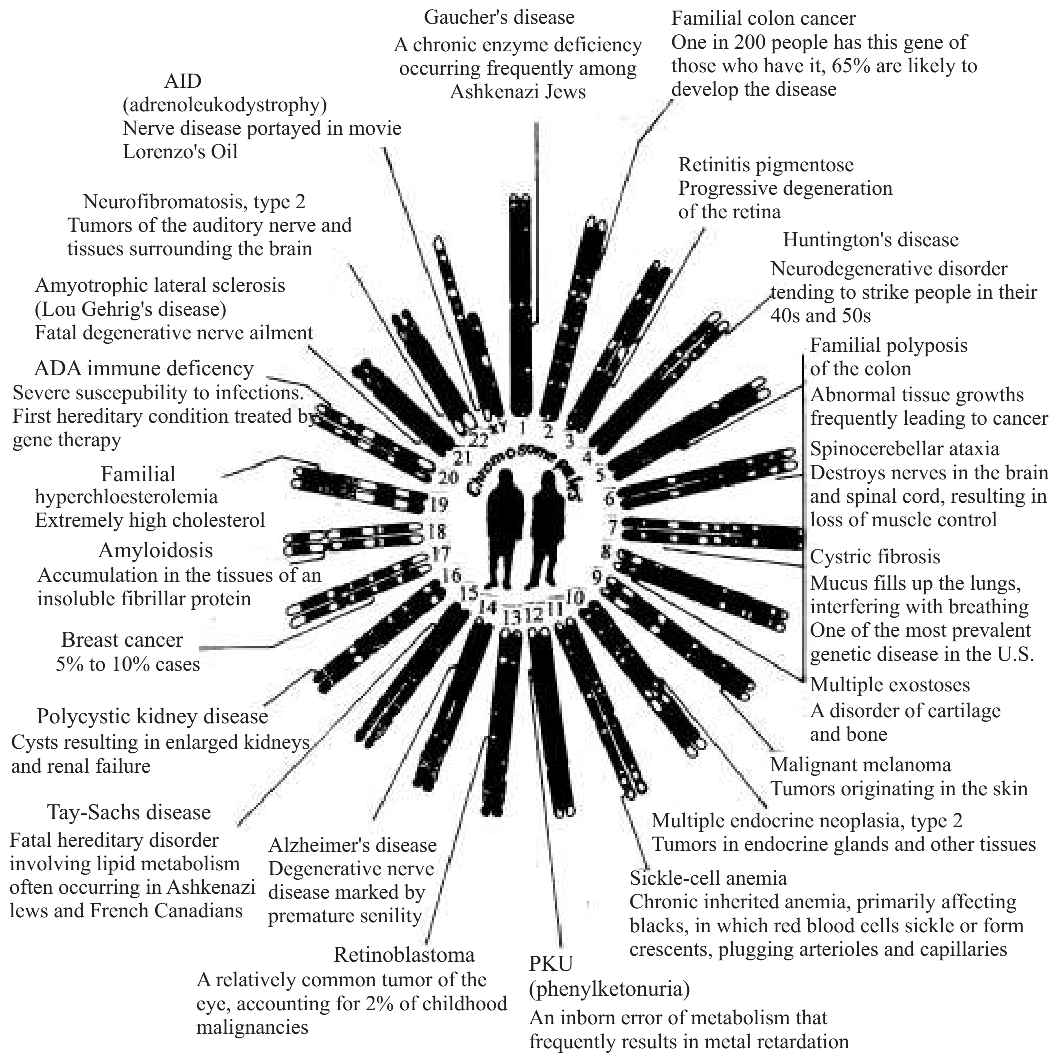


Fig. 24.5 Human genome showing location of some defective genes.

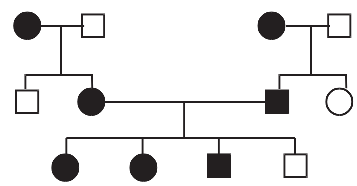
The human genome has been mapped in 2003. Humans have 23 pairs of chromosomes (2n = 46) and the human genome has 3×10^9 nucleotide base pairs and if the sequence of nucleotides (genes) is known, it will be possible to pinpoint (i) defective genes (as shown in the figure in the box) and (ii) identify genes for correction of genetic disorders (gene therapy) and genetic counselling.

24.9 GENETIC COUNSELLING

You have earlier learnt about dominant and recessive genes. If a child receives a dominant gene from one parent and its recessive from the other parent (heterozygous condition) the recessive gene does not express itself. Recessive genes get expressed only when they are in the homozygous condition, that is, both genes of a pair inherited from the parents are recessive.

You can probably appreciate why marriages between closed relations (termed consanguineous marriage) are discouraged. Being related, both parents may pass down the defective gene which may be present in a family. Most defective genes that cause genetic disorders are recessive. When both genes of a pair in the child are defective, the child is born with a genetic disorder. So if a couple wishes to know the chances of their child getting a particular disorder present in their family, they have to go to a **genetic counsellor. Genetic counselling** means advise given regarding a genetic disorder so that the couple knows whether to have any more children if their first child is suffering from a genetic disorder. The genetic counsellor has a very good knowledge of human genetics and can predict the chances of a genetic defect in a family.

The pattern of inheritance of a particular trait (feature) among humans is identified by the method of **pedigree analysis**. Pedigree is a diagrammatic representation of relationships showing a particular trait in a family. The genetic counsellor prepares a pedigree chart and can then advise accordingly. See the pedigree chart (Fig. 24.6) and study the squares and circles as explained.



The circles are females and the squares are males; filled in circles and squares are affected individuals, empty circles and squares are normal individuals

Fig. 24.6 Pedigree chart

INTEXT QUESTIONS 24.4

1. Define genome.

   ....

2. What is genomics?

   ....

3. What is the use of genomics?

   ....

4. Why should a genetic counsellor have good knowledge of genetics?

   ....

Notes

5. Expand the abbrenation PCR.

   ....

6. Why is the tehnique DNA fingerprinting named so?

   ....

WHAT YOU HAVE LEARNT

- From prehistoric times, humans have had a curiosity to know how traits (features) are inherited.
- Domestication of animals and cultivation of crops like rice, wheat, maize and date palm can be traced to earlier then 5000 BC.
- Modern genetics began after Mendel's laws of inheritance were accepted. Soon after it become clear that genes are carriers of hereditary features and they are present on chromosomes. That genes mutate also became known.
- The last fifty to sixty years have been an era of Molecular Genetics when it was confirmed that DNA is the genetic material and the mechanism of DNA replication and protein sysnthesis in a cell were discovered.
- In the last few years, many techniques such as rDNA technology, DNA fingerprinting have been put forth.
- Gene cloning means producing and preserving desired genes in a clone of bacteria through recombinant DNA technology. A gene bank is one where several clones of bacteria carrying different desired foreign genes (for example genes of humans) are preserved for future use of products of these genes.
- Genetic engineering, also called recombinant DNA technology uses specific restriction endonuclease from different bacteria to cut genes, that is, particular DNA sequences from DNA molecules of an organism (e.g. humans) and similar sequences from plasmids and join the foreign DNA to the plasmid and introduce the plasmid with foreign DNA into its host bacterium and raise a bacterial clone.
- Genetic engineering is useful for creating genetic libraries, gene therapy and genetically modified organisms.
- Genetically modified organisms are also called transgenics. Transgenic microbes, plants and animals carry in their genetic make up, gene or genes of another kind of organism. Transgenic bacteria are used for extracting metals and decomposing pollutants. Transgenic plants are herbicide and pest resistant. Transgenic animals are larger in size and transgenic goats may carry a human gene responsible for a particular protein which is then released in its milk.
- PCR or polymerase chain reaction is a technique to make many copies of a small amount of DNA.

- DNA fingerprinting is a technique to identify the DNA of a particular person. It is used to scientifically investigate a crime and identify the real criminal.
- Genomics is the analysis of a complete set of genes found in an organism. The complete set of genes is called a genome.
- Genetic counselling is the advise given by an expert on the chances of an unborn baby getting a genetic disorder.

TERMINAL EXERCISES

1. Name the three eras in the history of genetics.
2. Define gene cloning. What is the usefulness of a gene bank?
3. Give the various steps of recombinant DNA technology.
4. What are the benefits of genetic engineering?
5. What are transgenics? Give examples of a transgenic microbe, plant and animal.
6. Define genomics
7. Draw and explain a pedigree chart.
8. What is genetic counselling and why is it important?
9. What is DNA fingerprinting? Justify that it is the foolproof tecnique for sorting out paternity issues.
10. List the steps of Polymerase chain reaction.
11. What are Bt crops? What are the benefits and fearns related to their use?
12. Write notes on (i) Biopatent (ii) Biopiracy and (iii) Necessity for a biosafety protocol.

ANSWERS TO INTEXT QUESTIONS

24.1

1. Genetic engineering or recombinant DNA technology, gene cloning, DNA fingerprinting (any two).
2. A technique of producing many identical copies of a particular gene.
3. A collection of all the genes of any human or genes of any other organisms in various clones of bacteria.

24.2

1. Genetic engineering.
2. Joining of two pieces of DNA belonging to different species.
3. Plasmid is a separate round piece of DNA found in bacteria. It is used to carry desired gene from a particular organism into bacteria.

24.3

1. Transgenic crop like Bt crops reduce the need for use of insecticides which are toxic to humans and other animals.
2. Due to worries of (i) Bt crop evolving resistance (ii) non target species feeding on Bt crops may die (iii) production of super weeds.
3. *Cry* protein produced by Bt crop causes toxicity or poisoning when it enters the pest stomach killing the pest
4. Biopiracy
5. 1970
6. 20 years

24.4

1. Collective term for the full set of genes of an organism.
2. Science of analysis of genes in the DNA of an organism relating each gene to its function.
3. Helps to identifying defective genes so that correction may be possible by gene therapy.
4. Because the counsellor has to advise regarding the possibility of genetic disorder in the next generation.

MODULE - IV
ENVIRONMENT AND HEALTH

25

PRINCIPLES OF ECOLOGY

Earth is the only planet in the solar system that supports life. This is because of the three physical systems on it that is, soil, water and air which provide material essential for life. All the living beings differ from each other but they are all interdependent and interact with each other as also with, their environment directly or indirectly. In this lesson we study the earths own life support system, the organisational levels of living beings and their characteristics.

OBJECTIVE

After completing this lesson, you will be able to:

- *define environment, ecology and biosphere;*
- *list the various components of the environment;*
- *name the biotic and abiotic components of the environment;*
- *mention the various levels of organisation of life.*
- *define terms related to environment or ecology like habitat, niche, population community, an biome.*
- *discuss inter-relationship between plants and animals in an ecosystem;*
- *describe food chain and food web;*
- *trace the path of energy flow through the food chain;*
- *differentiate between food chain and food web;*
- *pinpoint the position of human beings in a food chain;*
- *define biome;*
- *list the various biomes and their characteristics (flora and fauna);*
- *describe the biogeochemical cycles such as Carbon, Phosphorus and water cycles.*

25.1 ENVIRONMENT, ECOLOGY AND BIOSPHERE

25.1.1 Environment

The term environment denotes all the physical, chemical and biotic conditions surrounding and influencing a living organism. Favourable environmental conditions are required to sustain life on earth.

The environment can be divided into two main components : Non Living and Living

1. **Abiotic or Non-living components include** the physical (climatic), edaphic (nature of soil) and chemical. For example temperature, light, pressure, humidity, precipitation, wind, mineral elements of soil and composition of air. Some of these environmental factors serve as **resources** (air, soil and water) while others act as **regulatory factors** (light, temperature and pressure etc).
2. **Biotic or Living components include** All living organisms found in the environment including plants, animals and microorganisms.

25.1.2 Ecology

Ecology is the scientific study of the relationship and interactions between organisms and their environment. The term ecology is derived from a Greek word *Oekologie* where "*oikos*" meaning "household"and "*logos*" means "the study of".

25.1.3 Organisation of Life

Various levels of organization exist in the living systems starting from the molecules such as DNA (genes) to the whole **biosphere**. The **levels of organization** are as follows :

Genes $\rightarrow$ Cell $\rightarrow$ organ $\rightarrow$ organism $\rightarrow$ Species Population $\rightarrow$ Community $\rightarrow$ Ecosystem $\rightarrow$ Biome $\rightarrow$ Biosphere

25.1.4 Levels of biotic organizations show direct impact of the environment

- An organism is a self reproducing system capable of growing and maintaining itself and is directly influenced by the surrounding environment.
- A population is an assemblage of similar organisms belonging to the same species, living together at one place at a given time. A population always lives a specific place known as its *habitat*. Habitat is thus the physical environment in which an organism lives. The environment provides for its needs. For example, the environmental requirement of an elephant would be a forest and not the ocean. Many different species with similar requirements may share a habitat. For example, a single ocean as a habitat may support a whale, a sea-horse, seal, phytoplankton, sea weeds and many other kinds of organisms. Forest, ocean, river etc. are some examples of **'habitat'** which in common language are the

'addresses' of organisms. The features of the habitat can be represented by its structural components (Fig. 1), namely:

1. Space
2. Food
3. Water
4. Cover or Shelter

Earth has four major habitats-(1) Terrestrial (2) Freshwater (3) Estuarine (where rivers meet the ocean) and (4) Oceanic. The human gut is the habitat of a tapeworm and the rotting log, a habitat of a fungus.

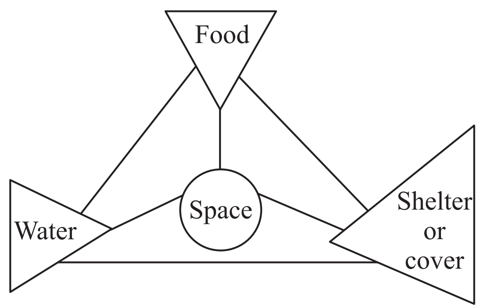


Fig. 25.1: Structural components of a habitat

Niche and Organism

In nature, many species occupy the same habitat but they perform different functions. The functional characteristics of a species in its habitat is referred to as "**niche".** While habitat of a species is like its 'address' (i.e. where it lives), niche can be thought of as its "profession" (i.e. activities and responses specific to the species). The term **niche means the sum of all the activities and relationships of a species by which it uses the resources in its habitat for its survival and reproduction.**

A niche is unique for a species (Fig. 25.2) while many species may share the same habitat. No two species in a habitat can have the same niche. This is because, if two species occupy the same niche they will compete with one another until one is displaced. For example different species of insects may be pests of the same plant but they can co-exist as they feed on different parts of the same plant that is because their niches are different (Fig. 25.3).

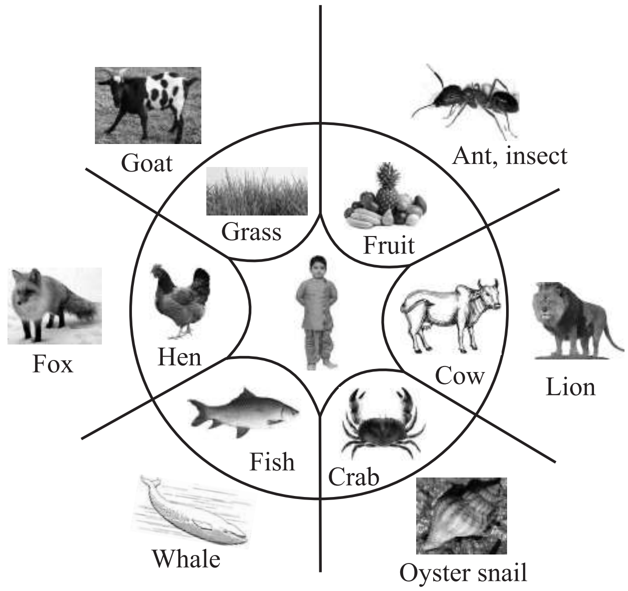


Fig. 25.2: The ecological niche of human being

Another such example is the vegetation of the forest. The forest can support a large number of plant species as they occupy different niches: the tall trees, the short trees, shrubs, bushes and grasses. Their heights vary and they differ in their requirements for sunlight and nutrients and so they can all survive together (Fig. 4)

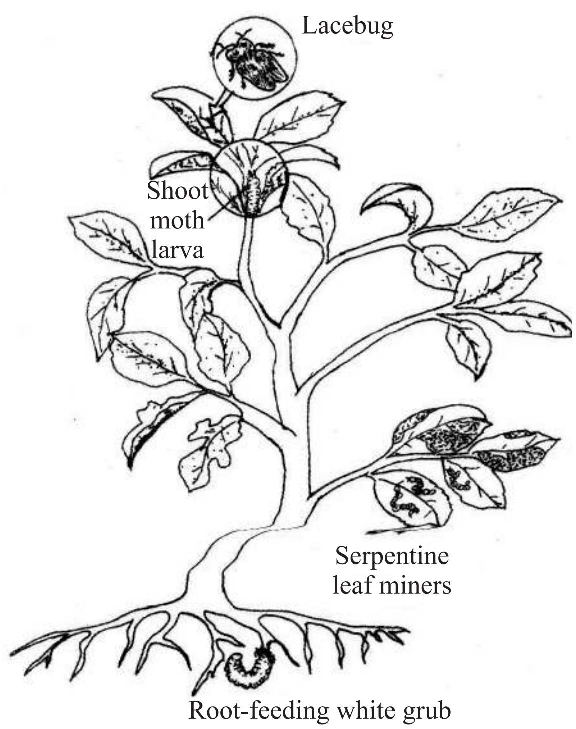


Fig. 25.3: Different species of insects feeding on different parts of the same plant

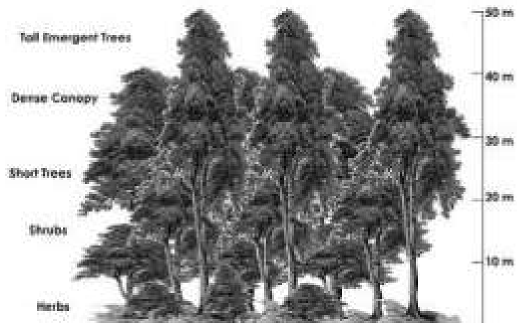


Fig. 25.4: Stratification a Tropical Rain Forest (Forest Ecosystem)

The most important resources available in the niches of animals are food and shelter while in case of plants, they are moisture and nutrients (phosphorus and nitrogen).

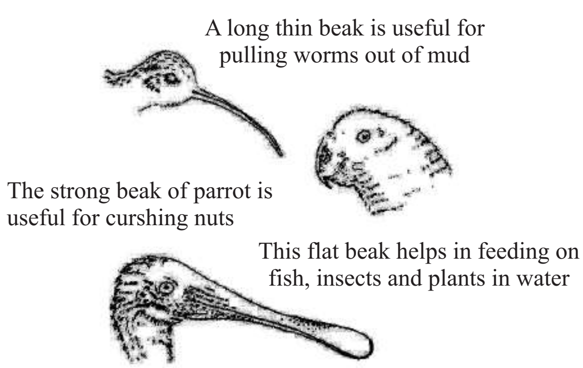
Adaptation

Every organism is suited to live in its particular habitat. You know that coconuts are adapted for growing in water while a camel is adapted for life in the desert. **An adaptation is thus, "the appearance or behaviour or structure or mode of life of an organism that allows it to survive in a particular environment".**

Presence of gills and fins are examples of adaptation of fish to aquatic habitat. In aquatic flowering plants, absence of wood formation and highly reduced root system are adaptations to aquatic environment. Adaptations can be observed in structure or behaviour or physiology of an organism. Adaptations have a genetic basis and have been evolved and perfected through the evolutionary process.

Following are examples of basic adaptations that help animals and plants to survive in their respective environments.

- Shape of bird's beak suited to the kind of food it needs to procure. (Fig. 25.5a)
- The thickness or thinness of fur depends on the elimate in which the animal lives.
- Presence of feathers and wings in birds for movement in air.
- Presence of thorns on leaves and stems for protection, from herbivores (Fig. 25.5b).



(a)

(b)

Fig. 25.5: (a) Adaptation in the types of beaks in birds: The beaks of different birds are adapted for feeding on different kinds of food (b) Plant with thorns for protection

INTEXT QUESTIONS 25.1

1. Name the various levels of organizations.
2. Define the term ecology.
3. What are the three physical systems that support life on earth?
4. Name the major components of the environment.
5. Enumerate the various physical factors of the environment
6. Why is habitat called the address of organisms and its niche 'the profession'? Justify.
7. What do we mean by 'fins are an adaptation of fish to aquatic life'? Explain.

Species

If you bring the sunfish from two different ponds and put them together in one pond, they can interbreed. So both the populations of sunfish belong to one species. *A **species** is defined as a group of organisms which can interbreed and reproduce successfully. These organisms may be separated in space and time into smaller groups called **populations***. For example human populations live in different geographical areas but all belong to the species, *Homo Sapiens*.

25.4 POPULATION

'Population' is defined as a group of freely interbreeding individuals of the same species present in a specific geographical area at a given time.

A population has traits of its own which are different from those of the individuals forming the population. For example (i) An individual is born and dies but a population continues. Population may change in size depending on birth and death rates of the population. (ii) An individual is either female or male, young or old but a population has a sex ratio which means, the ratio of male to female in the population which also has (iii) age structure, which means the various age groups into which the population may be divided.

The **characteristics of any population** depends on the following factors.

(i) density of the population, (ii) natality (birth rate), (iii) mortality (death rate), (iv) dispersal, (v) biotic potential (vi) age distribution (vii) dispersion and (viii) growth form.

Density: The number of individuals per unit area at a given time is termed population density which may vary from time to time and place to place.

For example, you may notice more plant and animal species in the garden during the monsoon season.

Density of a particular organism in a region is determined by selecting random samples from an area of particular dimension (size) called quadrat from that region.

In case of large mobile animals like tigers, leopards, lions, deer etc, the density may be determined by counting individual animals directly or by the pugmarks (foot imprints) left by the animals in a defined area (Fig. 25.6).

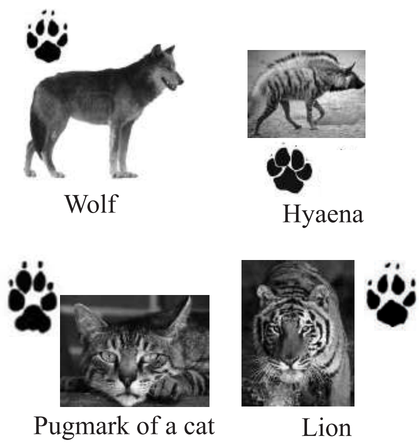


Fig. 25.6: Pugmarks (Foot prints of soft padded feet) of wild animals

Counting of human population is called **census** and is carried out by the Indian government every 10 years. In census however each individual is physically counted.

Birth Rate or Natality: The rate at which new individuals are born and added to a population under given environmental conditions is called natality.

In case of humans, natality or birth rate is usually expressed in terms of births per thousand per year.

Death Rate or Mortality: Loss of individuals from a population due to death under given environmental conditions is called mortality.

Mortality rate in human population may be expressed in terms of number of persons dead per thousand per year.

Dispersal: The movement of individuals of a population out of a region on a permanent basis is termed **emigration**. **Immigration** refers to the movement of individuals into a new area. Dispersal includes both emigration (going away permanently from an area) and immigration (influx of new individuals into the area).

The density of a population thus basically depends on four factors: (i) natality, (ii) mortality, (iii) immigration and (iv) emigration (Fig. 25.7)

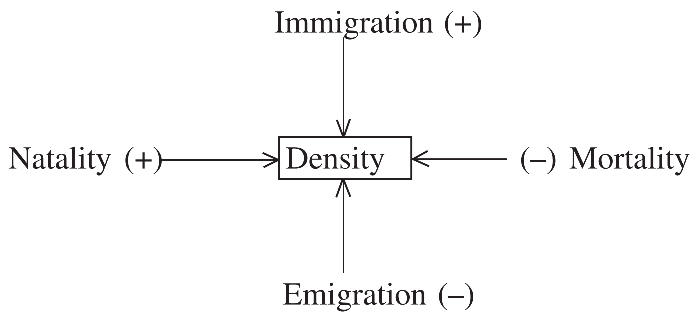


Fig. 25.7: Parameters of population.

Age distribution: Natural populations include individuals of all age groups. **Age distribution refers to the proportion of individuals of different age groups in a population**.The population may be broadly divided into three age groups:

- **pre-reproductive group**: comprising of juvenile individuals or children,
- **reproductive group**: consisting of individuals capable of reproduction ,
- **post-reproductive group**: contains aged individuals who are incapable of reproduction.

A rapidly growing population will usually contain a large proportion of individuals in the reproductive age group; a stationary population (where there is no increase or decrease in population) contains an even distribution of all age groups, and a declining population contains a large proportion of old or individuals of post-reproductive age.

Sex ratio: Sex ratio is an important aspect of population. It refers to the ratio between female and male individuals in a population.

Population Growth

The growth, stability or decline in number of individuals in a population is influenced by its relationship with the environment. Populations have characteristic patterns of growth with time, which is depicted by population growth curves. Two basic forms of population growth curves can be identified:

(i) 'J'shaped growth curve

(ii) 'S' shaped or sigmoid growth curve.

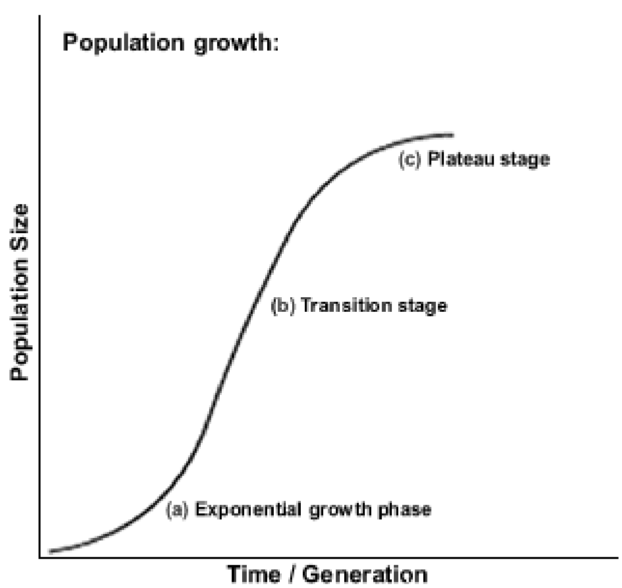


Fig. 25.8

The 'J' shaped growth curve is typical of the species which reproduce rapidly and which are greatly affected by seasonally fluctuating environmental factors such as light, temperature and rainfall. In this type of curve, population density increases rapidly in exponential (geometric) progression (total number doubles at regular intervals of time). **This type of exponential growth occurs in nature when a population has abundant supply of resources**. After reaching a peak there is a sudden crash or decline due to environmental or other factors. Such type of growth may be exhibited by insect populations which show explosive growth during the monsoon season and then abruptly disappear at the end of the season.

S-shaped curve or sigmoid growth curve has a lag phase, growth phase and a stable phase as shown in the figure, when few organisms occupy a hitherto unoccupied area reproduction occurs after some time (lag phase). Natality and mortality remain small. When growth phase begins, rapid increase in size of population occurs as there is plenty of food and no competition. Eventually, food or water or some source (e.g. nutrients in soil for plants) becomes limiting and population enters stable phase (plateau). Natality and mortality then become almost equal.

INTEXT QUESTIONS 25.2

1. A population with equal number of births and deaths will show:
   (a) Acceleration phase of growth (b) Plateau phase
   (c) Exponential growth phase (d) Initial phase of growth
2. When population reaches carrying capacity:
   (a) Mortality rate = Birth rate (b) Mortality rate $>$ Birth rate
   (c) Mortality rate $<$ Birth rate
3. Human population shows:
   (a) S-shaped growth curve (b) J-shaped growth curve
   (c) Z-shaped growth curve

- **Biological community** refers to the populations of different species occupying a common place of living. For example all the living organisms in a pond belong to one community. A biological community along with its nonliving environment of energy and matter makes an **ecosystem** (Fig. 25.9). Ecosystem can range in size from a puddle of water to a stream or a patch of wood to entire forest or desert.

> *The study of groups of organisms in relation to their environment is called* ***synecology****.*

Biosphere

A thin layer on and around the earth which sustains life is called **biosphere**. Life exists in the diverse forms of living organisms. All these living organisms of the biosphere are directly or indirectly dependent on one another as well as on the physical components of the earth. The three physical components of the earth are **atmosphere, lithosphere** and **hydrosphere** (air, land and water).

The **atmosphere** is a gaseous envelope surrounding the earth's surface, It is made up of nitrogen, oxygen, carbon dioxide and many other gases in very small amounts.

Hydrosphere is all the water supply to the earth which exists as liquid, vapour or frozen form of fresh and salt water.

Lithosphere comprises the soil and rock of the earth's crust.

Recently the term ecosphere is being used more commonly. It is used to denote biosphere (living components) along with its three abiotic components –atmosphere, hydrosphere and lithosphere of the earth as one entity (unit).

Ecosphere = Biosphere + Lithosphere + Hydrosphere + Atmosphere)

25.3 ECOSYSTEM

Ecosystem is a self sustaining unit of nature. It is defined as a functionally independent unit (of nature) where living organisms interact among themselves as well as with their physical environment. In nature two major categories of ecosystems exist : **terrestrial** and **aquatic**.

Forests, deserts and grasslands are examples of terrestrial ecosystem.

Ponds, lakes, wet lands and salt water are some example of aquatic ecosystem. Crop lands and aquarium are the example of man made ecosystems.

The interaction between the living organisms and their environment can be studied in a puddle of water or a hole in a tree, which are very small ecosystems or in large ecosystems such a forest, river or ocean. Irrespective of their sizes all ecosystems share many common characteristics. Let us study moderate sized pond ecosystem to understand its structural and functional components.

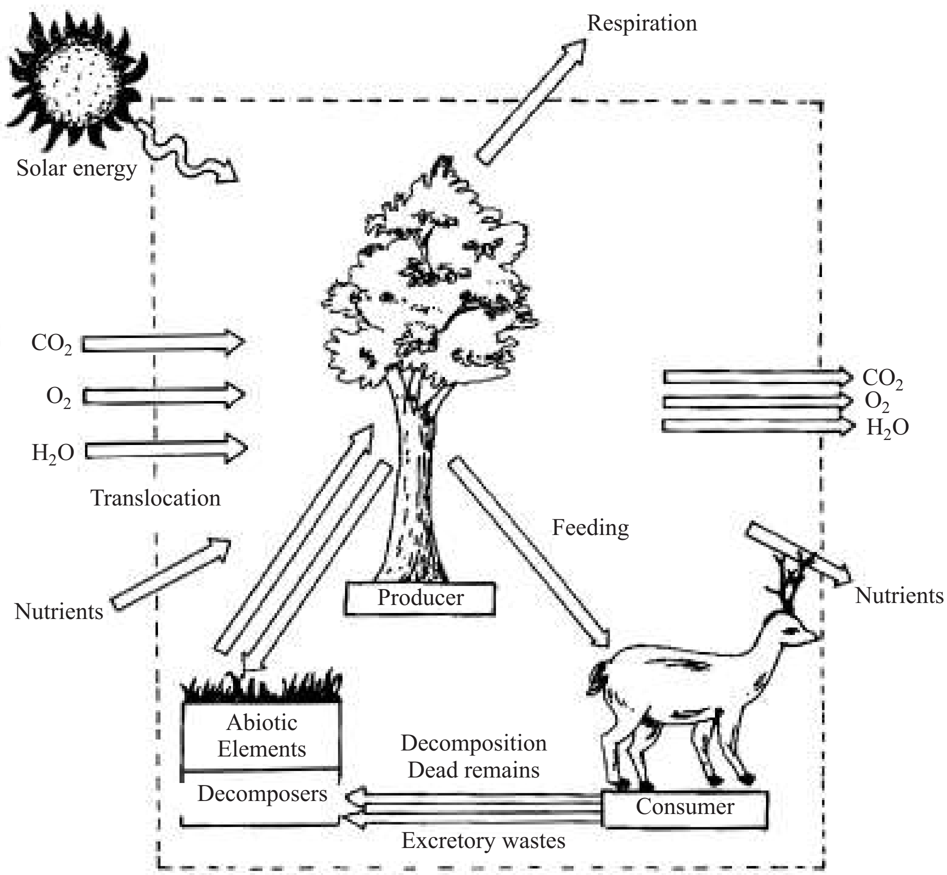


Fig. 25.10: Components of an ecosystem.

In the Fig. 25.2 (pond ecosystem), you can see that it is a shallow body of water. Sun's light can penetrate into it. It has sediment as a substrate at the bottom that is a source of nutrition for living organisms. The living organisms in it are small floating plants, submerged vegetation and rooted plants. There are animals of various sizes ranging from microscopic to large fishes. All these components of the pond ecosystem can be arranged to give it a definite structure.

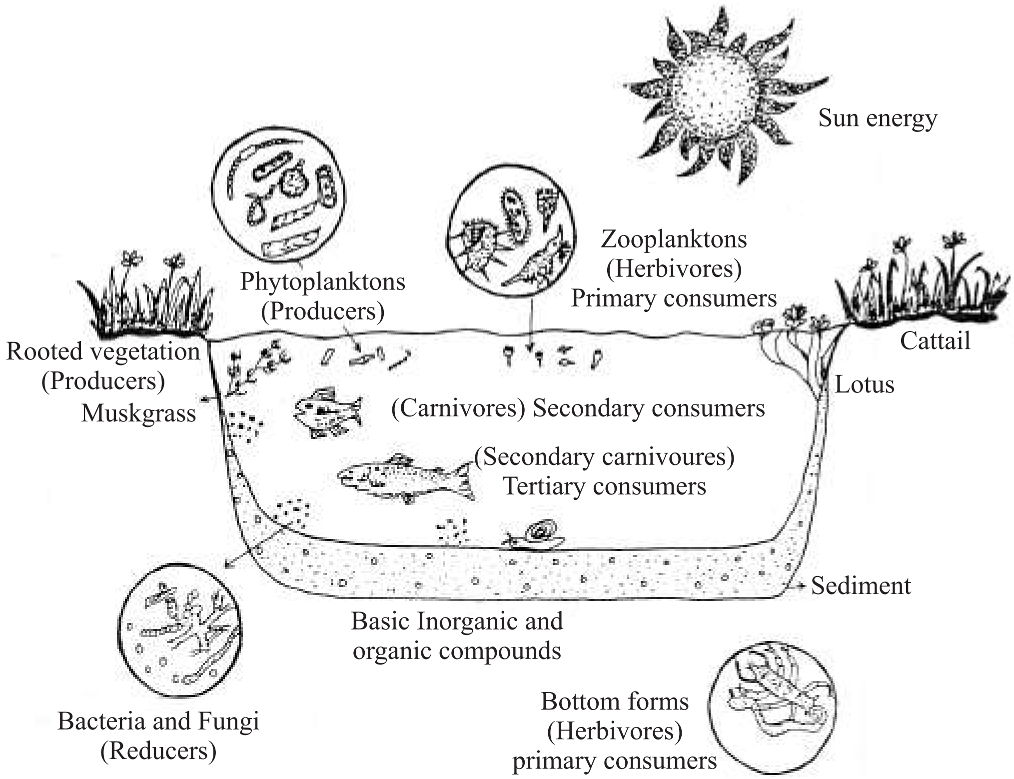


Fig. 25.11: Pond ecosystem

25.3.1 Structure of Pond Ecosystem

Abiotic Components

1. **Physical or climatic regime :** Pond receives solar radiation, which provides it heat and light energy to sustain life.

   (a) **Light :** In case of shallow ponds with clear water sun light can penetrate up to the bottom . In deep ponds penetration of light depends on the transparency of water The amount of dissolved/suspended particles, nutrients and number of animals and plants determine the transparency of water and control the penetration of light in it.

   (b) **Temperature :** Heating effect of solar radiation leads to diurnal (day and night) or seasonal temperature cycles. In the tropical regions there are not much temperature variations. At higher latitudes there are remarkable seasonal temperature variations.

2. **Inorganic substances :** These are water, carbon, nitrogen, phosphorus, calcium and a few other elements like sulphur or phosphorus depending on the location of the pond. O_2 and CO_2 are in the dissolved state in water. All animals and plants depend on water for their food and exchange of gases.

3. **Organic compounds :** The commonly found organic matter in the pond is amino acids and humic acids and the breakdown products of dead animal and plant tissues. They are partly dissolved in water and the remaining are accumulated in sediment.

Biotic Components

1. **Producers or Autotrophs :** They synthesize food for all the heterotrophs of the pond. They are of the following two types.

   (a) Floating plants (b) Rooted plants

   (a) **Floating plants :** They are called **phytoplankton** ("phyto"- plants, "plankton" - floating.) for example, *Spirogyra*, *Ulothrix*, diatoms and *Volvox*.

   (b) **Rooted plants :** These plants occur in concentric layers from periphery to the deeper zones. Some examples of rooted plants are *Typha bulrushes*, *Sagittaria*, *Hydrilla*, *Rupia*, *Chara.*

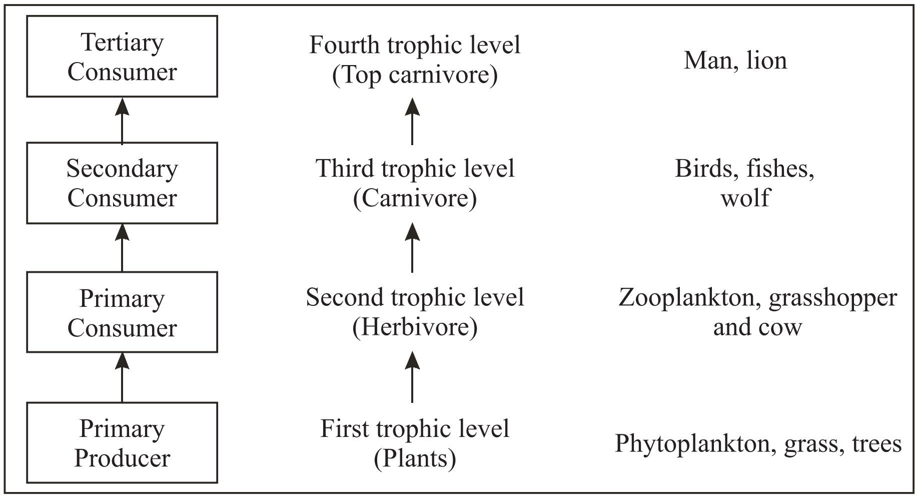
2. **Consumers or Heterotrophs :** Animals, which feed directly on autotrophs (e.g. insect larvae, tadpole, snails) or on other animals (sunfish and bass)

3. **Decomposers :** They are distributed in the whole pond but are most abundant at the bottom of the pond in the sediment e.g. bacteria and many different types of microbes.

25.4 ECOSYSTEM : STRUCTURE AND FUNCTION

You have already learnt that ecosystems are capable of persisting as independent units of nature. In the following part of the lesson you will learn about the structure and functions of ecosystem. Interaction between biotic and abiotic components results in a physical structure characteristic of each type of ecosystem. The important structural features are **species composition** (types of plants and animals) and **stratification** (vertical and horizontal distribution of various species occupying different levels). Another way of looking at the structural components is through food relationships of producers and consumers. Several **trophic levels** exist in the ecosystem. These feeding relationships can be studied as food chain, food web and standing crops. These structural components function as a unit and produce certain functional aspects of ecosystem. Some of these aspects are :

- Productivity, energy flow, nutrient cycle



Diagrammatic representation of trophic levels in an ecosystem

25.4.1 Species Composition

A community is an assemblage of many populations that are living together at the same place and time. For example a tropical forest community consists of trees, vines, herbs and shrubs along with large number of different species of animals. This is known as species composition of tropical forest ecosystem. Each ecosystem has its own species composition depending upon the suitability of its habitat and climate. If you compare animal and plant populations of a forest they are entirely different from those of a grass land. Not only are the types of species different in these two ecosystems but even their total number and biomass varies. A forest ecosystem supports much larger number of species of plants and animals than a grassland. The total number and types of species in a community determine its stability and **ecosystem balance** (ecosystem equilibrium).

25.4.2 Stratification

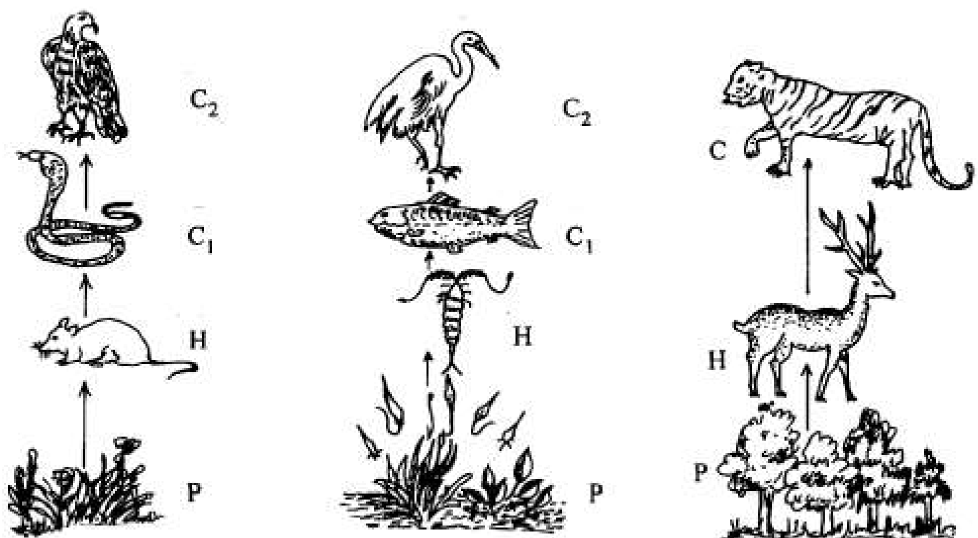
The vertical and horizontal distribution of plants in the ecosystem is called **ecosystem stratification**. You would have observed that the plants are of different heights in forests. Tallest trees make the top canopy. This is followed by short trees and shrubs and then the forest floor is covered with herbs and grasses. Some burrowing animals live underground in their tunnels or on the roots of the plants. Each layer from the tree top to the forest floor has its characteristic fauna and flora. This is termed as vertical stratification of forest ecosystem. On the other hand desert ecosystem shows low discontinuous layers of scant vegetation and animals with some bare patches of soil showing a type of horizontal stratification.

25.4.3 Food Chain

Transfer of food from the plants (producers) through a series of organisms with repeated eating and being eaten is called a food chain e.g.

Grasses	$\rightarrow$ Grasshopper	$\rightarrow$ Frogs	$\rightarrow$ Snakes	$\rightarrow$ Hawk/Eagle
1	2	3	4	5

1. Each step in the food chain is called trophic level. In the above example grasses are first and eagle represents the fifth trophic level.
2. Some more examples of food chain are given in Fig. 25.13.



Grassland
P = Producers

Pond
H = Herbivores

Forest
C = Carnivores

Fig. 25.13: Some examples of food chain.

Three important features that you can note in these chains are :

- Weaker organisms are attacked by the stronger organisms
- Number of organisms is reduced at each higher level but the size of organisms is increases.
- The number of steps in a food chain is limited to 4-5.

A. A food chain consists of the following trophic levels :

(i) **(Producers) Autotrophs :** They produce food for all other organisms of the ecosystem. Autotrophs represent the first trophic level. They are largely green plants they convert inorganic substances by the process of photosynthesis into food (organic molecules) in the presence of sun light. The total rate at which the radiant energy is stored by the process of photosynthesis in the green plants is called Gross Primary Productivity (GPP). This is also known as total photosynthesis. A part of the gross primary productivity is utilized by the plants for their own metabolism, maintenance and reproduction. Energy required for all these functions is produced by the process of respiration. The remaining is stored by them as Net Primary, Productivity (NPP) and is available to the heterotrophs or consumers, (The next trophic level)

$$GPP = NPP + R \quad \text{or} \quad GPP - R = NPP$$

Productivity in the biological system is a continuous process but it is different in different ecosystems.

(ii) **Primary consumers Herbivores** : These are animals which feed directly on the plants. They are first level consumers and therefore they are also known as primary consumers and make the second trophic level in the food chain e.g. grasshopper in the above example. Other examples are insects, birds, rodents and ruminants. Herbivores are capable of converting energy stored in the plant tissue into animal tissue and therefore they are also known as key industry. They can digest high cellulose diet.

(iii) **Secondary consumer Carnivores :** Carnivores are the animals that feed on other animals or its tissues. Therefore they are secondary, tertiary or quaternary level consumers. Frog is secondary level consumers as it feeds on herbivorous grasshopper. Snake is tertiary level consumer since it consumes other carnivore that is frog. Frog, snake, dog, cat and tiger are all carnivores. Generally the size of the carnivore/ increases at each trophic level.

(iv) **Decomposers :** They make up the final trophic level in a food chain. Decomposers are the organisms that feed on dead organic matter called detritus of all the trophic levels and help in recycling the nutrients. Examples of decomposers are bacteria, fungi, mites, millipedes, earthworms, nematodes, slugs, crabs and molluscs.

Special feeding groups (Consumers)

(i) **Scavengers** : These are the animals that feed on the dead plants and animals. e.g. termites and beetles feed on the decaying wood, and many marine invertebrates. Vultures, gulls and hyena are other examples of scavengers.

(ii) **Omnivores :** Omnivores consume both plants and animals as source of their food e.g. human beings. Some of the omnivores like the red fox feeds on berries small rodents as well as on dead animals. Thus it is a herbivore, carnivore and also a scavenger.

(iii) **Parasites :** They live and feed on/in other living organisms called *host*. Parasites not only feed on their host but they also cause lethal or nonlethal disease in it.

B. Position of human beings in the food chain ; Human beings are consumers and may occupy

Primary, secondary or tertiary levels. Vegetarian people are 'primary consumers; when they consume small fish chicken or goat meat they are 'secondary' consumers and when they consume big fishes they are 'tertiary' consumers. Can you explain why big fishes feed upon small fishes and other smaller aquatic animals?

25.4.4 Food Web

In nature the food chains are not isolated sequences but they are interconnected with one another. *A net work of food chains which are interconnected at various trophic levels of the food chain to form a number of feeding connections is called a food web*. In a food web one trophic level may be connected to more than one food chain. A snake can feed on frog or rat or any other small rodent. In the figure given below sunfish consumes zooplanktons as well as bloodworms.

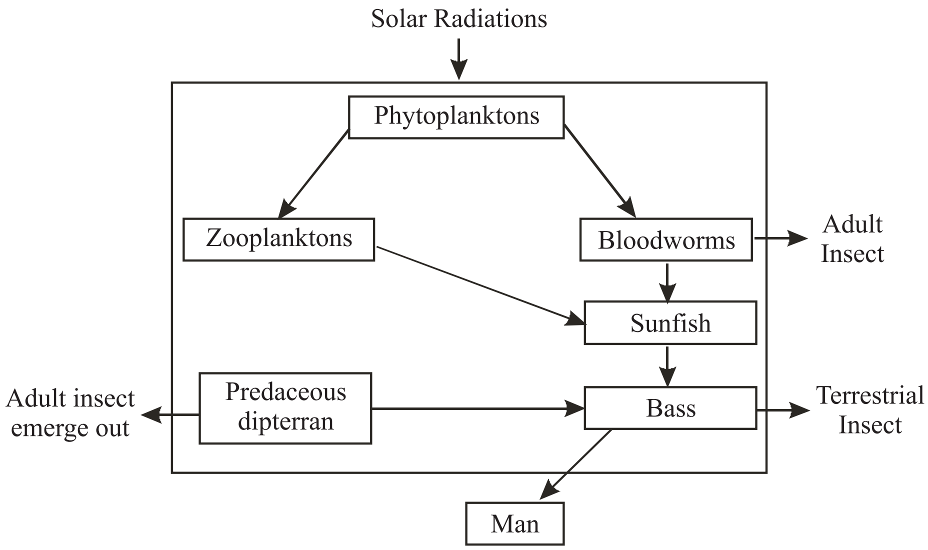


Fig 25.14: Simple food web in a pond ecosystem.(modified from Odum)

INTEXT QUESTIONS 25.3

1. Define an ecosystem.

   ....

2. What are the main components of an ecosystem?

   ....

3. Give reason, why are decomposers necessary in an ecosystem?

   ....

4. What is the role of decomposers in nature?

   ....

5. Why are plants called autotroph and animals called heterotrophs?

   ....

6. Give one example of food chain.

   ....

7. Name the trophic level frog belongs to.

   ....

8 Snake can be both a secondary as well as tertiary consumer Justify.

   ....

25.4.5 Energy flow through an ecosystem

The energy enters into the ecosystem in the form of solar radiation and is converted into food (plant biomass) by the producers. Food stored by the plants and their biomass (matter) is the chemical form of energy. From the producers this chemical form of energy passes through various trophic levels in the food chain. *This process of transfer of energy through various trophic levels of the food chain is known as flow of energy.*

All the functions of ecosystem depends on the flow of energy through it. In figure 25.5, boxes represent the trophic level and the pipes depict the energy flow in and out of each trophic level. The quantity of energy flowing through the successive trophic levels decreases as indicated by the reduced size of the boxes and thickness of pipes in the figure. This is because all the energy entering at each trophic level is not used for production of biomass due to the following two reasons.

- Firstly a part of the energy (not utilized) as and lost as heat.
- Secondly a part of it is used up by the organisms and lost as heat for their own metabolism through the process of respiration.

If herbivores consumes 1000 kcal. of plant energy in the form of food, only 100 kcal. is converted into herbivore tissues, and 10 kcal. into first level carnivore and only 1 kcal into second level carnivore. This is known as 10% law (or ecological rule of thumb) where by only 10% of the energy is transferred to the next higher trophic level.

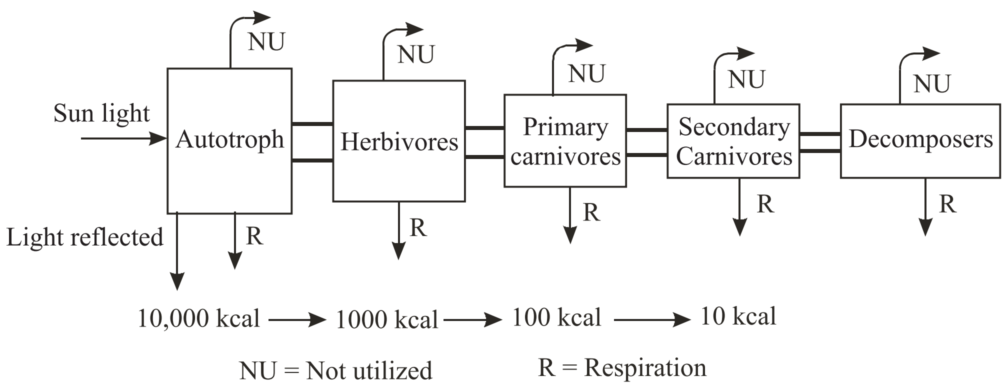


Fig. 25.15: Energy flow in a ecosystem. Boxes indicate the standing crop biomass and pipes indicate the energy flowing

The entire process of energy flow can be summarized in the following four steps:

- The flow of energy in an ecosystem is always linear or one-way.
- At every step in a food chain the energy received by the organism is also used for its own metabolism and maintenance. The left over is passed to next higher trophic level. Thus energy flow decreases with successive trophic levels.
- It follows the ecological thumb rule of 10%.
- The number of steps is limited to four or five in a food chain for the transfer of energy.

25.4.6 Ecological Pyramids

Standing crop is the amount of biomass or energy present in different trophic levels at any given time. This is another important characteristic of an ecosystem. It can be expressed in terms of

- biomass,

Notes

- number or
- total energy fixed at each step at each trophic level.

These three parameters give a definite trophic structure to the ecosystem. It is represented with the producers at the base and the subsequent trophic levels as the tiers. This gives a gradually sloping pyramidal shape.

This graphical representation of the standing crop expressed as number, biomass or energy is called pyramid of number, pyramid of biomass and pyramid of energy respectively. Collectively they are known as ecological pyramids. Some examples

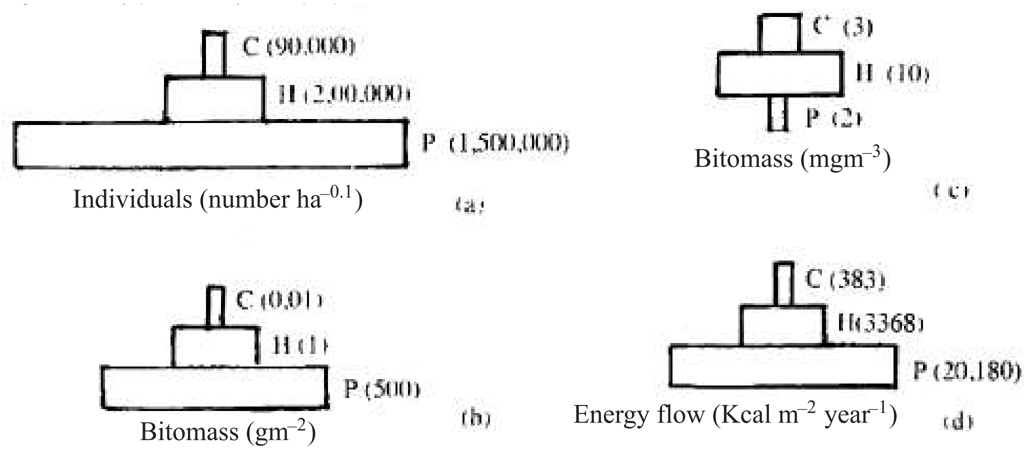


Fig. 25.16: Ecological Pyramids (P = producer; C1 Herbivores; C2 Primary carnivores; C3 secondary carnivores)

INTEXT QUESTIONS 25.4

1. What can be the maximum number of steps in a food chain?

   ....

2. Why is energy flow linear in ecosystem?

   ....

3. Define : (a) biomass (b) pyramid of number.

   ....

4. What is meant by community stratification?

   ....

25.5 TYPES OF ECOSYSTEMS – NATURAL AND HUMAN MODIFIED

You have already learnt about the components, structure and functions of an ecosystem. Now you can easily identify and study a few ecosystems around you. Ecosystems are classified as natural and human modified depending upon whether they are fully dependent on the solar radiation and other natural sources of energy or on fertilizers and fossil fuels. Natural ecosystems are such as ponds, lakes, meadows, marshlands, grasslands, desert and forests. They are our natural resources and provide us food, fuel, fodder and medicines. Human modified ecosystem are made and managed by human beings for their better living. Urban ecosystem, rural ecosystem, agro-ecosystems, aquaculture and spaceship aquarium terrarium, are some examples of the human modified ecosystems.

BIOTIC INTERACTIONS IN ECOSYSTEMS

The biological community in an area or ecosystem is a complex network of interactions.

The interaction that occurs among different individuals of the same species is called **intraspecific interaction** while the interaction among individuals of different species in a community is termed as **interspecific interaction.**

Interactions between organisms belonging to the same trophic level often involve **competition**. Individuals of a population may compete for food, space and mates. For example if a mouse has been eaten by a cat, other cats competing for this resource would have one less mouse to prey on. The snake another predator of the mice would also have fewer mice to eat during the night if the cat has succeeded. Direct competition, though, between the cat and snake is not much as they prey at different times. They also eat a variety of different foods. So competition may be intraspecific as well as interspecific.

Interspecific relationship may be direct and close as between a lion and deer or indirect and remote as between an elephant and a beetle. This is because interactions between two species need not be through direct contact. Due to the connected nature of ecosystems, species may affect each other through intermediaries such as shared resources or common enemies. Specific terms are applied to interspecific interactions depending upon whether the interaction is beneficial, harmful or neutral to individuals of the species. The various possible interactions between two species are given in Table 1

Table 1: Possible biological interactions between two species

S.No.	Type of interaction	Result of one species on the other	Effects of interaction
I.	**Negative Interactions**		
(i)	Amensalism	0	One species is inhibited while the other species is unaffected
(ii)	Predation	+	Predator-prey relationship: one species (predator) benefits while the second species (prey) is harmed and inhibited.

(iii)	Parasitism	+		Beneficial to one species (parasite) and harmful to the other species (host).
(iv)	Competition	0		Adversely affects both species
II.	**Positive Associations**			
(i)	Commensalism	+	0	One species (the commensal benefits, while the other species has neutral Interactions)
(i)	Neutralism	0	0	Neither species affects the other(the host) is neither harmed nor inhibited
(ii)	Mutualism	+	+	Interaction is favourable to both species
III.	**Neutral Interactions**			
(i)	Neutralism	0	0	Neither species affects the other

+ = beneficial; – = harmful; 0 = unaffected neutral

Interactions may be of various kinds

1. **Amensalism**: This is a negative association between two species in which one species harms or restricts the other species without itself being adversely affected or harmed by the presence of the other species. Organisms that secrete antibiotics and the species that get inhibited by the antibiotics, together form example of amensalism. For example the fungus called bread mould or *Pencillium* produces penicillin, an antibiotic, which inhibits the growth of a variety of bacteria. *Pencillium* benefits apparently by having greater availability of food when in the competition bacteria are removed.
2. **Predation**: In this type of interaction, predator captures, kills and eats an animal of another species called the prey. The predator naturally benefits from this relationship; while the prey is harmed. Predators like leopards, tigers and cheetahs use speed, teeth and claws to hunt and kill their prey.
3. **Parasitism**: In this type of interaction, one species is harmed and the other benefits. Parasitism involves small sized organisms or parasites living in or on another living species called the host from which the parasite gets its nourishment and often shelter.

   The parasite is benefited and the host is harmed. Many organisms like, bacteria and viruses are parasites of plants (Fig. 10a) and animals (Fig. 10b). Plants like dodder plant (*Cuscuta*) (Refer again to Fig. 10a) and mistletoe (*Loranthus*) are parasites that live on flowering plants. Tape worm, round worm, malarial parasite, many bacteria, fungi, and viruses are common parasites of humans.

(a) (i)

Dodder, a parasitic plant is eating up a bush

(ii)

Dodder, a leafless parasitic plant, growing on the leaf of a grass tree

(b) *Ascaris lumbricoides* infections. A mass of large round worms from a human infestatic

Fig. 25.16: Parasite-host relationship (a) Plant parasite: Dodder (*Cuscuta)* plant is a parasitic weed that obtains moisture and nourishment by attaching to a green, living plant. (b) Animal parasite: *Ascaris* or round worms are internal parasites found in the human intestine

4. **Competition**: This is an interaction between two populations in which both species are harmed to some extent. Competition occurs when two populations or species, both need a vital resource that is in short supply. The vital resource could be food, water, shelter, nesting site, mates or space. Such competition can be: (i) **interspecific competition**-occurring between individuals of two different species occurring in a habitat and (ii) **intraspecific competition**-occurs between individuals of same species.

   Intraspecific competition occurs between members of the same species and so it is very intense.

5. **Commensalism:** In this relationship one of the species benefits while the other is neither harmed nor benefited. Some species obtain the benefit of shelter or transport from another species. For example sucker fish, remora often attaches to a shark by means of its sucker which is present on the top of its head. This helps remora get protection, a free ride as well as a meal from the left over of the shark's meal.The shark does not however get any benefit nor is it adversely affected by this association. Another example of commensalism is the relationship between trees and epiphytic plants. Epiphytes live on the surface of other plants like ferns, mosses and orchids and use the surface of trees for support and for

obtaining sunlight and moisture.The tree gets no benefit from this relationship nor are they harmed.

6. **Mutualism**: This is a close association between two species in which both the species benefit. For example the sea anemone, a cnidarian gets attached to the shell of hermit crab for benefit of transport and obtaining new food while the anemone provides camouflage and protection by means of its stinging cells to the hermit crab (Fig. 11).

Fig. 25.17: Sea anemone, attached to a shell inhabited by a hermit crab

However, some examples of mutualism are such that the interacting species can no longer live without each other as they depend totally on each other for survival. Such close associations are termed **symbiosis**. An example of such close mutualistic association is that of termite and their intestinal flagellates. Termites can eat wood but have no enzymes to digest it. However, their intestine contains certain flagellate protists (protozoans) that have the necessary enzymes to digest the cellulose of the wood eaten by termites and convert it into sugar. The flagellates use some of this sugar for their own metabolism while enough is left for the termites. Both termite and flagellates cannot survive without each other. Another familiar example of symbiosis is seen in pollination of flowers where flowering plants are cross pollinated by the bees which benefit by getting nectar from the plants. Both cannot survive without the other.

INTEXT QUESTIONS 25.5

1. Fill in the blanks
   (a) The relationship between two organisms where one receives benefits at the cost of other is known as ....
   (b) A group of several species living together with mutual tolerance or adjustment and beneficial interactions in a natural area is known as ....
   (c) A force that acts against maximum population growth is ....
   (d) Association between insect polinated flowers and pollinating insect is an association termed as ....

25.6 BIOMES

When you travel long distances in a train from one part of the country to the other you enjoy watching outside. Your train passes through the thick forests, grasslands deserts, croplands and some times mountains. If you look at the earth from a distance it shows beautiful kaleidoscopic patterns. All these patterns are because of the different types of plants that grow in these regions. The plant growth is determined by physical, edaphic and geographical characteristics of a place. These are the natural broad biotic zones of the biosphere called, **Biomes**. Each biome is characterized by uniform life form of vegetation such as grass, desert plants, deciduous trees or coniferous trees. A Biome is a large ecosystem which is embracing the large land scape, characterised by specific flora and fauna. Biomes can be classified as :

A. **Terrestrial :** These are the biomes found on land e.g,, Tundra, forest, deserts, grasslands

B. **Aquatic.** These are the biomes found in water. These can be :

   (i) Fresh waters, such as pond, lake and river

   (ii) Marine as oceans, shallow sea

25.6.1 Terrestrial Biomes

A. **Forests :** Forests are one of the largest plant formations, densely packed with tall and big trees. Forests are of many different types, depending on the climatic regime in which they are found. Three main forest types are:

   1. Tropical rain forests
   2. Temperate deciduous forests
   3. Boreal or north coniferous forests

1. **Tropical Rain (Evergreen) Forest :** These are in the tropical region of very high rain fall. Such forests are well developed over the western coast of India and North eastern Himalayas and scattered in south east Asia, west Africa and north cost of South America.

   Main characteristics

   - Temperature and light intensity are very high
   - Rain fall is greater than 200 cm. per year.
   - Soil of these regions is rich in humus,
   - The rate of **turnover** of the nutrients is very high leading to high productivity and have highest standing crop and biomass.

- The vegetation includes broad evergreen trees of about 200 feet like bamboos, ferns, shrub etc. Epiphytes and woody wines (liannas) are also abundant. Many tree species show buttresses (swollen stem bases) and leaves with drip tips.

These forests have rich invertebrate and vertebrate fauna. Snails, centipedes, millipedes and many insect species are common near the forest floor. *Rhacophorus* (flying frog), aquatic reptiles, *Chameleon* and many birds are common in these forests. Mammals of these forests are sloths , monkeys, ant eaters, leopards, jungle cats and giant flying squirrels.

2. **Temperate Deciduous Forests :** Trees of deciduous forests shed their leaves in autumn and a new foliage grows in spring. They occur mostly in northwest, central and eastern Europe, eastern north America, north China, Korea, Japan, far eastern Russia and Australia.

Climate : These forests occur in the areas of moderate climatic conditions such as

- Annual rainfall is 75 to 150 cm
- Winter lasts for four to six months.
- Temperature ranges between 10 to 20°C.
- Soil is brown and rich in nutrients.

Flora and fauna : Commonly found trees in this ecosystem are oak, birch heath, chest nuts, pitch pine, cyprus. Invertebrate fauna comprises green oak moth, bark beetle, green flies, aphids, sapflies, moths and butterflies. Prominent grazers are grass eating rodents, deer and bison. Rodents play a very important role in these forests. They feed on the seeds, fruits and leaves of the trees and consume much more food than the large sized grazers. Common carnivores in temperate forests are wild cat, wolves, foxes, tawny owl and sparrow hawk. Black bear, raccoons and skunks are the omnivorous animals of these forests.

3. **Coniferous forests :** Coniferous forests are also known as **Taiga** or **Boreal** forests. They extend as a continuous belt across north America and north Eurasia below the arctic tundra. In the Himalayas, these are distributed above 1700 to 3000 metre altitude. They also occur at high altitude below the alpine tundra and tree line.

Climate : Climate is cold.

- Long and harsh Winters is for more than six months. Mean annual temperature is below 0°C,
- Soil is poor in nutrients and acidic in nature.

Flora and fauna : Coniferous forests are characterized by conifers (gymnosperms). They are evergreen, drought resistant and woody. In many species the canopy is cone shaped. The common species of trees of these forests are Spruce, fir and pine trees. The productivity is much less than other ecosystem. There are very few animals in these forests. The herbivores are red squirrel, deer, goat, mule, moose etc. The carnivores are timber wolves, lynxes, wolverine, weasels mink and bear. Some common birds are cross bill, thrushes, warblers, flycatchers, robin and sparrow.

B. Grasslands

Distribution : Grasslands are dominated by the grasses. They occupy about 20% of the land on earth's surface. They occur in both tropical and temperate regions where environmental conditions are better than that of the desert but rainfall is not enough to support the growth of trees. Grasslands represent an **ecotone** (a zone in between two ecosystems) and are found between forest on one side and deserts on the other. They are subjected to greater variation of temperature, moisture, wind and light intensity of the sun.. Grasslands are known by various names in different parts of the world. For example they are called prairies, steppes, savannas and pampas.

Tropical grasslands are commonly called Savannas. They occur in eastern Africa South America, Australia and India. Savannas form a complex ecosystem as they contain grasses with groups of trees. Soil of grassland is rich and fertile.

Flora and fauna : Grasses are the dominating plants with scattered drought resistant trees in the tropical grasslands. Trees are less than 10 m in height. Animals are much reduced in grasslands because there is no shelter. The large herbivores of this biome are bison, proghorn (North America) wild horse, ass, saiga (Eurasia) , zebra and antelope (South Africa). Carnivores are quite small in number and size They are coyotes, weasels, badgers foxes and ferrets . Hawks, lark sparrows, warblers, Great Indian Bustard and peafowl are the common birds found in grassland. Grasslands are very rich in reptilian and insect fauna.

C. Deserts

Distribution : Deserts are waterless barren regions of the earth. They occupy about one-seventh of the land on earth's surface. Deserts form an extreme condition in sequence of ecosystems with respect to the climatic condition . They occur in two belts that encircle the northern and southern hemispheres roughly centered over the tropics of Cancer and Capricorn. Sahara deserts of Africa are the largest Indian Thar deserts are an extensions of Sahara deserts through Arabian and Persian deserts.

Climate:

- Annual rain fall is very little. It may be less than 25 cm per annum. At some places if it is high it is unevenly distributed.
- Temperature may be very high in subtropical deserts and very low in cold deserts e.g. Ladakh.
- Winds have high velocity.

Flora and fauna : Cacti, *Acacia, Euphorbia* and prickly pears are some of the common desert plants. Desert animals are insects, reptiles, and burrowing rodents. Desert shrew, fox, kangaroo, wood rat, rabbit, armadillo are common mammals in desert. Camel is known as the ship of the desert as it can travel long distances without drinking water for several days.

D. Tundra

The word tundra means a "barren land" since they are found in those regions of the world where environmental conditions are very severe. There are two types of tundra **arctic** and **alpine**.

Distribution

- **Arctic tundra** extend as a continuous belt below the polar ice cap and above the tree line on the northern hemisphere. It occupies the northern fringe of Canada Alaska, European Russia, Siberia and island group of arctic ocean.
- **Alpine tundra** occur at high mountain peaks above the tree line. Since mountains are found at all latitudes therefore alpine tundra show day and night temperature variations

Climate

- A permanently frozen subsoil called **permafrost** is found in the arctic and antarctic tundra. The summer temperature may be around 15°C and in winter it may be as low as –57°C in arctic tundra A very low precipitation of less than 400 mm per year
- A short vegetation period of generally less than 50 days between spring and autumn frost
- Productivity is low

Flora and fauna : Typical vegetation of arctic tundra is cotton grass, sedges, dwarf heath, willows birches,and lichens. Animals of tundra are hurepian reindeer, musk ox, arctic hare, caribous, lemmings and squirrel. Their body is covered with fur for insulation, Insects have short life cycles which are completed during favourable period of the year.

INTEXT QUESTIONS 25.6

1. Define alpine tundra ecosystems.

   ....

2. Give two examples of plants of tundra.

   ....

3. Give two common characteristics of tundra and desert biome.

   ....

4. Names of three main types of forests.

....

5. Where are savannas found?

....

6. What are deciduous trees?

....

25.6.2 Aquatic Biomes

Aquatic ecosystems are constituted by water bodies . Water covers about one third of the earth's surface. Origin of life took place in aquatic ecosystem. Therefore, these ecosystems make an important component of our biosphere. Aquatic ecosystems are classified on the basis of salinity into following two types:

1. Freshwater 2. Marine

1. Fresh Water Ecosystem

Water on land which is continuously cycling and has low salt content is known as fresh water. The study of fresh water ecosystem is known as **limnology**. Fresh waters are classified into two types:

(i) Standing or still water **(Lentic)** e.g. pond, lake, bogs and swamps.

(ii) Running water **(Lotic)** e.g.. springs, mountain brooks, streams and rivers.

Commonly found flora in ponds and lakes include

(i) Phytoplankton (freely floating microscopic plants) such as algae, diatoms

(ii) Floating plant : *Pistia,* water hyacinth, *Lemna, Azolla*

(iii) Rooted plant : Hydrilla, *Vallisnaria*, trapa and water lily.

The common animals in ponds and lakes include

(i) Zooplankton (freely floating microscopic animals) such a protozoans and crustaceans;

(ii) Actively swimming fishes, frogs, tortoises.

(iii) Bottom dwellers like hydra, worms, prawns crabs, snails.

(iv) Birds such as herons, water fowls and ducks occurs in and around water.

Wetlands are between aquatic and terrestrial ecosystem *They show an **edge effect** and form a **ecotone**. Ecotone is a transitional zone between two ecosystems.* Examples of wet zone are swamps, marshes and mangroves.

2. Marine Ecosystem

Distribution : Marine ecosystem covers nearly 71 % of the earth's surface with an average depth of about 4000 m. Fresh water rivers eventually empty into ocean. Salinity of open sea is 3.6 percent and is quite constant Sodium and chlorine make up nearly 86 percent of the sea salt and the rest is due other elements such as sulphur, magnesium, potassium and calcium

Temperature : The range of temperature variation is much less in sea than on the land although near the surface it is considerable from –2°C in antarctic ocean to 27°C in the warmer waters of pacific ocean. In the deeper layers temperature is constant at about 2°C.

Light : The light reaches upto a certain depth only. Deeper regions are permanently dark.

Pressure : Pressure increases with depth in oceans. It is 1 atmosphere near the surface and 1000 atmosphere at greatest depth.

Tides : The gravitational pulls of the sun and the moon cause tides in oceans. At the time of full moon and new moon tides are high and are called **spring tides**. At quarter moon the tides are exceptionally low and are known as low tide or **neap tides**

Flora and fauna : Life in the oceans is limited but its biodiversity is very high as compared to terrestrial ecosystems. Almost every major group of animals occur somewhere or the other in the sea. except for insects and vascular plant which are completely absent in marine ecosystem.

INTEXT QUESTIONS 25.7

1. What are plankton?

   ....

2. Name two phytoplanktons and two bottom dwellers in fresh water ecosystem.

   ....

3. What is the maximum pressure in ocean.

   ....

4. Give an example of (a) wet land (b) lotic type of ecosystem.

   ....

25.7 ECOLOGICAL SUCCESSION

Biotic communities are dynamic in nature and change over a period of time. **The process by which communities of plant and animal species in an area are replaced by another over a period of time is known as ecological succession**. Both the biotic and abiotic components are involved in this change. This change is brought about both by the activities of the communities as well as by the physical environment of that particular area.

The physical environment often influences the nature, direction, rate and optimal limit of changes. During succession both the plant and animal communities undergo change. There are two types of successions (i) Primary succession and (ii) Secondary succession.

Primary Succession

Primary succession takes place over bare or unoccupied areas such as rock outcrop, newly formed deltas and sand dunes, emerging volcano islands and lava flows as well as glacial moraines (muddy area exposed by a retreating glacier) where no community has existed previously. The plants that invade the bare land, where soil is initially absent for the first time are called **pioneer species**. The assemblage of pioneer plants is collectively called **pioneer community**. A pioneer species generally shows high growth rate but short life span (Fig 8)

Primary succession is much more difficult to observe than secondary succession because there are relatively very few places on earth that do not already have communities of organisms. The community that initially inhabits a bare area is called **pioneer community**. The pioneer community after some time gets replaced by another community with a combination of different species. This second community gets replaced by a third community. This process continues sequence-wise in which a community is replaced by another community.

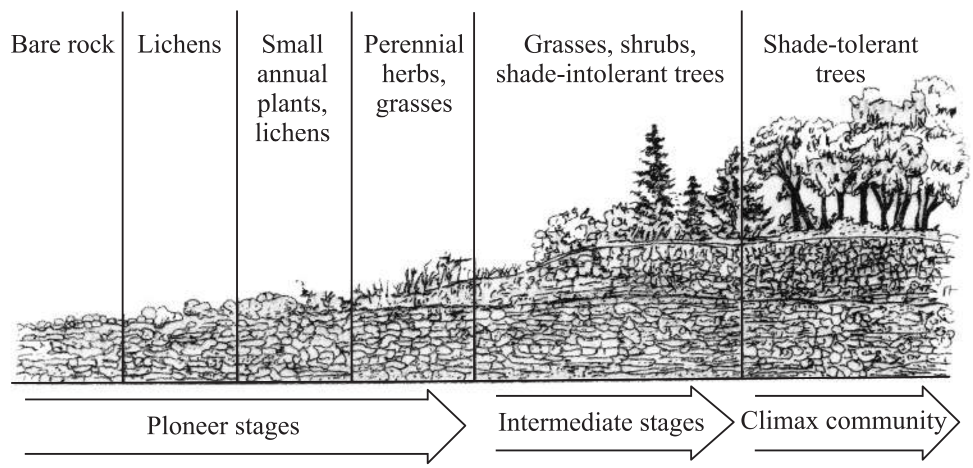
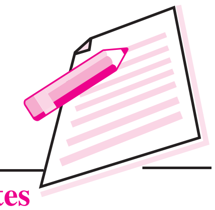


Fig. 25.18: The orderly sequence of primary succession

Each transitional (temporary) community that is formed and replaced during succession is called a stage in succession or a **seral community** (Fig. 9). The terminal (final) stage of succession forms the community which is called **climax community**. A climax community is stable, mature, more complex and long lasting. The entire sequence of communities in a given area, succeeding each other, during the course of succession is termed **sere** (Fig 9).



Notes

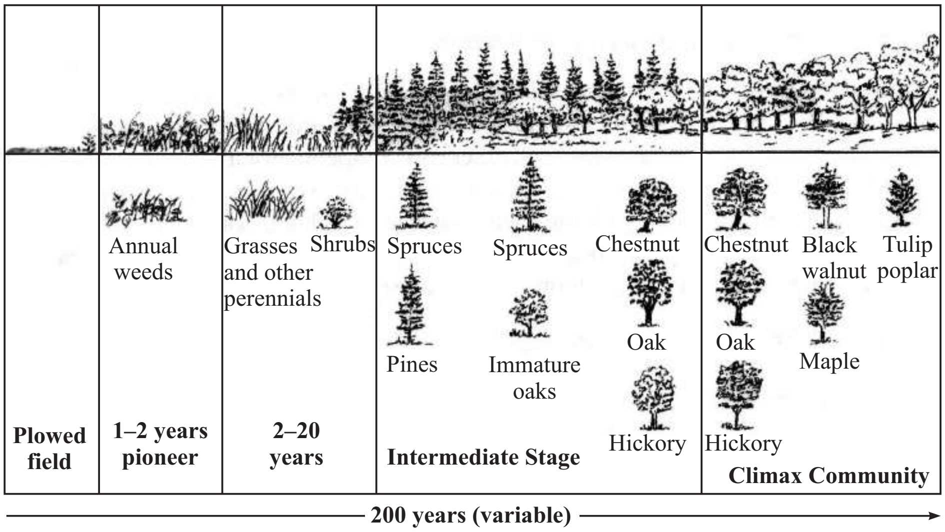


Fig. 25.19: Secondary succession on land

The animals of such a community also exhibit succession which to a great extent is determined by plant succession. However, animals of such successional stages are also influenced by the types of animals that are able to migrate from neighbouring communities. A climax community as long as it is undisturbed, remains relatively stable in dynamic equilibrium with the prevailing climate and habitat factors. Succession that occurs on land where moisture content is low such as on bare rock is known as **xerarch**. Succession that takes place in a water body, like ponds or lake is called **hydrarch**.

Secondary Succession

Secondary succession is the development of a community which forms after the existing natural vegetation that constitutes a community is removed, disturbed or destroyed by a natural event like hurricane or forest fire or by human related events like tilling or harvesting land.

A secondary succession is relatively fast as the soil has the necessary nutrients as well as a large pool of seeds and other dormant stages of organisms.

INTEXT QUESTIONS 25.8

1. What does the following sequence represent:

Blue green algae ⟶ Crustose lichens
↓
shrubs ⟵ mosses ⟵ Foliose lichens
↓
Dicotyledonous trees

(a) Ecological succession

(b) Genetic drift

(c) Phylogenetic trend

(d) A food pyramid

2. A community which starts succession in a habitat is:

(a) Pioneer community

(b) Social community

(c) Biotic community

(d) Ecosere

3. In ecological succession, beginning from pioneer and ending in climax community, the biomass shall

(a) decrease

(b) increase and then decrease

(c) decrease and then increase

(d) Increase continuously

25.7 BIOGEOCHEMICAL CYCLES

You have already learnt that living organisms required several chemical elements for their life processes. There may be used as part of their structural component or as parts of enzymes which influence various life processes unlike energy which flows unidirectionally, nutrients are continuously exchanged between the organisms and their physical environment.

("Bio" - living, "Geo" - rock, "Chemical" - element). The cycling of the nutrients in the biosphere is called **biogeochemical or nutrient cycle**. It involves movement of nutrient elements through the various components of an ecosystem. There are more than 40 elements required for the various life processes by plants and animals. These elements are continuously cycling in the ecosystem through the biogeochemical cycles and the planet earth has no input of these nutrients. The nutrients (matter) from the dead remains of organisms are recovered and made available to the producers by decomposers. Thus the nutrients are never lost from the ecosystems.

A. Carbon cycle

Atmospheric carbon dioxide is the source of all carbon in both living organisms as well as in the fossils (used as fossil fuel). It is highly soluble in water. Oceans also contain large quantities of dissolved carbon dioxide and bicarbonates.

The carbon cycle Fig. 25.17 comprises the following processes

Photosynthesis

Terrestrial and aquatic plants utilize CO_2 for photosynthesis. Through this process the inorganic form of carbon is converted into organic matter in the presence of sunlight and chlorophyll. The carbon dioxide is thus fixed and assimilated by plants. It is partly used by them for their own life processes and the rest is stored as their biomass which is available to the heterotrophs as food.

Respiration

Respiration is a metabolic process reverse of photosynthesis in which food is oxidized to liberate energy (to perform the various life processes) and carbon dioxide and water. Thus the carbon dioxide of the atmosphere is recovered through this process.

Decomposition

After the death of the organisms the decomposers break down the remaining dead organic matter and release the left over carbon back into the atmosphere.

Combustion

Fossil fuel such as crude oil, coal, natural gas or heavy oils on burning releases carbon dioxide and carbon monoxide into the atmosphere. Forests make a large amount of fossil fuel. *Fossil fuel is product of complete or partial decomposition of plants and animals as a result of exposure to heat and pressure in the earth's crust over millions of years.*

Forests also act like carbon reservoirs as carbon fixed by them cycles very slowly due to their long life. They release CO_2 by forest fires.

Impact of human activities

Carbon dioxide is continuously increasing in the atmosphere due to human activities such as industrialization, urbanization and increased use of automobiles. This increase in atmospheric CO_2 is bading to green house effect and global warming.

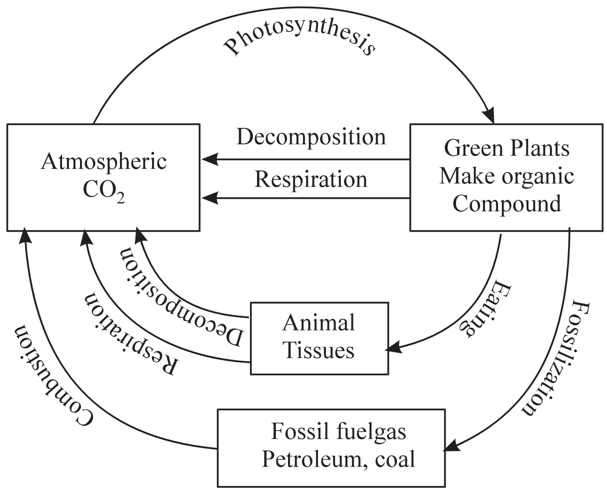


Fig. 25.18: Carbon cycle

(Arrows indicate the processes of the carbon cycle and compartments are the sites of these processes or the store houses of carbon in the reservoir pool and ecosystem)

B. Water cycle

This is also known as hydrologic cycle. You have already studied that earth is a watery planet of the solar system but a very small fraction of this is available to animals and plants. Water is not evenly distributed throughout the surface of the earth. Major percentage of the total water on the earth is chemically bound to rocks and does not cycle. Out of the remaining, nearly 97.3% is in the oceans and 2.1% exists as polar ice caps. Thus only 0.6% is present as fresh water in, the form of atmospheric water vapors, ground and soil water. The ice caps and the water deep in the oceans form the reservoir.

Solar radiation and earth's gravitational pull are the main driving forces of water cycle.

Evaporation, condensation and precipitation are the main processes involved in water cycle these processes alternate with each other

Water from oceans, lakes, ponds, rivers, streams and soil surface evaporates by sun's heat energy. Plants also transpire huge amounts of water through their leaves. Water remains in the vapour state in air and forms clouds, which drift with the wind. Clouds meet with the cold air in the mountainous regions above the forests and condense to form rain, which falls due to gravity.

Evaluation from Oceans, Earth and Leaf Surface

↓

Formation of Clouds

↓

Precipitation

↓

Surface Run off and Accumulation as Ground water

↓ Streams and Rivers | ↓ Run off into ocean

Streams and Rivers → Plants

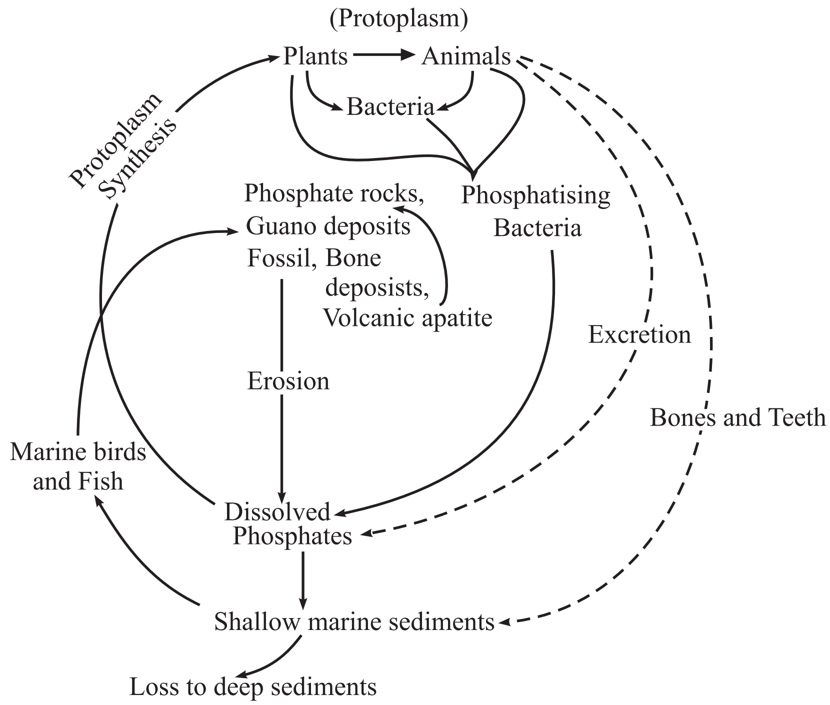
Plants ↙ Transpiration ↘ Evaporation

Fig. 25.8 Water cycle

On an average 84% of the water is lost from the surface of the oceans by evaporation. While 77% is gained by it from precipitation. The remaining 7% of the ocean evaporation is balanced by water run off through the rivers from the land.

C Phosphorus Cycle

We all know that phosphorus is a necessary and important constituent of the protoplasm in the living organisms. The reservoirs of phosphorus are the rocks or other deposits that have been formed in the past geological ages. The erosion of these deposits release phosphates in the ecosystem. However, much of it escapes into the sea where part of it is lost to the deep sediments and some of it deposited in the shallow marine sediments. Plants take up inorganic phosphate as orthophosphate ions. Animals (consumers) that feed on these plants in turn take up phosphate from them. After the death of the plants and animals, the decomposers act on them and the phosphate is returned in the ecosystem in the dissolved form. The excreta of the animals also return some phosphorus to the cycle. Bones and teeth of animals are resistant to weathering and this accounts for some loss of phosphorus. Sea birds play an important role in bringing back phosphorus to the cycle through their guano deposits. Marine fishes also return some of the phosphorus to the cycle. A study of phosphate cycle reveals that the return of phosphate to the cycle is inadequate to compensate the loss. It is human beings who have hastened the rate of loss of phosphorus.



PHOSPHORUS CYCLE

Fig. 25.9 Phosphorus Cycle

INTEXT QUESTIONS 25.9

1. Define nutrient cycle.

   ....

2. Where are the bulk of nutrient stored in an ecosystem?

   ....

3. Name the nutrient cycle where atmosphere acts as the main reservoir.

   ....

4. List any two human activities that have led to increase in atmospheric CO_2.

   ....

5. Name the reservoirs for water cycle.

   ....

6. How do humans affect the phosphorus cycle?

   ....

7. How do the sea birds contribute to the phosphorus cycle?

   ....

Notes

WHAT YOU HAVE LEARNT

- Earth is the only planet to support life. Earth provides soil, water and air to support it.
- Environment is defined as the physical, chemical and biotic conditions that surround and influence on living organisms.
- The abiotic components of environment are temperature, light, humidity, precipitation, wind minerals and the composition of air.
- Biotic components include plants, animals and microorganisms.
- Ecology is defined as the study of relationship between organisms and their environment. Ecology deals with various form of interaction between the organisms and their environment.
- The levels of organisation in the living system starting from genes to community.
- The three physical components of earth are atmosphere, lithosphere and hydrosphere.
- Ecosystem is defined as functionally independent unit of nature where living organisms interact among themselves as well as with their physical environment.
- Terrestrial and aquatic ecosystems are the two categories of natural ecosystems. Croplands and aquarium are the examples of artificial ecosystem.
- Light, temperature, inorganic and organic compounds constitute the abiotic components of ecosystem whereas produces consumers and decomposers are its biotic components.
- These biotic components of ecosystem interact with each other to give a physical character. These represent structural features of an ecosystem to an ecosystem.
- The important structural features of an ecosystem may be represented by its species composition, stratification, food relationship (trophic level food chain an food web).
- The structural components interact in a unit and produce certain functional aspects of an ecosystem such as productivity, energy flow and nutrient cycle etc.
- Humans occupy both primary and secondary levels of consumers.
- Transfer of food from the plants (producers) through a series of organisms with repeated eating and being eaten is called food chain.
- A network of a connected food chains interrelated form a food web.

- The process of transfer of energy through various trophic levels of the food chain is known as flow of energy.
- The quantity of energy flowing through the successive trophic level decreases. This is because a part of the energy is lost as heat and a part of energy used by the organism for its metabolism.
- Only 10% of the energy that enters the trophic level is transferred to the next trophic level. This is known 10% law. The flow of energy in an ecosystem is always linear.
- The number of trophic level in a food chain is limited in number (4 or 5).
- The graphical representation of standing crop expressed as number biomass or energy is called pyramid of number. Pyramid of biomass and pyramid of energy respectively. These are collectively known as ecological pyramid.
- A biome is a large ecosystem which is embracing the large landscape. Each biome is characterised by a specific flora and fauna.
- The cycling of the nutrients in the biosphere is called biogeochemical or nutrient cycle. Carbon cycle and water cycle are two such example.
- Photosynthesis, respiration, decomposition and combustion are the important processes in carbon cycle.
- Evaporation, condensation and precipitation are the important processes in water cycle.

TERMINAL EXERCISES

1. What are the three physical life support systems on the planet earth?
2. Name the various biotic and abiotic components of the environment
3. Give differences between natural and human modified ecosystem
4. Why is the number of trophic levels restricted to four or five in a food chain?
5. Give only two differences between fresh water and marine biome.
6. What will happen if all the floating animals are removed from a lake ecosytem?
7. What are the benefits of natural ecosystems?
8. Give two differences between energy flow and biogeochemical cycle in an ecosystem.

ANSWERS TO INTEXT QUESTIONS

25.1 1. Ernst haeckel
2. Genes → Cell → Organ → Organism → Population → Community
3. Study of animals and plants in relation to their habit and habitat.
4. Atmosphere, lithosphere and hydrosphere

25.2 1. (i) Abiotic (ii) Biotic

2. light, temperature, humidity, precipitation, pressure and soil profile

3. Helps in recycling of nutrients in the environment.

4. Plants are capable of capturing solar energy and transforming it into food energy. Thus they produce their own food. Animals depend upon plants or other animals for food as they cannot produce their own food.

25.3 1. Ecosystem is a unit to study ecology/functionally independent unit to stud. The interrelation between biotic and abiotic components.

2. Main components

Biotic	Abiotic
(Producers)	light
Consumers	Temperature
Decomposers	Inorganic substances
organic compounds	

3. to breakdown products of dead animals and plants tissue.

25.4 1. Grass → Grasshopper → Frog → Snake → Hawk/eagle

2. Secondary level consumer

3. Snake can feed on a rat and then it is a secondary consumer. It can also feed on a frog and then it is a tertiary consumer.

25.5 1. Upto five (5)

2. Energy from solar radiation is fixed in the form of food by the producer. This energy is passed on to the consumers of different trophic level. At each trophic level energy is used by the member for metabolism and only left over energy is passed on each trophic level (10%).

3. See text

4. Vertical and horizontal distribution of plants in the ecosystem.

25.6 1. Its an ecosystem that occurs high mountain peak above the tree line. Environmental conditions are very severe and show day and night temperature variation.

2. Cotton grass, sedges, dwarf leath, willows, birches and lichens (any two).

3. 1. both of them have very harsh climatic conditions.

2. Scarce vegetation.

4. 1. Tropical rain forest temperature.
   2. Deciduous boreal or north.
   3. Coniferous rain forest.
5. Eastern Africa, South America, Australia and India (any two).
6. Trees which shed their leaves in autumn and grow new foliage during spring.

25.7
1. Free floating microscopic organisms
2. diatoms, algae, prawn, crabs, snail (any two)
3. 1000 atmosphere
4. (a) swamps, marshes and mangroves (any one)
   (b) streams, rivers, springs (any one)

25.8
1. Movement of nutrient elements through the various components of an ecosystem is called nutrient cycle.
2. In the Reservoirs pool
3. Gaseous cycle
4. Industrialization, urbanization, increased used of automobiles (any two)
5. Polar ice caps and water present deep in the oceans.

26

CONSERVATION AND USE OF NATURAL RESOURCES

Nature provides us with the basic needs for our survival such as food, shelter, clothes, etc. We use air, water, soil, minerals, coal, petroleum, animals, plants etc. in our daily life ? But do you ever think, how long these precious materials of nature will last ? The growing population, rapid industrialisation and– urbanisation have created heavy demand on natural resources. This lesson deals with means of conservation of natural resources through prevention of resource ever exploitation and sustainable development.

OBJECTIVES

After completing this lesson, you will be able to:

- *explain the term natural resources;*
- *familiarise with the traditions practised in India for conservation of nature;*
- *describe the reasons for degradation of natural resources and suggest measures to prevent these;*
- *define biodiversity and describe the need to conserve biodiversity;*
- *list the various endangered species of animals and plants;*
- *state the various environmental laws passed to conserve the natural resources;*
- *explain sustainable development and justify its need; and*
- *describe the various conventional as well as non-conventional sources of energy.*

26.1 NATURAL RESOURCES

The term "natural resource" means any thing that we use from our environment to achieve our objective. For example, we require bricks, cement, iron, wood etc. to construct a building. All these items are called resources for construction of building. **A resource can be defined as 'any natural or artificial substance, energy or organism, which is used by human being for its welfare.** These resources can be two types:

(a) Natural resources

(b) Artificial resources.

All that nature has provided such as soil, air, water, minerals, coal, sunshine (sunlight), animals and plants, etc., are known as **natural resources**. The resources, which have been developed by human beings during the growth of civilization, are called **artificial resources**. For example, biogas, thermal electricity, plastics. These man-made resources are generally derived from some other natural resources. For example, plastics from the natural resource, petroleum.

26.1.1 Classification of Natural Resources

The air we breathe and the light we get from the sun are available in unlimited quantity. But what about coal, forest, and petroleum? The stock of these resources is limited and is depleting day by day.

- Resources
  - Natural (e.g. coal)
    - Exhaustible (Petroleum)
      - Renewable (e.g. wind, water, forests)
      - Non-renewable (e.g. coal, petroleum, iron, biological species)
    - Inexhaustible (e.g. solar energy, wind, rainfall, tidal energy)
  - Artificial (e.g. electricity)

- **Inexhaustible Resources**

The resources which cannot be exhausted by human consumption are called **inexhaustible resources.** These include energy sources like solar radiation, wind power, water power (flowing streams) and tidal power, and substances like sand, clay, air, water in oceans, etc.

- **Exhaustible Resources**

On the other hand, there are some resources, which are available in limited quantities and are going to be exhausted as a result of continuous use. These are called **exhaustible resources**. For example, the stock of coal in the earth is limited and one day there will be no more coal available for our use.

- **Renewable Resources**

Some of the exhaustible resources are naturally regenerated after consumption and are known as **renewable resources.** e.g. Forest trees and plants that make a forest may be destroyed but new ones gow in their place. But if forest is totally cut down to get land for constructioni of buildings, it is lost forever. Some other examples are fresh water, fertile soil, forest (yielding wood and other products), vegetation, wildlife, etc.

- **Non-renewable Resources**

The resources, which cannot be replaced after the use, are known as **non-renewable Resources.** These include minerals (copper, iron etc.) fossil fuels (coal, oil etc.). Even wildlife species (rare plants and animals) belong to this category.

INTEXT QUESTIONS 26.1

1. Given below are certain wrong statements. Identify the mistake and write the correct statement below each.
   (i) Plastic is a natural resource.
   ....
   (ii) Forest is an exhaustible non-renewable resource.
   ....
   (iii) The exhaustible resources, which are not replaced after consumption are known as renewable resources.
   ....
2. Classify the following under the three respective categories of natural resources: Air, iron, sand, petroleum, wind, clay, fish, forest, gold, pearls.

Inexhaustible	**Renewable**	**Non- renewable**
....	....	....
....	....	....

26.2 CONSERVATION OF NATURAL RESOURCES

Consumption of natural resources is increasing with growing population. With the increasing industrialisation and urbanisation, we need to conserve natural resources for thier destruction will also upset the ecological balance.

Conservation is the proper management of a natural resource to prevent its exploitation, destruction or degradation.

Conservation is the sum total of activities, which can derive benefits from natural resources but at the same time prevent excessive use leading to destruction or degradation.

26.2.1. Need for Conservation of Natural Resources

We know that nature provides us with all our basic needs but we tend to over exploit. If we go on exploiting nature, there will be no more resources available in future. Hence there is an urgent need to conserve nature for the following reasons. Some of the needs are :

- to maintain ecological balance for supporting life.
- to preserve different kinds of species (biodiversity).
- to make the resources available for present and future generations.
- to ensure survival of human race.

26.2.2. Coservation of Natural Resources and Traditions of India

The need for conservation of natural resources was felt by our predecessors and in India, there was a tradition of respecting and preserving nature and natural resources. Natural resources were conserved in the form of sacred groves/forests, sacred pools and lakes, sacred species etc e.g. the river ganges. In our country the conservaton of natural forests is known from the time of Lord Ashoka. Sacred forests are forest patches of different dimensions dedicated by the tribals to their deities and ancestral spirits. Cutting down trees, hunting and other human interferences were strictly prohibited in these forests. This practice is widespread particularly in peninsular, central and eastern India and has resulted in the protection of a large number of plants and animals. Similarly, several water bodies, e.g., Khecheopalri lake in Sikkim was declared sacred by people, thus, protecting aquatic flora and fauna. **Worshipping** certain plants like banyan, peepal, tulsi etc. has not only preserved them but also encouraged their plantation. History recalls numerous instances where people have laid down their lives for protecting trees.

Recent Chipko movement in India is one of the best examples. This movement was started by women in Gopeshwar village in Garhwal in the Himalayas. They stopped the felling of trees by hugging them when the lumbermen arrived to cut them. This saved about 12000 square kilometers of sensitive water catchment area. Similar movements also occurred in some other parts of the country.

INTEXT QUESTIONS 26.2

1. Why should we conserve natural resources? State any two reasons.

   (i) ....

   (ii) ....

2. Given below are certain incomplete words. Complete them by taking clues from the statement given below for each. Each blank space represents one letter only.

   (i) __ __ __ p k __

   (A movement started by women to stop the felling of trees by hugging them)

   (ii) T__ __ __ i

   (A sacred plant worshipped in India)

   (iii) Kh __ ch __ __ pa__ __ i

   (A lake in Sikkim that was declared sacred by the people)

26.3 SOIL

Soil is a very important natural resource and an abiotic component of the environment. Soil is the uppermost layer of earth's crust, which supports growth of plants. It is a complex mixture of (i) mineral particles (formed from rocks), (ii) humus (organic material formed from decaying plant remains), (iii) mineral salts, (iv) water, (v) air, and (vi) living organisms (larger ones like earthworms and insects and microorganisms like the bacteria and fungi).

> **Humus**
>
> A brown or black organic substance consisting of partially or wholly decayed vegetable or animal matter that provides nutrients for plants and increases the ability of soil to retain water.

Soil is both a renewable as well as non-renewable resource.

- Soil is renewable because its productivity can be maintained with fertilizers and manures rich in humus.
- If the soil has been removed from a certain place by erosion, it is practically non-renewable because formation of new soil may take hundreds and thousands of years.

26.3.1. Soil Erosion

Erosion literally means "to wear away". You might have noticed that in summer, when wind blows it carries away sand and soil particles. Similarly flowing water removes some amount of soil along with it. **This removal of top layers of soil by wind and water is called soil erosion.** The top layers of soil contain humus and mineral salts, which are vital for the growth of plants. Thus, erosion causes a significant loss of humus and nutrients, and decreases the fertility of soil.

26.4.2. Causes of soil Erosion

There are several causes of soil erosion.

(a) Natural causes; and

(b) Anthropogenic causes (human generated causes)

(a) Natural Causes of Soil Erosion

Erosion of soil takes places due to the effect of natural agents like wind and water. High velocity winds over lands, without vegetation, carry away the loose top soil. Similarly in areas with no or very little vegetation, pouring raindrops carry away the soil.

(b) Anthropogenic Causes of Soil Erosion

Besides the natural agents, there are some human activities, which cause soil erosion. Let us know about them.

1. **Deforestation:** If the forests are cut down for timber, or for farming purposes, or construction then the soil is no longer protected from the effect of falling rains. Consequently, the top soil is washed away into the rivers and oceans.

2. **Poor farming methods:** Improper tillage and failure to replace humus after successive crops and burning the stubble. The short, stiff stalks of grain or hay remaining on a field after harvesting of weeds reduce the water-holding capacity of the soil. So the soil becomes dry and can be blown away as dust.
3. **Overgrazing:** Overgrazing by flocks of cattle, buffaloes, goats and sheep leave very little plant-cover on the soil. Their hooves make the soil dry and soil can be blown away easily.

26.4.3 Conservation of Soil

Soil conservation means checking soil erosion and improving soil fertility by adopting various methods.

1. **Maintenance of soil fertility:** The fertility can be maintained by adding manure and fertilizers regularly as well as by rotation of crop.
2. **Control on grazing:** Grazing should be allowed only on specified areas.
3. **Reforestation:** Planting of trees and vegetation reduces soil erosion.
4. **Terracing:** Dividing a slope into several flat fields to control rapid run of water. It is practised mostly in hilly areas.
5. **Contour ploughing:** Ploughing at right angles to the slope allows the furrows to trap water and check soil erosion by rain water.

INTEXT QUESTIONS 26.3

1. How do the following cause soil erosion?

   Wind : ____________________

   Overgrazing : ____________________

   Water : ____________________

2. Match the items of column A with those of Column B.

Column-A	Column-B
(i) Terracing	(a) Decayed vegetable or animal matter
(ii) Erosion	(b) Cutting down forests
(iii) Deforestation	(c) Practised in hilly areas
(iv) Humus	(d) To wear away

26.4 WATER – A PRECIOUS RESOURCE

Water is essential for survival of all living organisms. It is the most important component of all life forms and necessary for sustaining life. Water also regulates climate, generates electricity and is also useful in agriculture and industries.

About 97% of the water on earth is saline in nature, found in seas and oceans. The remaining 3% is fresh water, most of which is stored in ice caps and glaciers, and just about 0.36% is distributed in lakes, rivers, ponds, etc. as 'fresh water'.

Sea water supports marine life and contributes to the production of fish and sea foods and several other commercial products (iodine, agar, coral, pearls, etc.). Fresh water is needed by humans for their personal use (drinking, cleaning, sewage disposal), It is also used by other animals, in agriculture, and in industries. Fresh water is a renewable resource as it is continuously being produced through hydrological cycle (evaporation, condensation and precipitation). A from lesson 24.

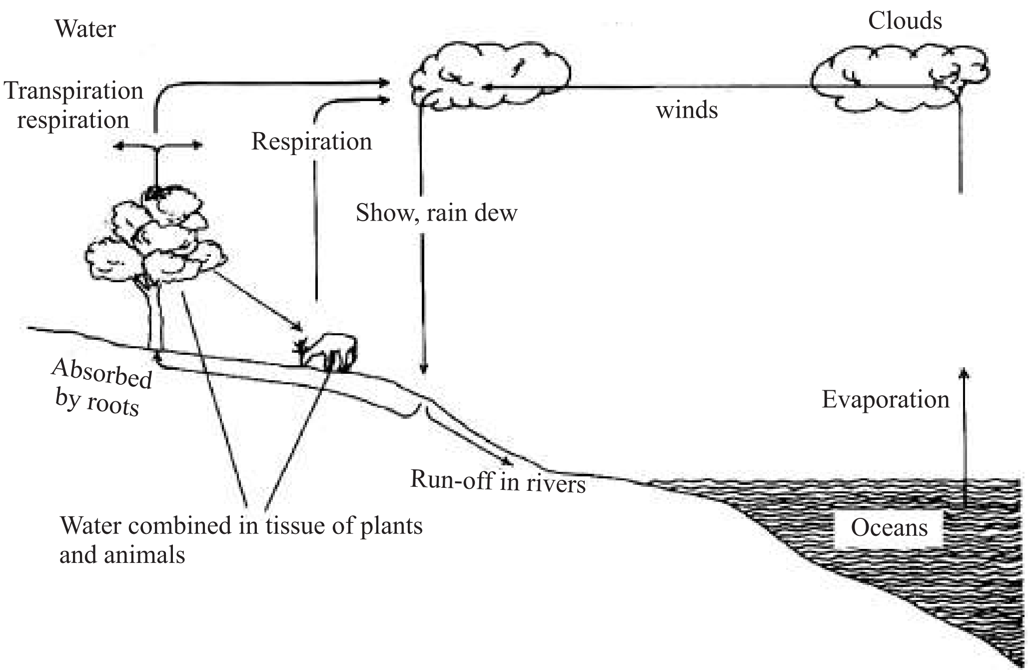


Fig. 26.1 Hydrological cycle

26.4.1.Degradation of Water

With increase in population and industrial growth, water is being degraded day by day. The main reasons for the degradation of water are:

1. to meet the need of increasing population, surface water (water from ponds, lakes, rivers, etc) and ground water are overdrawn, depleting volume of water.
2. sewage i.e., waste water from domestic and municipal use makes fresh water unfit for use by human beings and animals.
3. waste water, from all industries flows down into the surface water bodies and ground water bodies and they get polluted.

4. agricultural wastes containing manures, fertilizers and pesticides enter the water bodies and degrade the quality of water.
5. the continuous decrease of ground water level along coastal regions often cause movement of saline sea water into freshwater wells, thus, spoiling their water quality.

26.4.2. Conservation of Water

Conservation and management of water are essential for the survival of mankind, plants and animals. This can be achieved adopting the following methods:

1. **Growing vegetation** in the catchment areas, which will hold water in the soil and allow it to percolate into deeper layers and contribute to formation of ground water.
2. **Constructing dams and reservoirs** to regulate supply of water to the fields, as well as to enable generation of hydroelectricity.
3. **Sewage** should be treated and only the clear water should be released into the rivers.
4. **Industrial wastes (effluents)** should be treated to prevent chemical and thermal pollution of fresh water.
5. **Judicious use** of water in our day-to-day life.
6. **Rainwater harvesting** should be done by storing rainwater and recharging groundwater.

INTEXT QUESTIONS 26.4

1. Why do we consider fresh water as a renewable resource?

   ....

2. Give three methods of water conservation.

   ....

26.5 BIODIVERSITY

When we observe our surroundings, we find different types of plants, ranging from small green grasses to large trees, large variety of animals, from tiny insects to human beings and many other big animals. Besides these there are micro-organisms in the soil, air and water that we can't see through our naked eyes. These varieties of plants, animals and microbes together form the biological diversity or biodiversity of your surroundings.

So **biodiversity can be defined as the flora and fauna i.e. variety of all plants, animals and microbes of a region.**

26.5.1 Importance of Biodiversity

Biodiversity is essential for maintenance of ecosystem. It maintains gaseous composition of atmosphere, controls climate, helps in natural pest control, pollination of plants by insects and birds, soil formation and conservation, water purification and conservation, geo-chemical cycles etc.

Some of the uses of biodiversity are given below :

- Food : All kind of food is derived from plants and animals.
- Drugs and Medicines : Around 25% of drugs are obtained from plants e.g. quinin used for treatment of malaria is obtained from *Cinchona officinalis*. All antibiotics are derived from microbes.
- Cultural and Aesthetic value : You enjoy watching butterflies, animals, birds and flowers. Eco-tourism is a source of income.
- Religious values : Plants like tulsi, peepal, banyan and animals like cows, ox, elephant are worshiped.
- Biodiversity conservation is essential for maintenance of ecosystem.
- It is also required for disposal and pollinaiton in plants, formation and conservation of soil and purification and conservation of water.

Hot Spots of Biodiversity

Biodiversity is not uniformly distributed across the geographical regions of the earth. Certain regions of the world are very rich in biodiversity. We call such areas as "**mega diversity zones**". We also refer to them as "**hot-spots**". For example, India accounts for only 2.4 % of the land area of the world; but it contributes approximately 8% species to the global diversity due to existence of such pockets. The hot spots are the richest and the most threatened reservoirs of biodiversity on the earth. The criteria for determining an area as a hot spot are:

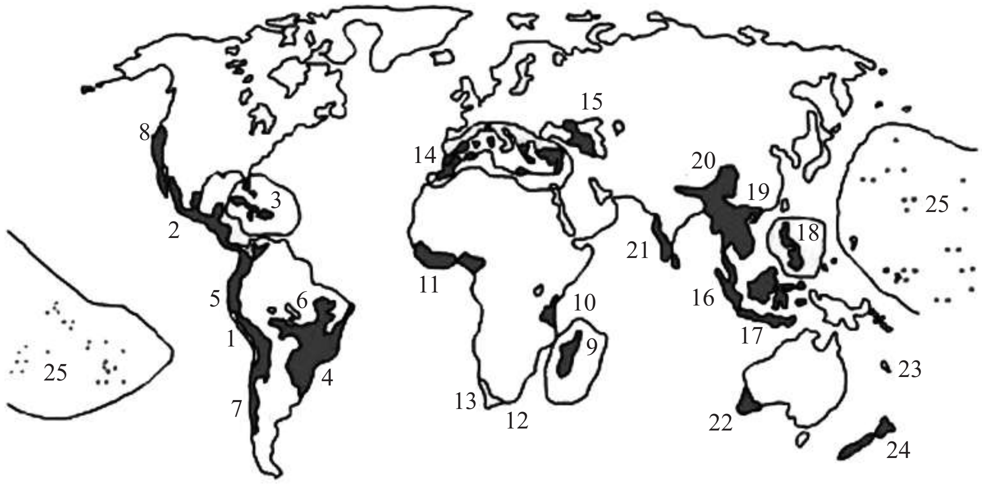
(i) The area should support >1500 endemic species,

(ii) It must have lost over 70 % of the original habitat

Twenty-five biodiversity hot spots have been identified in the world. These hot spots are characterized by supporting exceptionally high biodiversity.

Among the 25 hot spots of the world, two are found in India namely **Western Ghats** and the **Eastern Himalayas**. These two areas of the country are exceptionally rich in flowering plants, reptiles, amphibians, butterflies and some species of mammals.

The eastern Himalayan hot spot extends to the north – eastern India and Bhutan. The temperate forests are found at an altitude of 1780 to 3500 m. Many deep and semiisolated valleys are exceptionally rich in endemic plant species.



1. Tropical Andes, 2. Mesoamerica, 3. Caribbean, 4. Brazil's Atlantic Forests, 5. Chico/Darien/ Western Equador, 6. Brazil's Cerrado, 7. Central Chile, 8. California Floristic Province, 9. Madagascar, 10. Eastern Arc and Coastal Forests of Tanzania/Kenya, 11. West African Forests, 12. Cape Floristic Province, 13. Succulent Karoo, 14. Mediterranean Basin, 15. Caucasus, 16. Sundland, 17. Wallacea, 18. Phillipplnes, 19. Indo-Burma, 20. South Central Chaina, 21. Western Ghats/Sri Lanka, 22. Southwest Australia, 23. New Caledonia, 24. New Zealand, 25. Polynesia/Micronesia.

Fig. 12.1a: The terrestrial biodiversity hot spots

CASE STUDIES

There are many amongst us humans who are motivated to solve societal problems, however difficult. There are several success stories of which three are mentioned below regarding water management in water starved areas:

Case Study 1

Rajasthan for many years suffered as ‘land without water’. Geared by an urge to solve the water crisis, Rajinder Singh, a devout follower of Mahatma Gandhi and Jaiprakash Narayan, gave up a lucrative job to serve the people. With the help of villagers, he dug ‘johads’, which means ‘dug out ponds’ as water conservation structures where rain water began to collect year after year. Rajendra Singh’s initiative worked wonders and today there are 3500 ‘people made’ water conservation structures and no water scarcity.

Case Study 2

In Gandhigram, a coastal village in Kutch district, the villagers had been facing a drinking water crisis for the past 10 to 12 years. The groundwater table had fallen below the sea level due to over extraction and the seawater had seeped into the ground water aquifers. The villagers formed a village development group, Gram Vikas Mandal. The mandal took a loan from the bank and the villagers contributed voluntary labour (Shramdan). A check dam was built on a nearby seasonal river, which flowed past the village. Apart from the dam, the villagers also undertook a micro-watershed project. Due to these water retention structures, the villages now have sufficient drinking water.

Case Study 3

Rainwater harvesting – another success story: The area surrounding the River Ruparel in Rajasthan is a good example of proper water conservation. The site receives very little rainfall, but proper management and conservation have ensured water availability throughout the year. The water level in the river began declining due to extensive deforestation and agricultural activities along the banks and, by the 1980s, a drought-like situation began to spread. Under the guidance of local people, the women living in the area were encouraged to take the initiative in building johads (round ponds) and dams to hold back rain water. Gradually, water began coming back as proper methods of conserving and harvesting rainwater were followed. The revival of the river has transformed the ecology of the place and the lives of the people living along its banks.

26.5.2. Threat to Biodiversity

Though biodiversity is so important for our survival, we are destroying it knowingly or unknowingly. It is under threat due to the following reasons:

(i) Destruction of habitat by cutting down trees, filling up the wetland, ploughing of grassland or burning a forest.

(ii) Population explosion has increased demand for food and shelter. It has led to culture of single crop (monoculture) that will result in disappearance of some other crops.

(iii) Industrialisation and urbanisation has changed and destroyed the natural habitat of plants and animals.

(iv) Pollution of soil, air and water changes the habitat quality and may reduce or eliminate sensitive species.

(v) Mining activities add to the pollution of air and water and threaten the survival of the animals in the nearby areas.

(vi) Construction of dams, roads and railways destroys huge patches of forests, grassland etc. thus, disturb the biodiversity.

(vii) Indiscriminate killing of animals for different purposes has resulted in their reduction.

(viii) Introduction of exotic/foreign species in an area threaten the survival of existing natural biodiversity; e.g., water hyacinth clogs rivers and lakes and threatens the life of many aquatic species in our country.

26.5.3 Conservation of Biodiversity

There are two basic strategies for conservation of biodiversity:

(i) **In-situ** conservation

(ii) **Ex-situ** conservation

(i) **In-situ (on site)** conservation includes the protection of plants and animals within their natural habitats or in protected areas. Protected areas are areas of land or sea dedicated to protection and maintenance of biodiversity. For example: e.g., National Parks, Wildlife Sanctuaries, Biosphere Reserves, etc.

(ii) **Ex-situ (off site)** conservation is the conservation of plants and animals outside their natural habitats. These include Botanical Gardens, Zoo, Gene Banks, DNA Banks, Seed Banks, Pollen Banks, Seedling and Tissue Culture etc.

INTEXT QUESTIONS 26.5

1. Some of the following words/terms are related to conservation of biodiversity and some are threat to biodiversity. Identify the points relating to conservation by mentioning 'C' and threat to biodiversity by mentioning 'T' against the points.

   (i) Wildlife sanctuaries (......................)
   (ii) Population explosion (......................)
   (iii) Industrialisation (......................)
   (iv) Zoo (......................)
   (v) Tissue culture (......................)
   (vi) Pollution (......................)

26.6 ENDANGERED SPECIES

You have already learnt about the various reasons due to which our biodiversity is under constant threat. You also learnt about the strategy to protect the biodiversity. Let us know about some of the plants and animals which have already become extinct or are going to be extinct from the earth surface.

The species, which have already disappeared, are called the **extinct** species and the phenomenon of disappearance is known as extinction. Another category of species called **endangered species are those which have been reduced in number to a critical level and facing a high risk of extinction in the near future.**

The World Conservation Union, formerly International Union for the Conservation of Nature and Natural Resources (IUCN) has enlisted endangered plants and animals in the **Red Data Book.** Few endangered plants and animals are listed below:

Endangered Animals

1. Asiatic Lion,
2. Green sea turtle, loggerhead turtle,
3. Tortoise
4. Marsh crocodile and gharial
5. Tiger
6. Rhinoceros
7. Asiatic Elephant, Indian Python
8. Great Indian Bustard, butterflies

Endangered Plants

1. Pitcher plant
2. Indian belladona
3. Orchids
4. Nilgiri Lily
5. *Ginkgo biloba* (Maiden hair tree)

26.7 WILDLIFE

Now we shall learn about an important resource of nature called wildlife. At home you may have a pet dog or a cat, even some of you may have cows, buffalos, sheep, goats etc. In your garden you may grow different types of vegetables and flowering plants. In addition to these, there are other plants and animals, which are not cultivated by you. **The plants, animals and microorganisms other than the cultivated plants and domesticated animals constitute wildlife.**

Animals and plants living in their natural habitat constitute **wildlife**. Wildlife forms an important resource as it plays a major role in maintaining ecological balance. It is used in research as experimental material and also used for recreational purposes. Like other resources it is also facing severe threat. So it should be conserved and maintained for the use of future generation.

26.7.1 Need for Conservation of wildlife

Wildlife needs to be conserved for :

- maintaining ecological balance for supporting life.
- preserving different kinds of species (biodiversity).
- preserving economically important plants and animals.
- conserving the endangered species.

26.7.2 Methods of Conservation of Wildlife

After knowing the need for conservation of wildlife, let us discuss how to conserve it. We can protect it by adopting various means, like:

- Establishing biosphere reserves, national parks and sanctuaries.
- Afforestation (Tree planting programme).
- Special schemes for preservation of threatened species.
- Improvement of natural habitats of wildlife.

- Educating people about the need and methods of conservation of wildlife.
- Formulation of Acts and Regulations to prevent poaching (killing animals) for sports and money.

> Wildlife week is being observed in India in the month of July every year since 1955. It aims at creating awareness among people about the importance of wildlife and to highlight the conservational and management needs of wildlife.

INTEXT QUESTIONS 26.6

1. What is Red Data Book?

   ....

2. Define the term Wildlife.

   ....

3. Below are certain incomplete words. Complete them by taking clues from the statement given below for each. Each blank represent the letter only.

   (i) A __ __ or __ __ __ at __ on

   (Tree planting programme)

   (ii) Be __ __ ado __ __ a

   (An endangered Indian plant)

   (iii) Rh __ no __ __ r __ __

   (An endangered animal)

26.7.3 Wildlife Reserves in India

Many National Parks and Sanctuaries have been established to preserve wildlife in their natural environment. Some of them are given below along with the important species found in these.

- Kaziranga sanctuary (Assam) – one-horned rhinoceros
- Manas sanctuary (Assam) – wild buffaloes
- Gir forest (Gujarat) – lions, chital, sambar, wild bears
- Kelameru bird sanctuary (Andhra) – pelicans and marine birds
- Dachigam sanctuary (Jammu and Kasmir) – Kashmir stags, Himalayan tahr, wild goats, sheep, antelopes
- Bandipur sanctuary (Karnataka) – Indian bison, elephants, langurs
- Periyar sanctuary (Kerala) – elephants, barking deer, sambar

- Kanha National Park (Madhya Pradesh) – tiger, leopards, wild dogs
- Similipal National Park (Orissa) – mangroves, marine turtles lay eggs
- Bharatpur bird sanctuary (Rajasthan) – ducks, herons
- Corbett National Park (Uttaranchal) – tigers, barking deer, sambar, wild bear, rhesus monkey
- Jaladpara sanctuary (West Bengal) – rhinoceros

26.7.4 Agencies Dealing with Conservation of Wildlife

There are various agencies both at national and international levels which take care of conservation of wildlife. Some of them are given below

(i) Indian Board for Wildlife (IBWL) advises state government on wildlife protection.

(ii) Constitution of India includes forest and wildlife protection.

(iii) World Wildlife Fund for nature (WWF) : It is an international organisation formed in the year 1961 and is engaged in protection of wildlife. India became a member of it in 1969 and has its headquarter in Mumbai. It has supported the well-known "Project Tiger".

(iv) International Union for Conservation of Nature and Natural resources (IUCN), World Conservation Union (WCU) is engaged in protection of wildlife and their habitats.

(v) Convention of International Trade in Endangered Species (CITES) is an international organisation to check trade products from endangered animals. India became a party to CITES in 1976.

26.8 LEGISLATION FOR CONSERVATION

Various acts and laws have been passed in Indian constitution for conservation of natural resources. Some of them are:

- Environment Protection Act, 1986
- Forest (Conservation) Act, 1980
- National Forest Policy, 1988
- Wildlife Protection Act, 1972 and amended in 1991

INTEXT QUESTIONS 26.7

1. Expand the following.

   (i) WWF ....

   (ii) CITES ....

   (iii) IUCN ....

2. Match the items of column A with those of Column B.

	Column – A		Column – B
(i)	Periyar sanctuary	(a)	Rajasthan
(ii)	Kanha National Park	(b)	Orissa
(iii)	Similipal National Park	(c)	Uttaranchal
(iv)	Bharatpur bird sanctuary	(d)	Kerala
(v)	Corbett National Park	(e)	Madhya Pradesh

26.9 SUSTAINABLE DEVELOPMENT

However, these industries, factories, cities, towns, roads, railways, dams etc. for development, the governors of all countries build have replaced the natural habitats of plants and animals. Natural resources have been dedpleted gradually and a day will come when many natural resources will not be available for our future generation. So it is high time to think about maintaining a balance between environment and development so that both present and future generations can derive proper benefits out of these resources. This can only be achieved by the process of sustainable development.

Sustainable development is the development that meets the needs of the present generation and conserves resources for the future generation.

Sustainable development should include –

- reducing excessive use of resources and enhancing resource conservation.
- recycling and reuse of waste materials.
- scientific management of renewable resources, especially bio-resources.
- planting more trees.
- green grassy patches to be interspersed between concrete buildings.
- using more environment friendly material or biodegradable material.
- use of technologies, which are environmental friendly and based on efficient use of resources.

INTEXT QUESTIONS 26.8

1. A and B are two friends. In their daily life both have different opinion on certain matters. Considering the necessity of sustainable development give your suggestions in the given space.

   A says - Polythene bags should be used to carry vegetables.

   B says – Jute bags should be used to carry vegetables.

   Who is right and why?

   ....

2. Mention any two activities which will help in sustainable development.

....

26.10 ENERGY RESOURCES

We have always been using different forms of energy obtained from various sources for our daily activities like cooking, heating, ploughing, transportation, lighting, etc. For example, heat energy required for cooking purpose is obtained from firewood, kerosene oil, coal, electricity or cooking gas. LPG (liquefied petroleum gas) We use animal power (horse, bullock, etc.) for transportation and for running minor mechanical devices like the Persian wheel for irrigation or for running a "kolhu" for extracting oil from oilseeds. Different forms of these energies are obtained from various sources. We will discuss about them in detail.

26.10.1 Types of Energy Sources

There are two main categories of energy sources:

(i) **Conventional Sources of Energy,** which are easily available and have been in usage for a long time.

(ii) **Non-Conventional Sources of Energy,** that are other than the usual, or that are different from those in common practice.

The table 26.2 below summarises the list of both the above categories of energy resources.

Table 26.2 Various types of energy sources

Sources of Energy		
Conventional Energy		**Non-Conventional Energy**
Conventional Non-renewable Energy (Mostly fossil fuels found under the Ground) Examples: Coal, Oil, Natural gas etc.	**Conventional Renewable Energy** (Mostly non-fossil fuels seen above the Ground) Examples: Firewood, Cattle Dung, Farm Vegetable Wastes, Wood charcoal, etc	• Solar Energy • Hydel Energy • Wind Energy • Nuclear Energy • Hydrogen Energy • Geothermal Energy • Biogas • Tidal Energy • Bio-fuel

26.10.2 Conventional Sources of Energy

Conventional sources of energy have been in used since ancient times. Most important among them are the fossil fuels.

Fossil Fuels

Fossil fuels are the fossilised remains of plants and animals, which over millions of years have been transformed into coal, petroleum products and natural gas.

Coal is the most abundant fossil fuel. It is widely used for combustion in cooking and industrial activities. There are different types of coal products such as coal gas, coal tar, benzene, toluene, etc., which are used for various purposes.

Oil and Natural gases are formed from plants and animals which once lived in the tropical seas. Oil (or petroleum) is a source of countless products. Apart from petrol, diesel and other fuels, petroleum products include lubricants, waxes, solvents, dyes, etc. Petroleum reserves are supposed to last for another 100 years or so.

Natural gas is often found with petroleum. The gas mainly contains methane. Apart from serving as fuel in several industries, it is being increasingly used as domestic fuel in many countries including India. United States of America is the largest producer as well as consumer of natural gas.

Now-a-days in big cities and towns it is being supplied through pipelines which is called Piped Natural Gas (PNG). The natural gas is also used as a fuel to run vehicles. It is known as Compressed Natural Gas (CNG). It is accepted as an economical and less polluting fuel for transport.

The Liquefied Petroleum Gas (LPG) is the common cooking gas used in Indian homes. It is a mixture of propane and butane gases kept under pressure in liquid form, but they burn in gaseous form. This gas is made available in a specific container for domestic as well as industrial uses. It is a byproduct of petrolium refineries

INTEXT QUESTIONS 26.9

1. Coal is a non-renewable source of energy whereas wood charcoal is renewable. Why ?

   ....

2. How are the following useful in our day to day life?

   (i) CNG ....

   (ii) PNG ....

   (iii) LPG ....

3. A and B are two friends. In their daily life both have different opinion on certain matters. Considering the necessity of sustainable development give your suggestions in the given space.

   A says – Coal should be used as a fuel to cook our food

   B says – LPG should be used as a fuel to cook our food.

   Who is right and why?

   ....

26.10.3 Non-Conventional Sources of Energy

We have already learnt known about conventional sources of energy, whether renewable or non-renewable (coal, oil, etc.), which are fast depleting and will not last long. Therefore, greater utilisation of non-conventional sources of energy (solar, wind, hydro, geothermal, etc) will have to be used.

1. Solar Energy

Solar energy is the ultimate source of all energy on earth. Firewood, coal, oil or natural gas are the products of plants and other organisms, which had used solar energy for the synthesis of organic molecules during photosynthesis. Even today it will turn out to be the most important answer to problems of energy except nuclear energy. The solar energy has the following advantages:

(i) It is abundant

(ii) It is everlasting

(iii) It is available almost everywhere.

(iv) It is free from political barriers.

Various technologies in which solar energy can be, and is being utilised are as follows:

(i) Solar cookers

(ii) Solar hot water systems

(iii) Solar dryers (used for drying crop yields)

(iv) Solar air heaters

(v) Solar kilns

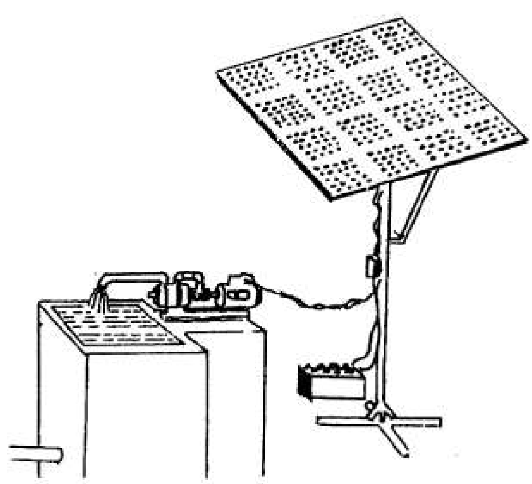


Fig. 25.2 Solar battery that can run a water pump or put to any other use.

(vi) Solar desalination systems

(vii) Solar batteries (Fig. 26.2).

2. Hydel /Hydro Energy

The generation of electricity by using the force of falling water is called hydro-electricity or hydel power. It is cheaper than thermal or nuclear power. For its generation dams are built to store water, which is made to fall to rotate turbines that generate electricity.

3. Wind Energy

Wind as an energy can be utilised in our daily life by converting it into mechanical energy. This mechanical energy is used to generate electricity, raise water from wells and rivers for irrigation and other purposes. Windmills have been in use since early times to provide power for grinding grains. It is also used for grain cutting and shelling. In India a large number of windmills are being constructed on the sea beach and hilly areas. (Fig. 26.3).

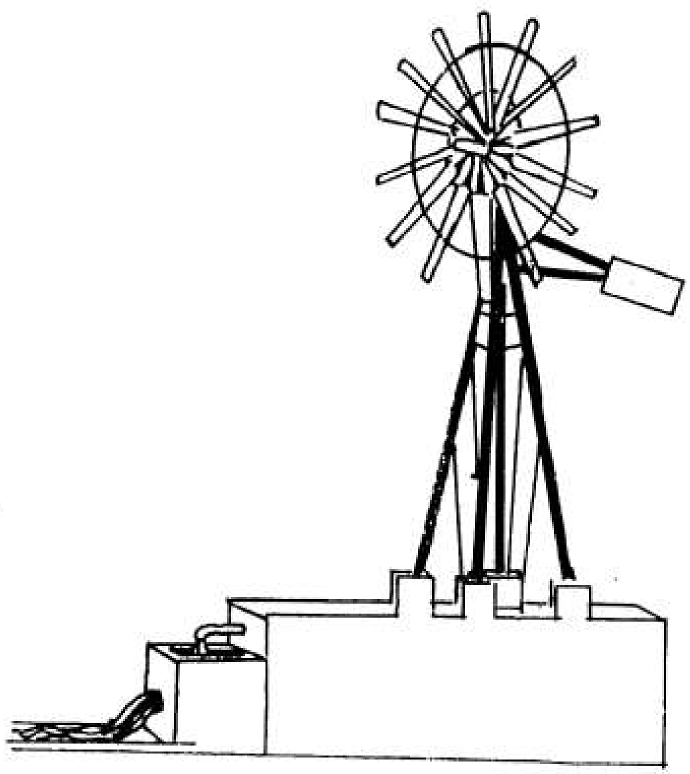


Fig: 26.3 Windmill

Minimum wind speed required for operating the windmill is 7 km/hour. A windmill can draw water upto a maximum depth of 55 feet and the output is 4000-9000 litres (of water) per hour.

4. Tidal Energy

Tidal energy is one that is produced by making the use of water movement from a high tide to a low tide. Ocean waves and tides can be made to turn a turbine and generate electricity. Areas where rivers flow into the sea experience waves and tides and electricity can be generated there. It has much potential. As you know we have a large coastline and major river systems in our country, electricity can be generated on a large scale from waves and tides.

5. Nuclear Energy

Radioactive elements like uranium and thorium disintegrate spontaneously releasing large quantities of energy. This energy can be trapped to produce electricity. 25% of world's thorium reserve is found in our country, which can be utilised to generate electricity. Most advanced countries have nuclear power stations. We too have some in India, for example, Tarapur (Maharashtra), Kalpakkam (Tamil Nadu), Narora (Uttar Pradesh), Kota (Rajasthan). Approximately 3% of India's electricity comes from nuclear power and about 25% is expected to come by 2050.

Installation costs of nuclear power stations are very high, but maintenance costs are relatively low. If not carefully maintained, these also have an inherent risk of causing radioactive pollution.

6. Hydrogen Energy

Hydrogen is the primary fuel for the hydrogen based fuel cells and power plants. Power can be generated for industrial, residential and transport purposes by using hydrogen.

7. Geothermal Energy

This is the energy derived from the heat in the interior of the earth. In volcanic regions, springs and fountains of hot water called "geysers" are commonly found. These eruptions of hot steaming water can be used to turn turbines and produce electricity in geothermal power plants. In this method cold water is allowed to seep through the fissures in the rocks till it reaches the hot rocks in the lower layers. Water gets heated and gets converted into steam which forces out to the surface to be used in power generation. Besides the superheated steam of hot springs can also generate electricity. There are 46 hydrothermal areas in India where the water temperature normally exceeds 150 degree centigrade. Electricity can be generated from these hot springs.

8. Biogas

Another form of non-conventional energy is **biogas**. It is produced by the microbial activity on cattle dung in a specially designed tank called digester. A mixture of water and cattle dung is poured in this digester where anaerobic decomposition takes place and biogas is generated. This gas contains 55 – 70 percent methane, which is inflammable and it is generally used as cooking gas and for generation of electricity. The "waste" left in the tank after the generation of biogas is used as manures. Thus, biogas plant provides us both the fuel and the manure. Biogas plants are becoming very popular in rural India.

There are two types of biogas plants:

(a) Family type gas plants- These are small and are used individually by a family.

(b) Community type gas plants- These are large and are used by larger rural populations.

9. Bio-fuel

You know it very well that fossil fuels have been the main source of energy for transportation and industries for more than a century. Their rapid consumption has depleted the reserves of fossil fuels. Their fast depletion and non-renewable nature has sent an alarm to look for alternative fuel. Among the fuels, consumption of liquid fuels is the highest. So there are attempts to identify potential plant species as sources of liquid hydrocarbons, a substitute for liquid fossil fuels. The hydrocarbons present in such plants can be converted into petroleum hydrocarbons. This liquid hydrocarbon is the bio-fuel and the plants producing it are called petro-plants. The plant species, *Jatropha curcus* is the most suitable one, which yields bio-diesel. The Indian Oil Corporation is carrying out experiments for preparation of bio-diesel from various vegetable oils extracted from rice bran, palm, karanjia, sunflower etc.

Advantages of Bio-diesel

Bio-diesel has several advantages; some of them are given below-

- It is an agriculture based fuel substitute.
- It can be made from both vegetable oil and animal fats.
- It can be used without major modifications in engines.
- It does not need separate infrastructure for storage and delivery.
- Handling bio-diesel is safer.
- Planting of *Jatropha curcus* will utilise wasteland in our country.
- It's combustion emits less carbon monoxide, sulphates, unburnt hydrocarbons and particulate matters, thus reduces air pollution.

26.10.4 Conservation of Energy Sources

We have already leant about the different types of sources of energy and how they are useful to us. Now you think about your daily activities and the types of energy you are using in each activity. Make a list of the sources, which produce these energies. Everyday you and your family members are using four to five sources of energy. Similarly other people, industries and different establishments are using energy everyday. The demand for energy is increasing day-by-day and exploitation of the energy sources is on the rise. Thus, energy sources are depleting gradually. There is an urgent need to conserve energy, else adequate energy will not be available in future. Some methods to conserve energy are:

- Minimise exploitation of non-renewable energy resources.
- Emphasis on use of renewable sources of energy.
- Stop wastage of energy.
- Creating awareness among people regarding wise and judicious use of energy.
- Make more use of bio-mass based energy.

INTEXT QUESTIONS 26.10

1. Why do we consider sun as the best source of energy?

   ....

2. What is meant by 'radioactive pollution'?

   ....

3. What are the advantages and disadvantages of nuclear energy?

   ....

4. The following table contains the different sources of energy and their uses. Put a tick mark under the source against the appropriate use(s).

	Geothermal	Bio gas	Bio-diesel
(i) Generation of Electricity			
(ii) Fuel for Cooking			
(iii) Fuel for Vehicles			

5. Mention any three ways of conservation of electric energy at your home.

   (i) ....

   (ii) ....

   (iii) ....

WHAT YOU HAVE LEARNT

- Any natural or artificial substance, energy or organism, which is used by human being for its welfare is called a resource. Two types of resources are, (a) Natural resources; and (b) Artificial resources.
- Natural resources are classified into (i) inexhaustible- air, water (in oceans), solar energy etc. and (ii) exhaustible- soil, forest, fresh water, minerals, fossil fuels, etc. Exhaustible resources may be non-renewable such as metals fossil fuels, and renewable such as water, wood, natural pastures, forests, etc.
- Conservation is the sum total of activities, which can derive benefits from natural resources but at the same time prevent excessive use leading to destruction or neglect.
- Soil is the uppermost layer of earth's crust, which supports growth of plants. It is both a renewable and non-renewable resource.
- Water is the most important component of all life forms. It regulates climate, generates electricity and is also useful in agriculture and industries. With increase in population and industrial growth, water is degraded day by day. Conservation and management of water are essential for the survival of mankind, plants and animals
- The variety of all plants, animals and microbes of a region is termed biodiversity. Biodiversity is essential for maintenance of ecosystem.
- Though biodiversity is important for our survival, it is under threat due to the various human activities. So we should protect biodiversity by strategies like, (i) In situ conservation, and (ii) Ex situ conservation.
- The endangered species are those, which have been reduced in number to a critical level and facing a high risk of extinction in the near future.
- The plants, animals and microorganisms other than the cultivated plants and domesticated animals constitute wildlife. Wildlife forms an important resource for maintaining ecological balance. Conserve it by establishing biosphere reserves, national parks and sanctuaries etc.
- Sustainable development is the development that meets the needs of the present generation and conserves it for the future generation.
- There are two main categories of energy sources: (i) conventional sources of energy; and (ii) non-conventional sources of energy. Conventional sources of energy may be (a) **conventional non-renewable energy** (Mostly fossil fuels found under the ground like coal, oil and natural gas etc.); and (b) **Conventional renewable energy** (firewood, cattle dung, charcoal etc.)

- The Non-Conventional Energy includes Solar energy, Hydel energy, Wind energy, Nuclear energy, Hydrogen energy, Geothermal energy, Biogas energy, Tidal energy, Bio-fuel, etc.
- The demand for energy and exploitation of the energy sources is increasing day-by-day. Energy sources are depleting fast. There is an urgent need to conserve energy; else adequate energy will not be available in future.

TERMINAL EXERCISES

1. Define conservation.
2. What is meant by soil erosion?
3. Define the term biodiversity.
4. State the meaning of sustainable development.
5. Mention any two methods of conservation of energy resource.
6. Why should wildlife be conserved?
7. Why is soil considered as both renewable and non-renewable resource?
8. State any three reasons for degradation of water.
9. Distinguish between *in-situ* and *ex-situ* conservation strategies.
10. Describe natural gas as conventional source of energy.
11. Describe the natural and the anthropogenic causes of soil erosion.
12. Describe the various methods of conservation of soil.
13. Future generations of mankind will depend more and more on non-conventional sources of energy. Discuss.
14. Explain any five methods of conservation of water.
15. Describe any three non-conventional sources of energy.

ANSWERS TO INTEXT QUESITONS

26.1 1. (i) Plastic is an artificial resource.

(ii) Forest is an exhaustible renewable resource.

(iii) The exhaustible resources, which are not replaced after consumption are known as non-renewable resources.

OR

The exhaustible resources, which are replaced after consumption, are known as renewable resources

2.

Inexhaustible	Renewable	Non- renewable
Air	Fish	Iron
Sand	Forest	Petroleum
Wind	Pearls	Gold
Clay		

26.2 1. (i) To maintain ecological balance for supporting life.
(ii) To preserve different kinds of species.

2. (i) Chipko
(ii) Tulsi
(iii) Khecheopalri

26.3 1. Wind : Carries away the loose top soil
Overgrazing : Removes the protective vegetation, thus help in erosion by wind and water
Water : Rain drops carry away the soil not covered by vegetation.

2.

Column – A		Column – B	
(i)	Terracing	(c)	Practised in hilly areas
(ii)	Erosion	(d)	To wear away
(iii)	Deforestation	(b)	Cutting down forests
(iv)	Humus	(a)	Decayed vegetable or animal matter

26.4 1. It is produced continuously through hydrologic cycle.

2. (i) Constructing dams and reservoirs
(ii) Rainwater harvesting
(iii) Judicious use

26.5 1. (i) C (ii) T (iii) T (iv) C (v) C (vi) T

26.6 1. It is published by IUCN that gives information on endangered plants and animals.

2. The plants, animals and microbes other than the cultivated plants and domesticated animals constitute the wildlife.

3. (i) Afforestation
(ii) Belladonna
(iii) Rhinoceros

26.7 1. (i) World Wildlife Fund
(ii) Convention of International Trade in Endangered species
(iii) International Union for Conservation of Natural Resources

2. (i) (d), (ii) (e) (iii) (b)(iv) (a)(v) (c)

26.8 1. (i) B is right; because jute bags are biodegradable and eco-friendly. Though science has invented the bio-degradable polythene bags, all are not bio-degradable, hence cause pollution.

(ii) see text

26.9 1. Coal cannot be regenerated after consumption. But wood charcoal is obtained from wood and wood can be obtained continuously from trees/ forest.

2. CNG : Cooking, Transportation

   PNG : Cooking

   LPG : Cooking, Lightening, Transportation

3. B is right LPG causes less pollution than coal.

26.10 1. It is available free of cost and in ample quantity, everlasting. It has no boundaries and is also free from political barriers.

2. The radioactive elements when not disposed off properly cause disintegration in the soil and water and thus cause pollution.

3. India has sufficient Thorium to generate electricity cause pollution.

4.

		Geothermal	Bio-gas	Bio-diesel
(i)	Generation of Electricity	√	√	√
(ii)	Fuel for Cooking		√	
(iii)	Fuel for Vehicles			√

5. (i) Judicious use of electricity

   (ii) Use of florescent lamp instead of incandescent lamp

   (iii) Create awareness about the proper use of electricity, or any other.

27

POLLUTION

You have already learnt about the environment and its components in the earlier lessons. You have also studied the importance of maintaining a life-supporting environment. However, the environment has undergone many changes over the period of time. Population explosion in recent times has resulted in a number of environmental problems. The population of India has crossed the figure of 2 billion and the world population is estimated to have touched the 7 billion mark. To meet the demands of food, housing and energy, environmental resources are being exploited at a fast pace. Over-exploitation of resources and human activities have resulted in many environmental problems, such as deforestation, destruction of wild life, air, water, land and noise pollution, diminishing fossil fuels (oil, coal and natural gas), concentration of pesticides in alarming proportions in the bodies of organisms, and depletion of ozone layer and global warming.

In this lesson, you will learn about various kinds of environmental polluton, their causes effects and control.

OBJECTIVES

After completing this lesson, you will be able to :

- *define pollution;*
- *list various types of pollution and mention their sources;*
- *describe effects of air, water and soil pollution on flora and fauna;*
- *describe methods of control of air, water and soil pollution;*
- *describe methods of nuclear and solid waste management*
- *describe the causes and effects of sound pollution;*
- *describe the causes and effects of radiation pollution;*
- *discuss rates of entry and translocation of pollutants in the human body.*

27.1 POLLUTION

We perform a number of daily activities such as bathing and washing of clothes with soaps and detergents. By doing so we add some chemical residue to water and change its quality. This water may mix with the water in ponds and rivers due to ignorance and carelessness. Cooking of food by using firewood may release smoke in the air. Agricultural activities may dump fertilizers and pesticides in the environment. **The addition of unwanted substances in a concentration that has an adverse effect on organisms and environment, is called pollution.**

An undesirable change in the physical, chemical and biological characteristics of the environment especially air, water and land that may adversely affect human population and the wild life, industrial processes, cultural assets (building and monuments), is called **pollution.**

The agents that pollute the environment or cause pollution are called **pollutants.**

27.2 TYPES OF POLLUTION

Depending upon the area or the part of environment affected, pollution may be of the following types :

- Air pollution
- Water pollution
- Land pollution
- Noise pollution

27.2.1 Air pollution

We all breathe in air, we can feel, and even smell the air and say whether it is fresh or stale. The pollution in air may not be noticed until we see smoke coming out from some source. All human activities from cooking at home to activities in highly mechanized industries contribute to air pollution.

27.2.1a Sources of air pollution

The sources of air pollution can he divided into two categories (i) natural, and (ii) human-made

(i) Natural sources

(i) Ash from burning volcanoes, dust from storm, forest fires

(ii) Pollen grains from flowers in air are natural sources of pollution

(ii) Anthropogenic (human-made) sources

(i) Power stations using coal or crude oil release CO_2 in air

(ii) Also furnaces using coal, cattle dung cakes, firewood, kerosene, etc.

(iii) Steam engines used in railways, steamers, motor vehicles, etc. give out CO_2.

(iv) So do Motor and internal combustion engines which run on petrol, diesel, kerosene. etc.

(v) Vegetable oils, kerosene, and coal as household fuels

(vi) Sewers and domestic drains emanating foul gases

(vii) Pesticide residues in air

Major air pollutants

Some major air pollutants are discussed here.

• Carbon dioxide

Carbon dioxide is one of the major gases which contributes towards air pollution. It is mainly produced during the combustion of fuel in factories, power stations, household etc. The increasing CO_2 in the atmosphere is likely to have the following effects:

(i) **A rise in atmospheric temperature or global warming due to greenhouse effect. Also causes climate change.**

(ii) **Reduced productivity of the marine ecosystem**. This is due to the fact that water in the oceans would be more acidic due to increased concentration of CO_2 in the air, which dissolves in the water.

(iii) **Due to Global warming,** the increased surface temperature would cause **melting of continental and mountain glaciers** and thus would cause **flooding of coastal areas** of some countries.

• Sulphur dioxide

It is produced by the burning of coal in powerhouses and automobiles (car, trucks etc.). It causes **chlorosis** and **necrosis** of plants, irritation in eyes and injury to the respiratory tract (asthma, bronchitis) in humans responsible for discoloration and deterioration of buildings. High concentration of sulphur dioxide in the atmosphere dissolves in rain drops to form sulphuric acid which causes **acid rain**.

• Carbon monoxide

Carbon monoxide is produced as a result of incomplete combustion of fossil fuels like coal, petroleum and wood charcoal. Automobiles using diesel and petroleum are the major sources of carbon monoxide which gets added to the atmosphere. Carbon monoxide is more dangerous than carbon dioxide. It is a poisonous gas which causes respiratory problems. When it reaches the blood stream, it replaces oxygen due to its high affinity for haemoglobin. It also causes giddiness, headache and interferes with normal function of the heart.

• Fluorides

Upon heating,, rocks, soils and minerals that contain fluorides, give out hydrogen fluoride gas. This is an extremely toxic gas, which causes serious injury to livestock and cattle.

• Oxides of nitrogen

A few oxides of nitrogen, such as nitric oxide (NO), nitrous oxide (N_2O) and nitrogen dioxide (NO_2) are produced by natural processes as well as from thermal power stations, factories, automobiles and aircrafts (due to burning of coal and petroleum). They reduce the oxygen carrying capacity of blood, may cause eye irritation and skin cancer in human beings.

Smog

Smog is a mixture of smoke, dust particles and small drops of fog. Smog may cause necrosis and develop a white coating on the leaves (silvering) of plants. In human beings and animals, it may cause asthma and allergies.

Aerosol spray propellants

Suspended fine particles in the air are known as aerosols. Aerosols contain chlorofluoro carbons (CFCs) and fluorocarbons used in refrigerants and aerosol cans. They cause depletion of the ozone layer.

Domestic air pollutants

Smoke from cigarettes, *biri*, cigar and other such objects using burning tobacco, burning of coal, firewood, cow dung cakes, kerosene oil and liquefied gases are major domestic pollutants. The common pollutant gases emitted during the domestic burning of coal, kerosene oil, firewood, cow dung cakes, etc. are carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), etc. The pollution due to these pollutants causes suffocation, eye and lung diseases and low visibility.

27.2.1b Effects of air pollution

Major effects of air pollution on human health, plants and other animals is given in table 27.1.

Table 27.1: Some major air pollutants, their sources and effects

Pollutant	Source	Harmful effect
Carbon compounds (CO and CO_2)	Automobile exhausts burning of wood and coal	• Respiratory problems • Green house effect global warning and climate change
Sulphur compounds (SO_2 and H_2S)	power plants and refineries Volcanic eruptions	• Respiratory problems in humans • loss of chlorophyll in plants (chlorosis) • Acid rain
Nitrogen Compound (NO and N_2O)	Motor vehicle exhaust, atmospheric reaction	• Irritation in eyes and lungs • Low productivity in plants • Acid rain damages material (metals and stone)
Hydrocarbons (benzene, ethylene)	Automobiles and petroleum industries	• Respiratory problem • Cancer causing properties

SPM (Suspended Particulate matter) (Any Solid or liquid particles suspended in the air, (fly ash, dust, lead)	Thermal power plants. construction activities, metallurgical processes and automobiles	• Poor visibility, breathing problems • Lead interferes with the development of red blood cells and causes lung diseases and cancer • Smog (smoke+fog) formation leads to poor visibility and aggravates asthma in patients
Fibres (Cotton, wool)	Textile and carpet weaving industries	• Lung disorders

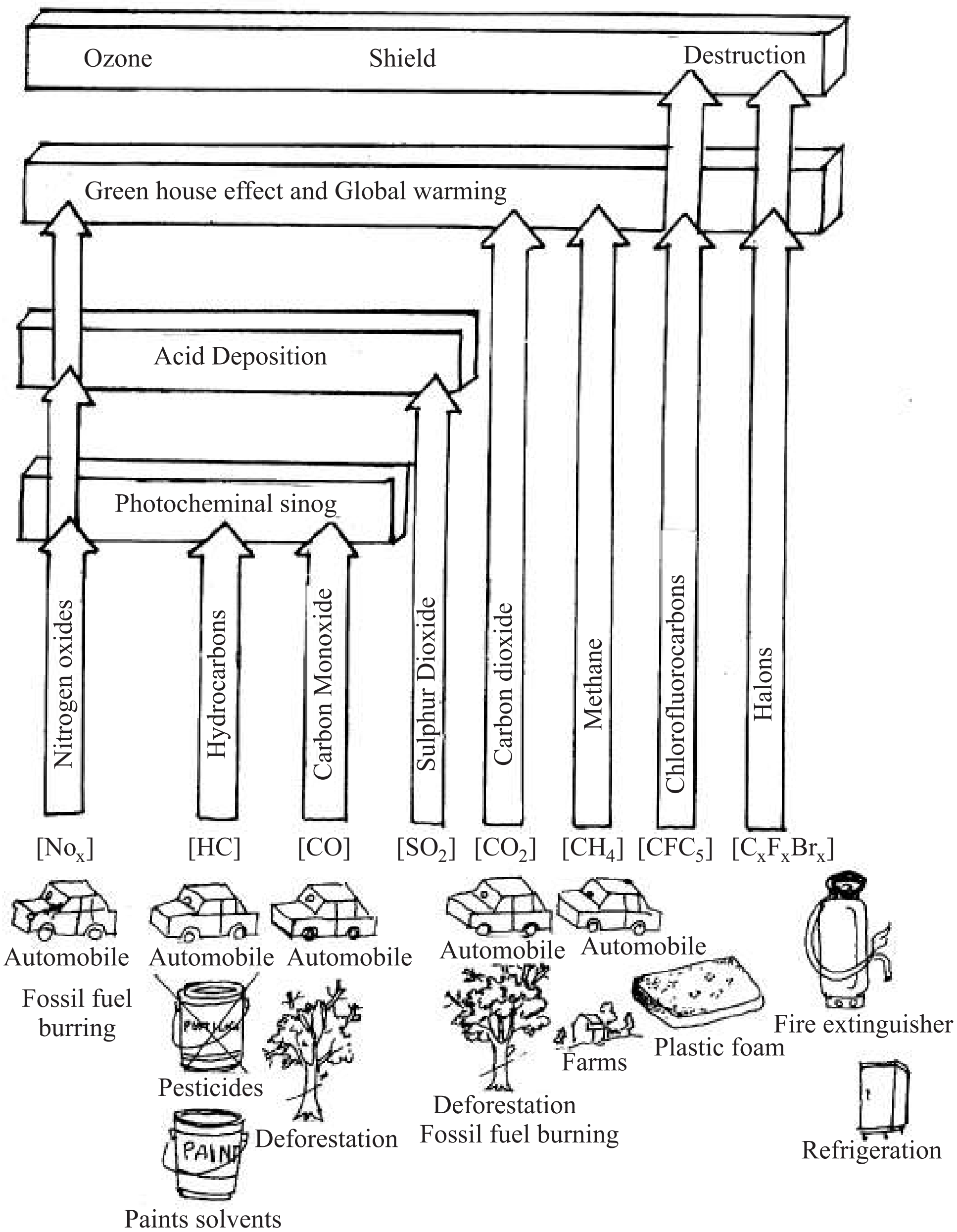


Fig. 27.1 Major effects of air pollution

27.2.1c Prevention and control of air pollution

There are two types of air pollutants—gaseous and particulate.

Methods of controlling gaseous air pollutants

(i) **Combustion.** This technique is used for controlling those air pollutants that are in the form of organic gases or vapours. In this technique, the organic air pollutants are subjected to flame combustion technique (also known as catalytic combustion). In this technique, organic pollutants are converted into less harmful products and water vapour.

(ii) **Absorption.** Absorption is a process in which a substance penetrates into another substance like scrubbers. In this technique, gaseous pollutants are passed through absorbing material like scrubbers. These scrubbers contain a liquid absorbent. This liquid absorbent removes the pollutants present in gaseous effluents. Thus the air coming into scrubber is free from pollutants and it is discharged into atmosphere.

(iii) **Adsorption.** Adsorption is a process in which a substance sticks to the surface of another substance (called absorbent). In this technique, gaseous effluents are passed through porous solid absorbent kept in containers. The gaseous pollutants stick to the surface of the porous material and clean air passes through. The organic and inorganic constituents of gaseous effluents are trapped at the interface of solid adsorbent by physical adsorbent.

Methods to control particulate air pollutants

The particulate air pollutants such as dust, soot, fly ash etc. can be controlled by using fabric filters, electrostatic precipitators, wet scrubbers and mechanical devices etc.

(i) ***Fabric filters.*** In this technique, gaseous emission containing dust, soot and fly ash is passed through porous fabric filters made of fabric (cloth) (woven or filled fabric). The particles of pollutants get trapped in this fabric and are collected in the filter and the gases free from the pollutant particles are discharged.

(ii) ***Mechanical devices.*** There are many mechanical devices that clean the air of pollutants either due to (i) gravity in which the particles settle down by gravitational force; or by (ii) sudden change in the direction of gas flow in which particles separate out due to greater momentum.

(iii) ***Electrostatic precipitators.*** In this technique, a gas or air stream containing aerosols in the form of dust, mist or fumes, is passed between the two electrodes of the electrostatic precipitator. During this process, the aerosol particles get precipitated on the electrodes.

27.2.1d Prevention and control of air pollution

(i) At domestic level, burning of wood and dung cakes can be replaced by use of cleaner fuel and biogas (formed by the decomposition of animal and plant wastes in a biogas plant).

(ii) Automobile pollution can be reduced by :

- pooling of transport or use of public transport.
- use of unleaded petrol and CNG (Compressed Natural Gas).
- regular tuning and servicing of the engines, and
- switching off the engine at red lights or when not in use.

(iii) Following measures can reduce industrial pollution:

- installation of tall chimneys,
- installation of devices that do not allow pollutants to be released in the environment, such as filters, electrostatic precipitators, scrubbers etc.,

INTEXT QUESTIONS 27.1

1. Define pollution.

   ....

2. Name four types of pollution.

   ....

3. Name one effect on plants and one on human caused by excess SO_2 in the air.

   ....

27.2.2 Water pollution

Addition of undesirable substances in water is called **water pollution**. Water pollution could be due to natural or human activities.

Natural sources of water pollution are soil erosion, leaking of minerals from rocks, and decaying of organic matter, while **human-made sources** include domestic, agricultural and industrial activities. Many water sources have become a dumping ground for wastes. Water pollution is one of the main causes of human diseases in India.

> Any physical, biological or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired use is called water pollution.

27.2.2a Sources of water pollution

There are two sources of water pollution on the basis of origin of pollutants:

(i) point sources. and (ii) non-point sources.

(i) ***Point sources.*** Those sources which discharge water pollutants directly into the water are known as point sources of water pollution. Oil wells situated near water bodies, factories. power plants, underground coal mines, etc. are point sources of water pollution.

(ii) **Non-point sources.** Those sources which do not have any specific location for discharging pollutants, in the water body are known as non-point sources of water pollution. Run-offs from agricultural fields, lawns, gardens, construction sites, roads and streets are some non-point sources of water pollution.

Water pollutants

River, lake and sea water may be polluted in many ways.

- **Domestic sewage** discharged into rivers from areas located on its banks
- **Industrial wastes** effluents from urban areas containing high concentration of oil, heavy metals and detergents
- **Minerals, organic wastes and crop dusting** from agricultural fields with phosphate and nitrogen fertilizers that reach lakes, rivers and sea (water becomes deoxygenated and poisonous, thus, cannot support aquatic life)
- **Chemical fertilizers, pesticides, insecticides, herbicides and plant remains**
- Industrial waste water containing several **chemical pollutants,** such as calcium, magnesium, chlorides, sulphide, carbonates, nitrates, nitrites, heavy metals and radioactive waste from nuclear reactor.
- **Excretory wastes of humans and animals in water bodies**
- **Disposal of urban and industrial waste matter into water bodies**

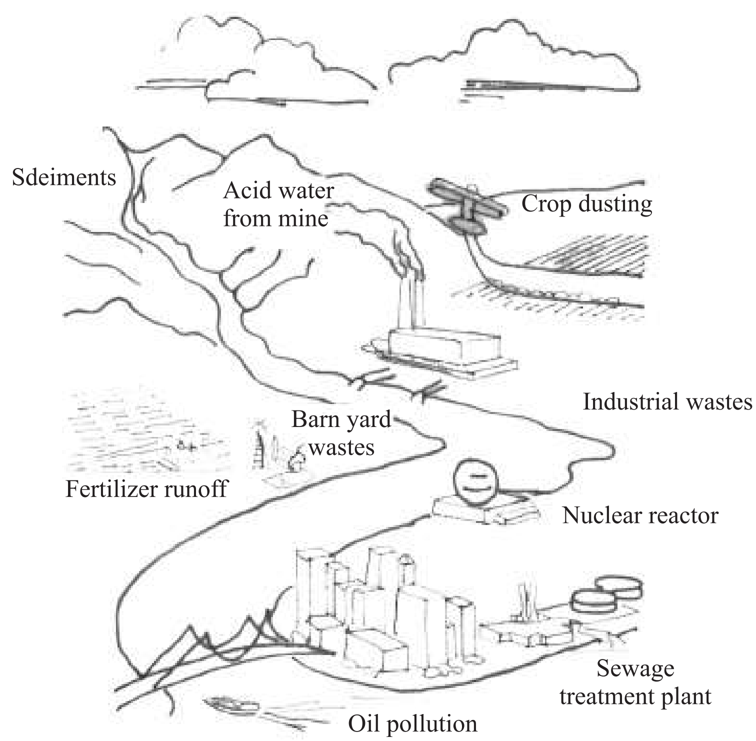


Fig. 27.2 Water pollution due to human activities.

27.2.2b Effects of water pollution

- Water pollution **adversely affects the fish and other aquatic life.**
- The presence of acids/alkalis in water **destroys micro-organisms**, thereby disturbing the self purification process in rivers.
- The toxic materials in water **cause serious health hazards** in human beings and other animals.
- Polluted water causes **spread of epidemics**, such as cholera, tuberculosis, jaundice, dysentery, typhoid and diarrhoea in human beings.
- The use of polluted water from lakes, ponds and rivers for irrigation of agricultural fields, damages crops severely and **decreases agricultural production.**
- The use of water contaminated with salts **increases alkalinity of the soil.**
- Heavily polluted water **affects the soil, decreases its fertility** and kills soil micro-organisms and even certain useful bacteria.
- Contamination of sea water due to oil slicks caused by the leakage of crude oil from oil tankers causes **ecological disasters** which results in the death of sea organisms including fishes.

The sources and effects of certain water pollutants have been given in the following table 27.2

Table 27.2: Some major disturbances in the ecosystem due to water pollution

Pollutant	Sources	Cause	Effect
Nitrates, phosphates, ammonium salts	Agricultural fertilizers, sewage, manure	Plant nutrients	Eutrophication
Animal manure and plant residues	Sewage, paper mills, food processing wastes	Oxygen deficiency	Death of aquatic animals
Heat	Power plants and industrial cooling	Thermal discharge	Death of fish
Oil slick	Leakage from oil ships	Petroleum	Death of marine life due to non availability of oxygen dissolved in water

Fertilizers and pesticides are widely used in agriculture. Their excessive use for increasing agricultural yield has led to the phenomenon of **eutrophication** and **biomagnification.**

Eutrophication

With the use of high yielding varieties of crops, the use of fertilizers and pesticides has increased a lot. Excess fertilizers may mix with surface water and may get drained into water bodies (surface runoff). The enrichment of water with nutrients such as nitrates and phosphates that triggers the growth of green algae is called **eutrophication.** (Fig. 27.3) This fast growth of algae followed by decomposition depletes the water body of its dissolved oxygen. As a result aquatic animals die of oxygen shortage.

Sewage and/or fertilizer run off from fields
↓
Enriched nutrient content in lakes (Eutrophication)
↓
Algae multiply to produce an 'algal bloom'
↓
Algae use up oxygen and begin to die
↓
Decomposers (bacteria) multiply and use more oxygen
↓
Organisms (such as fish) die due to lack of oxygen

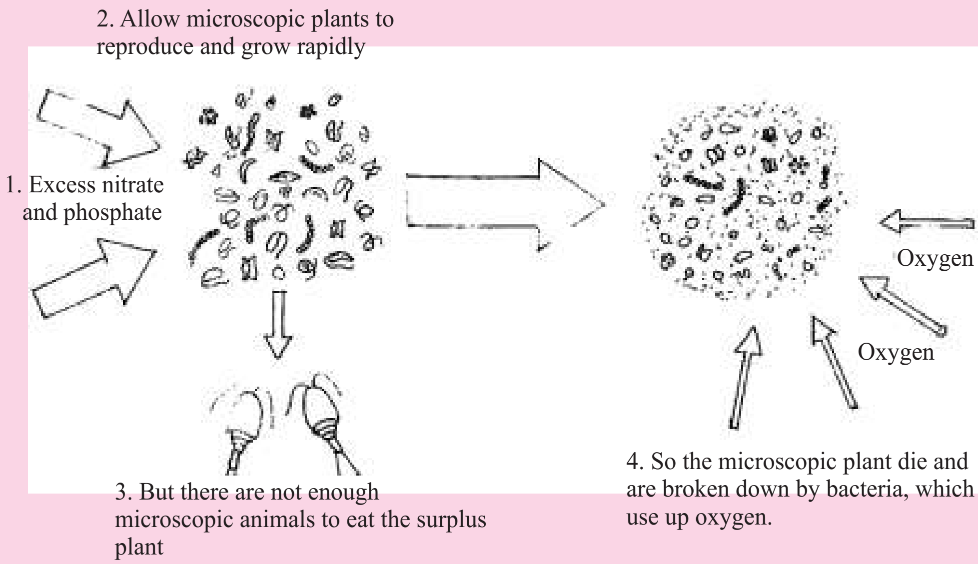


Fig 27.3 Sequence of events that may occur as a result of eutrophication

Biomagnification

Non-biodegradable pesticides, such as DDT are widely used for crop protection. Once they enter the food chain, their concentration keeps on increasing with each trophic level (steps of a food chain). As a result, accumulation of these compounds takes place in the body of top consumers over a period of time.

Entry of harmful non-biodegradable chemicals in small concentrations and their accumulation in greater concentrations in the various levels of food chain is called **biomagnification**.

Consider the following food chain. Is there any difference in the concentration of DDT in water and that in the body of the Pelican bird?

Water →	Algae →	Fish →	Pelican bird (top consumer)
0.2 ppm	77 ppm	500-600 ppm	1700 ppm

(ppm = parts per million)

DDT used in small quantities to kill mosquitoes can enter the food chain and may get concentrated in large concentration due to its non-biodegradable nature in the body of birds (top) consumer. This causes adverse effects, such as weak egg shells, resulting in decreased population. (Fig. 27.4).

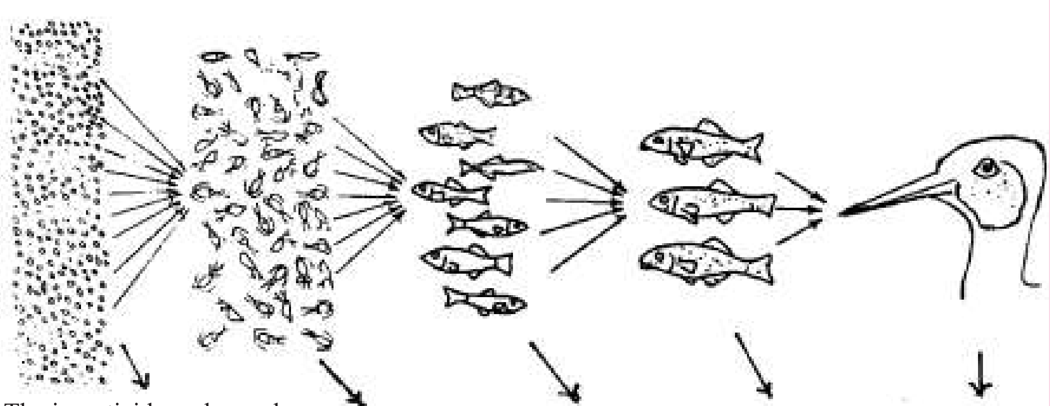


Fig. 27.4 How pesticides affect food chain

Table 27.3 and 27.4 show respectively the industrial sources of water pollution and sources and effects of some water pollutants.

Table 27.3 Sources of industrial pollution

Type of Industry	Inorganic pollutants	Organic pollutant
Mining	Chlorides, various metals, ferrous sulphate, sulphuric acid, hydrogen sulphide, ferric hydroxide surface wash offs, suspended solid, chlorides and heavy metals	
Iron and Steel	Suspended solids, iron cyanides, thiocyanate, sulphides, oxides of copper, chromium., cadmium and mercury.	Oil, phenol and naphtha.
Chemical Plants	Various acids and alkalies, chlorides, sulphates, nitrates of metals, phosphorus, fluorine, silica and suspended particles	Aromatic compounds
Pharmaceuticals		Protein, carbohydrates, organic solvents intermediate products, drugs and antibiotics.

Soap and Detergents	Tertiary ammonium compound alkalies.	Fats and fatty acids, glycerol, phosphates, polysulphonated hydrocarbons.
Food processing		Highly putrescible (easily rots) organic matter and pathogens.
Paper and Pulp	Sulphides and bleaching liquors	Cellulose fibre, bark, wood sugars organic acids,

Table 27.4 Some water pollutants, their sources and effect on human health

Pollutant	Source	Diseases in humans
Lead	Industrial waste	Nervous disorders, Kidney failure. blood poisoning
Tin	Industrial dust	Affects central nervous system (CNS) Affects, vision
Mercury	Industrial discharge	Affects central nervous system and peripheral nervous system, kidney failure, Numbness of lips, muscles and limbs, Blurred vision
Arsenic	Industrial discharge	Respiratory and skin cancer. Nervous disorder
Nickel	Aerosols, industrial dust	Pulmonary disorders, dermatitis
Cadmium	Industrial discharge	Kidney disorders, Pulmonary and skeletal diseases
Uranium, thorium cesium	Radioactive waste	Leucoderma, skin cancer

27.2.2c Prevention and control of water pollution

Water pollution can be controlled by

- **Treating industrial effluents** before discharging into rivers, separate channels for river and sewage water
- **Avoid contamination of rivers,** lakes and ponds by washing clothes, bathing. etc.
- **Not throwing waste,** food materials, paper, biodegradable vegetables and plastic **into open drains.**
- Setting up **sewage water treatment plants**
- Use of **septic tanks in houses** to avoid direct outlet of faecal matter and other wastes
- Effluents from distilleries and solid waste containing organic matter diverted to **biogas plants to generate energy**

- **Maintenance or safety standards** for the effluents discharged into the water system

27.2.2d Treatment of sewage

The sewage can be treated by a modern technique involving three steps— primary treatment, secondary treatment and tertiary treatment.

In **primary treatment** sewage is passed through a grinding mechanism. This is then passed through several settling chambers and lime is added to neutralise it. The neutralised sewage still contains a large number of pathogenic and non-pathogenic organisms and sufficient amount of organic matter.

In the **secondary treatment**, these neutralised effluents are passed through a reactor called UASB (Upflow anaerobic sludge blanket). In this reactor, the anaerobic bacteria degrades the biodegradable material into neutralised effluents. In this process, the foul odour and methane are released and the sewage is converted into clean water. This water is sent to aeration tanks where air and bacteria are added to it. This process is called biological or secondary treatment.

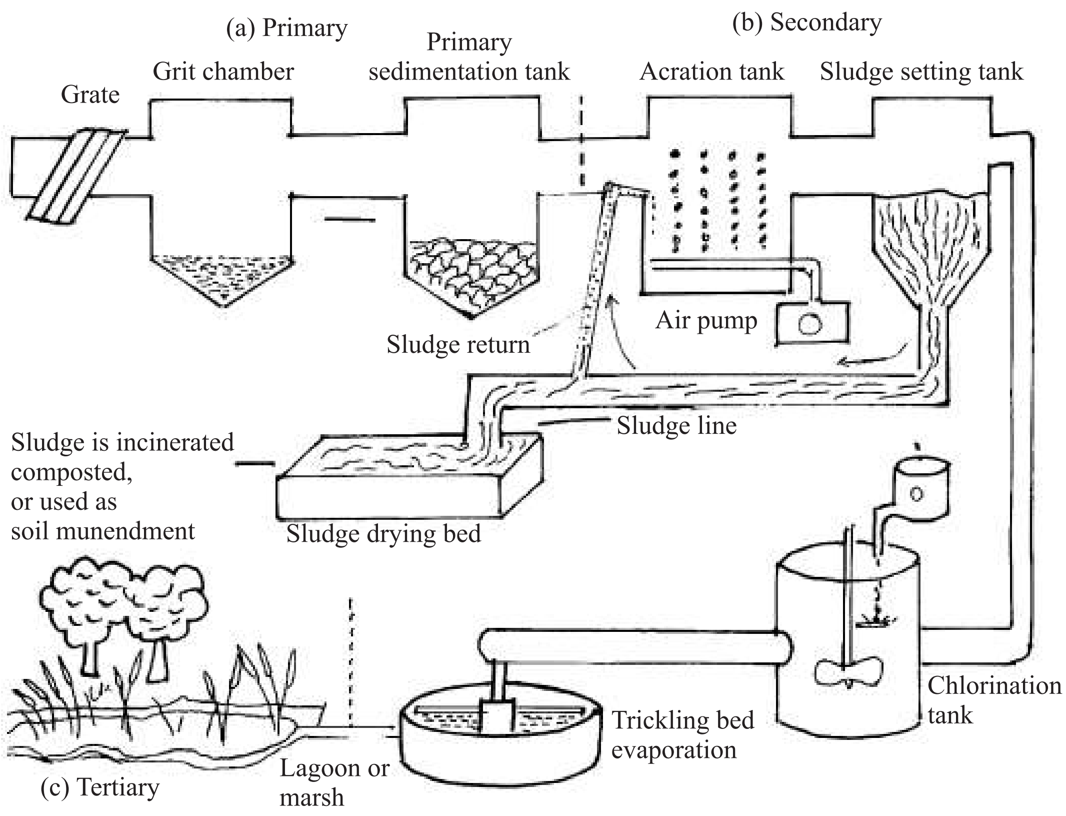


Fig. 27.5 Treatment of sewage

The water obtained as a result of secondary treatment is still unfit for drinking and needs further purification. This is done by **tertiary treatment.** In this treatment, which is a disinfecting process, final traces of disinfecting bacteria and any dissolved

Notes

organic solids arc removed. Then, the chlorination, evaporation and exchange absorption methods arc employed to obtain clean water.

INTEXT QUESTIONS 27.2

1. Give two examples of natural sources of water pollution.
   (i) ....
   (ii) ....
2. What is biomagnification?
   ....
3. Give the technical term for enrichment of water bodies with nutrients coming from fields.
   ....
4. Give one source of and one disease caused by from the following pollutants
   (i) lead ....
   (ii) Tin ....
   (iii) Nickel ....

27.2.3 Soil Pollution

Addition of substances that change the quality of soil by making it less fertile and unable to support life is called **soil pollution.**

27.2.3a Sources of soil pollution

Soil pollution is caused due to :

- Domestic sources : plastic bags, kitchen waste, glass bottles, and paper
- Industrial sources : chemical residue, fly ash, metallic waste, and
- Agricultural residues : fertilizers and pesticides.

Harmful effects of soil pollution

- Decrease in irrigated land thereby reduction in agricultural production.
- Decrease in soil productivity.
- Carry over of pollutants into the food chain.
- Damage to landscape

27.2.3b Control of Soil Pollution

- Judicious use of chemical fertilizers and pesticides.
- Proper and appropriate irrigation practices
- Conversion of farm wastes into compost and much use of bio fertilizers and manure in farming.

- Ensure use of pollution free or treated waste water only for irrigation.
- Recycling of waste material for example plastic, metal and glass are recyclable and incineration of non recyclable, wastes.

27.2.3c Soil Erosion

The process of detaching and removal of loosened soil particles by water (running water, ground water, rain, sea waves) and wind is known as soil erosion. Soil may be eroded by water and wind, each contributing towards a significant amount of soil loss every year in our country.

Types of soil erosion

Wind erosion

Erosion of large quantity of fine soil particles and sand from deserts by wind is known as wind erosion. It is spread over the cultivated land and thus, destroys fertility of that land.

Sheet erosion

When water moves over the land surface as a sheet, it takes away the topmost thin layer of soil. This phenomenon occurs uniformly on the slopes of hilly areas, riverbeds and areas affected by floods. This type of erosion is known as **sheet erosion**.

Gully erosion

When water moves down the slope as a channel, it scoops out the soil and forms gullies which gradually multiply and spread over a large area. This type of soil erosion is known as **gully erosion.**

Effects of soil erosion

Soil erosion may have several adverse effects such as,

- The top layer of productive land may be washed away.
- Roads, fences, bridges, trees and houses may get damaged.
- Fine soil may be transported far away.
- Crops and pasture lands may be destroyed either by being washed out or by getting covered with mud.
- Flooded fields may take a long time to recover and fertilizers may also be washed out leading to reduction in agricultural yield.
- Organic matter of the soil, residues or any applied manure, is relatively light-weight and can be readily washed off the field. Crop emergence, growth and yield are directly affected by the loss of natural nutrients and fertilizers in the soil. Seeds and plants can get disturbed or completely removed from the eroded soil.
- Soil erosion changes the composition of soil leaving infertile rock behind. Soil quality, structure. stability and texture may also be affected.

- The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture. Textural changes can in turn affect the water-holding capacity of the soil making it more susceptible to extreme conditions, such as drought.
- Sediment which reaches streams or water-courses due to soil erosion clog drainage and stream channels, deposit silt in reservoirs and reduce quality downstream water.

Causes of Soil Erosion

(i) Natural Sources

Water Erosion: During rainfall, drops of rain can break down soil aggregates and disperse them. The loosened soil particles are transported with the runoff water. If vegetation is depleted by drought, raindrops are free to hit the soil, causing erosion during rainfall.

Wind Erosion: Wind can move large amounts of soil. Wind erosion is a serious means of soil erosion. Blowing soil not only leaves a degraded area behind but can also bury and kill vegetation where it settles. Winds blow away the fine particles of soil during drought.

(ii) Anthropogenic (Produced by humans)

- Extensive cutting down of forests and trees exposes the ground surface to the direct impact of rain and wind. For example, in the absence of proper vegetation cover there is no interception of rainfall and the falling rain strikes the soil surface directly resulting in the throwing up of loose soil particles in the air which are washed away by rainwater.
- Construction work, mining, digging canals and ditches change the structure of soil. This accelerates soil erosion due to high-speed winds as well as rainwater.
- While making roads. soil is cut and massive digging of earth takes place. This leads to soil erosion by water or wind.
- Excessive use of plough, machines, fertilizers and irrigation may damage the land.
- In many areas, trees and grasses are depleted because of overgrazing by animals. This makes the soil susceptible to erosion.

Prevention of soil erosion

Some methods to control soil erosion are discussed below.

- The roots of the trees hold soil material together. Therefore, we should protect our forests and trees from being cut down. Afforestation means planting trees in place of cut-down forest trees. Planting of trees along river-side, waste lands and mountaineous slopes reduces excessive erosion of soil that takes place in these regions. It is also effective in controlling wind erosion.

- Grazing by domesticated animals in a planned way reduces soil erosion by protecting vegetation cover specially on the hill slopes which are more prone to soil erosion.
- Protected channels for water movement must be provided to stop soil erosion. 1f the waterways are properly maintained the speed of water gets reduced and soil erosion decreases. Dam should be constructed on rivers to control flooding and consequently soil erosion. This can also be done by diverting water to dry areas through canals, in a planned way.
- Obstructions known as bunds should be constructed in lands affected by gully erosion.
- Terracing is a method of farming to conserve the thin soil layer on the mountain slopes. This helps in controlling soil erosion and using water resources of these areas more economically and effectively for growing crops on these terraces.
- Ploughing and tilling of land along the contour levels in order to cause furrows to run across the land slopes is known as the contour ploughing. This method is most suited to areas that have a rolling landscape.
- Windbreaks which means planting trees to protect bare soil from the full force of wind also help in preventing soil erosion by wind. Windbreaks reduce the velocity of wind thereby decreasing the amount of soil that it can carry away.

INTEXT QUESTIONS 27.3

1. What is soil erosion?

   ....

2. Name the various types of soil erosion.

   ....

3. Name any two natural factors responsible for soil erosion.

   ....

4. How does terracing prevent soil erosion?

   ....

Biodegradable and non-biodegradable waste material

The waste generated from various sources can be categorized into two types:

(i) **Biodegradable waste** includes substances that can be degraded by microbes into harmless and non-toxic substances. Sewage, kitchen waste, agricultural and animal wastes like leaves, twigs. hay, dung, etc. are biodegradable waste.

(ii) **Non-biodegradable waste** cannot he easily degraded. Aluminium cans, plastics, glass, DDT, etc, are examples of non-biodegradable wastes. Radioactive wastes produced during nuclear reactions take a long time to decay and are harmful to human beings.

If a waste material is processed by some means and converted to a product, we call the process **recycling**. Recycling helps in efficient management of wastes and also reduces the load on natural resources.

Use of cow dung for the production of biogas is a good example of recycling of waste for the production of energy.

27.2.4 Noise pollution

Noise can be simply defined as "unwanted sound". It is generally higher in urban and industrial areas than in rural areas. Workers using heavy machinery are exposed to high noise levels for long period of work hours every day. Intensity of sound is measured in a unit called **decibel** or **dB.** *The lowest intensity of sound that human ear can hear is 20 dB.*

27.2.4a Sources of noise pollution

The major sources of noise pollution are :

- Use of loud speakers, loud music system and television at public places
- Means of transport i.e. automobiles, railways, aircrafts, etc.
- Heavy machines in industries fireworks

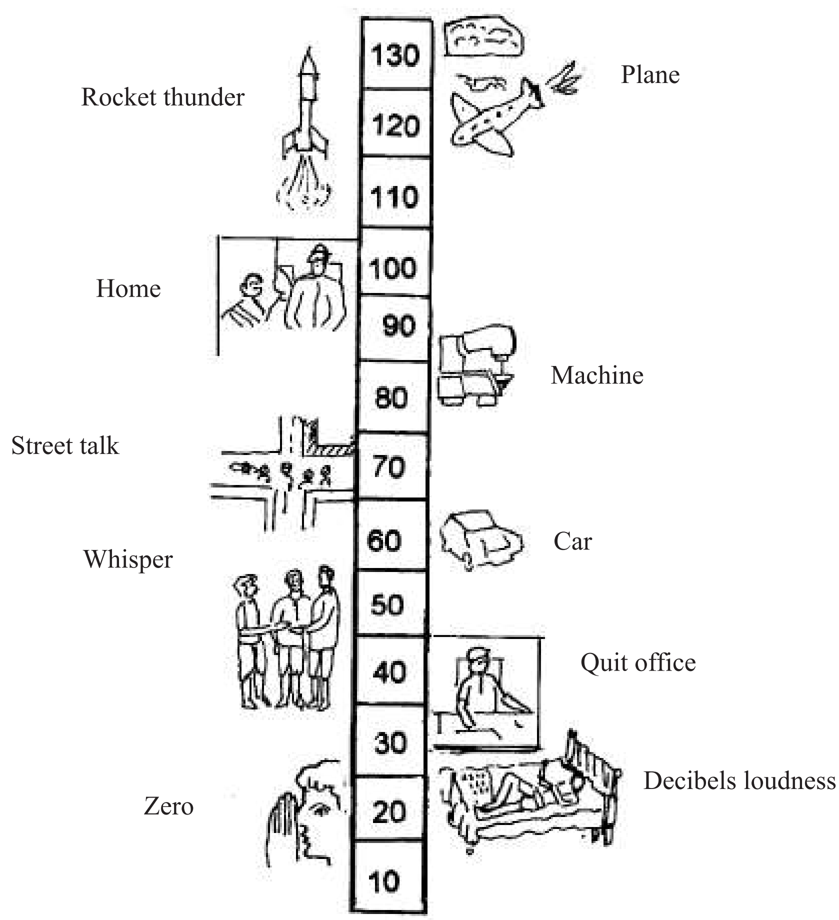


Fig. 27.6 Sources of noise pollution

27.2.4b Effects of noise pollution

- Inability to sleep, slow recovery from sickness.
- Irritability and interference in communication.
- Temporary loss of hearing, earache, sometimes even leading to permanent deafness.
- Inability to concentrate, headache.
- Ringing of ears (a feeling, sound coming from within the ear in a very quiet environment).
- Increased blood pressure, irregular heart beat.

27.2.4c Prevention and control of noise pollution

Following steps can be taken to control or minimize noise pollution :

- Control the noise emanating from your radio and television.
- Use automobile horn only in case of emergency.
- Do not burn fire crackers as they are noisy and also cause air pollution.
- Get all machinery and engines properly tuned and serviced at regular intervals and by the use of silencers.
- Use of sound proof cabins and sound-absorbing materials in the walls.
- A green belt of vegetation is an efficient absorber of noise.
- Not playing loudspeakers during odd hours. It is legally banned and should be reported to the police immediately.

27.3 GREENHOUSE EFFECT AND GLOBAL WARMING

In the earlier classes, you have studied about greenhouse effect and global warming. Greenhouse is an enclosure usually made of glass in which temperature inside is higher than outside. An increase in the percentage of greenhouse gases which prevent the escape of heat from earth, would increase the average temperature on earth worldwide known as greenhouse effect.

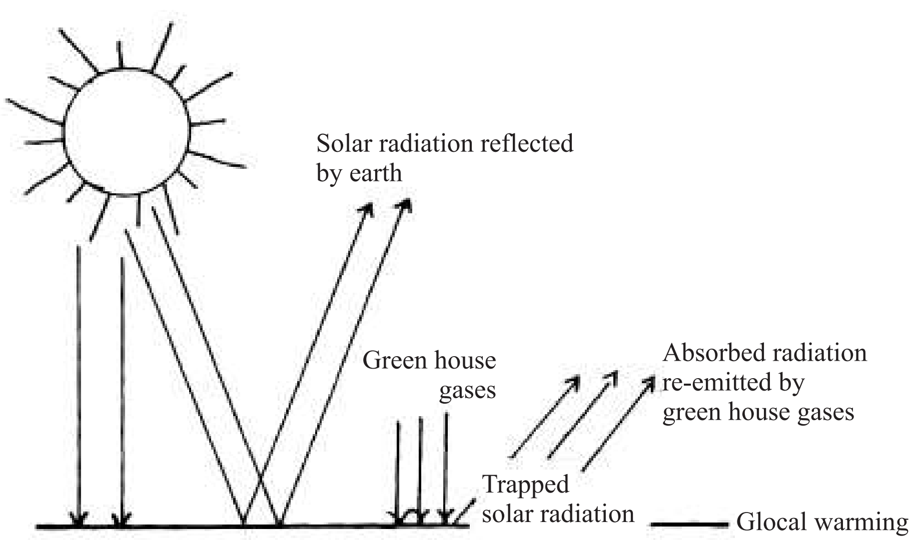


Fig. 27.7 (a) Green house effect

Greenhouse gases in the atmosphere behave much like the glass panes in a greenhouse. They allow sunlight to enter the atmosphere of earth. When the sunlight enters the surface of the earth, sun's energy is absorbed by land, water and biosphere. Some of this energy is reflected back to the atmosphere by earth. Some of this energy passes back into the space. However, most of the energy remains trapped in the atmosphere by the greenhouse gases causing global warming on earth.

27.3.1a Causes of global warming

Carbon dioxide (CO_2), Chlorofluorocarbons (CFCs), Methane (CH_4) and Nitrous oxides (N_2O) are the main greenhouse gases that cause global warming. An increase in the concentration of these greenhouse gases leads to an increased trapping of long wave radiations resulting in an increase in earth's temperature causing **global warming.**

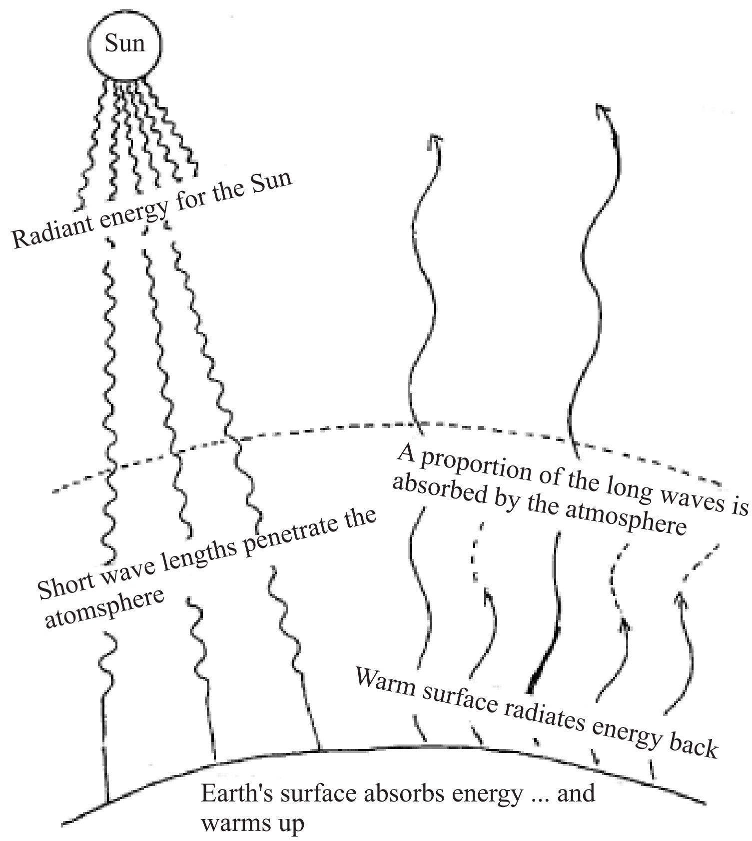


Fig. 27.7 (b) Global warming

There are various sources which add these greenhouse gases to the atmosphere.

- Human activities such as burning of fossil fuels in homes, industries and automobiles, biomass burning in agricultural practices etc. add large amount of carbon dioxide to the atmosphere.
- Marshes, paddy field, cattle sheds and biogas plants add methane to the atmosphere.

- Refrigerators, air conditioners etc emit CFCs to the atmosphere.
- Nitrogen oxides are added to the atmosphere by organic matter and fertilizers by denitrifying bacteria as well as automobiles.

27.3.1b Effects of global warming

- An increase in the atmospheric temperature will cause sea level to rise by 1 to 2 mm per year.
- Temperature near ocean surface would Increase and cause glaciers and polar ice sheets to melt faster. This would flood the low lying coastal areas and a number of islands.
- Global warming will produce severe heat waves during summers causing heat related illness and death.
- Due to increase in surface temperature, the parasites and pests will get adequate temperature to survive leading to an increase in their numbers. This will reduce the crop production and there will be more incidences of plant, animal and human diseases.
- Due to increased temperature of earth's atmosphere, the precipitation of water will increase. This will decrease the soil moisture content and lead to frequent downpours also.

27.3.1c Prevention and control of global warming

We can prevent global warming by reducing the production of greenhouse gases. This can be done by

- using energy efficient devices in automobiles and appliances other than fossil fuels.
- minimizing the use of fossil fuels such as petrol, diesel etc and opt for better alternatives like solar energy and other renewable sources of energy.
- reusing home wastes, newsprints, cardboards, glass and metals. By doing so we can reduce the CO_2 emission by 850 pounds annually.
- planting more and more trees. By planting more and more trees we can reduce the amount of CO_2 in the atmosphere. Because plants act as CO_2 sink as they take up CO_2 for photosynthesis.

27.3.2 The ozone hole : depletion of the ozone layer

The ozone layer present in the earth's atmosphere prevents the entry of sun's harmful ultraviolet (UV) radiations reaching the Earth's surface. Industrial use of chemicals called chlorofluorocarbons (CFCs) in refrigeration, air conditioning, cleaning solvents, fire extinguishers and aerosols (spray cans of perfumes, insecticides, medicines, etc.) damage the ozone layer. The ozone hole is formed as follows :

Chlorine contained in the CFCs on reaching the ozone (O_2) layer splits the ozone molecule to form oxygen (O_2) Amount of ozone, thus, gets reduced and cannot prevent the entry of UV radiations. There has been a reduction by 30-40% in the thickness of the ozone umbrella or shield over the Arctic and Antarctic regions.

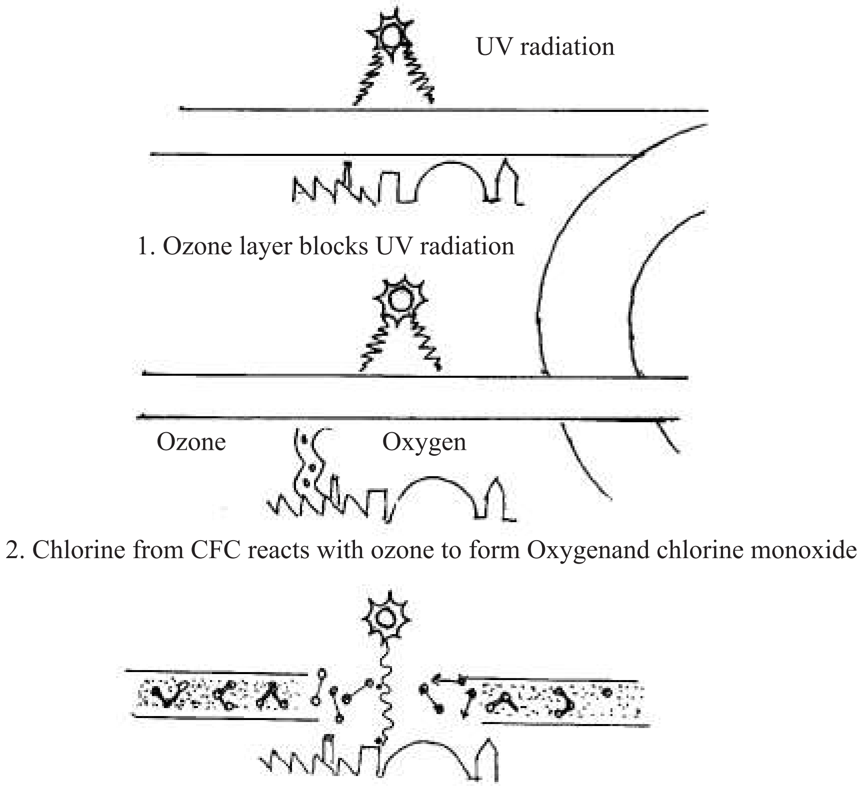


Fig. 27.8 Depletion of the ozone

27.3.2a Effects of depletion of ozone layer

- Sunburn, fast ageing of skin, cancer of skin, cataract (opaqueness of eye lens leading to loss of vision), cancer of the retina (sensitive layer of the eye on which image is formed)
- Genetic disorders
- Reduced productivity in the sea and the forests

27.3.2b Prevention of ozone layer depletion

Damage to the ozone layer can be prevented by :

- Reduced consumption of CFCs by adopting alternative technologies (substituting air conditioning gases by non-CFCs).
- Discouraging the use of spray cans containing aerosol.

27.3.3 Acid rain

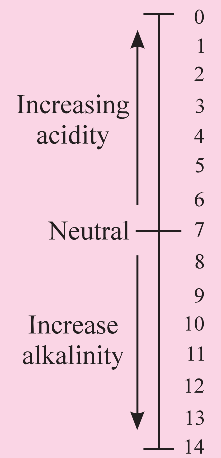
Acid rain occurs when Sulphur dioxide (SO_2) and oxides of Nitrogen (NOx) are emitted into the atmosphere, undergo chemical transformations and are absorbed by water droplets in clouds. This causes the formation of sulphuric and nitric acids in rain clouds. The droplets then fall to earth as rain, snow or mist. If rain falls through polluted air it picks up more of these gases and increases its acidity. This is called **acid rain**. This can increase the acidity of the soil, and affect the chemical balance of lakes and streams. Thus, acid rain is defined as any type of precipitation with a pH that is unusually low. A pH of less than about 5 is used as a definition of acid rain. Acid rain is a serious environmental problem that affects large parts of the world.

What is pH?

Acid rain is measured using a scale called pH. Because acids release hydrogen ions, the acid content of a solution is based on the concentration of hydrogen ions and is expressed as "pH." This scale is used to measure the acidity of rain samples.

- 0 = maximum acidity
- 7 = neutral point in the middle of the scale
- 14 = maximum alkalinity (the opposite of acidity)

The **smaller** the number on the pH scale, the more **acidic** the substance is. Rain measuring between 0 and 5 on the pH scale is acidic and therefore called acid rain. Clean rain usually has a pH of 5.6. It is slightly acidic because of carbon dioxide which is naturally present in the atmosphere. On the other hand, vinegar is very acidic and has a pH of 3.



The pH scale

27.3.3a Sources of acid rain

Sulphur dioxide (SO_2) is generally a byproduct of industrial processes and burning of fossil fuels. Ore smelting, coal-fired power generators and natural gas processing are the main contributors to sulphur dioxide in the atmosphere.

The main source of oxides of nitrogen (NOx) emissions is the combustion of fuels in motor vehicles, residential and commercial furnaces, industrial and electrical-utility boilers and engines, and other equipments.

27.3.3b Effects of acid rain

It causes acidification of lakes and streams and contributes to the damage of trees trees any many sensitive forest soils. In addition, acid rain accelerates the decay of building materials and paints, including heritage buildings, statues, and sculptures that are part of our nation's cultural heritage. Prior to falling to the earth, suphur dioxide (SO_2) and nitrogen oxide (NOx) gases and their particulate matter derivatives— sulphates and nitrates- contribute to visibility degradation and harm public health.

Some major effects of acid rain on vegetation, buildings and human health are given here.

Effect on surface waters and aquatic animals

Lower pH in surface water that occurs as a result of acid rain can cause damage to fish and other aquatic animals. Acidity releases aluminium into the water. This builds up as a layer of aluminium hydroxide in the gills of fishes. At pH lower than 5 most fish eggs do not hatch and lower pH can kill adult fish. As lakes become more acidic biodiversity is reduced.

Damage to plants

Acid rain is highly injurious to plants. Acid Rain depletes minerals from the soil and then it stunts the growth of the plant. It causes death of young shoots, leaves turn yellow and fall off. The fine root structure is damaged and the whole plant eventually dies. Acid rain can slow the growth of forests, cause leaves and needles to turn brown and fall off and die. In extreme cases trees or whole areas of the forest can die.

Effect on human health

The human beings may also be affected due to acid rain. Fine particles, formed from the same gases disolve in water and form as acid rain (sulphur dioxide and nitrogen dioxide) may cause illness in humans.

Damage to soil

Acid rain may make the soil more acidic. It may cause mineral nutrients to be washed away. It can release toxic chemicals such as aluminium and mercury into the soil. Thus, acid rain could make soil less fertile. The microbes which are unable to tolerate low pHs may be killed due to acid rain. This is because the enzymes of these microbes may be denatured by the acid.

Other adverse effects

Acid rain can also cause damage to certain building materials and historical monuments. Acid rain can cause erosion of ancient monuments. This is because the Sulphuric acid in the rain chemically reacts with the calcium in the stones (limestone, sandstone, marble and granite) to create gypsum. Which then flakes off'. Acid rain also causes an increased rate of oxidation for iron affecting iron furnitures, grills, doors, windows and other materials etc. Acid rain can also reduce visibility due to presence of sulphate and nitrate in the atmosphere due to acid rain.

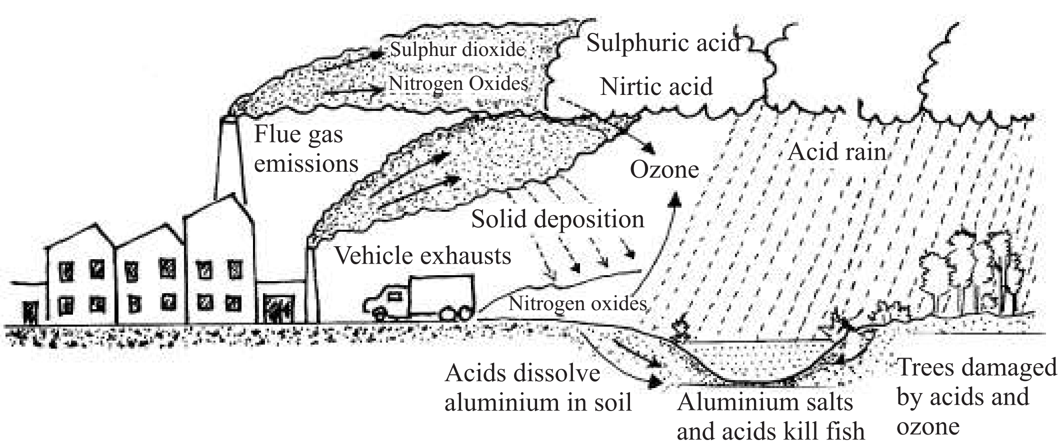


Fig. 27.9 Sources and effects of acid rain.

27.3.3c Prevention of acid rain

- There are several ways by which sulphur dioxide and nitrogen oxide emissions can be reduced.
- Coal can be crushed and washed before burning.
- Oil can be treated to remove sulphur.
- Cleaning systems can be fitted into chimneys to remove sulphur dioxide before it can be released into the atmosphere.
- Improved furnaces can be built which burn fuel more effectively and produce less pollution.
- Vehicle exhausts can be fitted in vehicles, which remove pollutants from engine emissions.

INTEXT QUESITONS 27.4

1. Name any two biodegradable pollutants.

   ....

2. Mention two source of noise pollution.

   ....

3. Name any two green house gases.

   ....

4. What is acid rain?

   ....

27.3.4 Radiation–an environmental pollutant

Radiation is one of the chief forms of energy consisting of high energy particles. Radiation could be natural (solar and cosmic) or and human (nuclear). Radiation has also become a major factor causing environmental pollution.

Radiation may have both short term or long term effects. They can further be divided functionally into :

- Ionising and
- Non Ionising (Table 27.5) radiations

Table 27.5: Ionizing and Non Ionising Radiations

Type	Ionizing	Non ionizing
Examples	Alpha, Beta, Gamma and X-Ray	Ultraviolet radiation
Properties	Short wave lengths, high energy.	Higher wave lengths, low energy
Effects	Causes ionisation in cells photo products	Damage through toxic
Harmful Effects	• Deep penetrating power effects both external & internal organs	• Only superficial tissues are damaged

	• Breakage of chromosomes • Gene mutation and genetic variations • Cancer of bone marrow (Leukaemia) • Loss hair • Male sterility	• Kills micro-organism and egg of fish & amphibians • Prevents synthesis of DNA and RNA, Cell division • Skin cancer in humans

> Inhabitants of Hiroshima (Japan) exposed to nuclear fallout had no children for a long time or had deformed infertile offsprings.

Effect of exposure to ionizing radiations on living organism

Time of exposure		**Effect of exposure**	
millisecond	⟶	energy absorption	
↓		↓	
few seconds	⟶	molecular changes	
↓		↓	
minutes	⟶	metabolic changes	genetic changes
↓		↓	↓
hours	⟶	cell damage	mutations
↓		↓	↓
hours to years	⟶	cell death	abnormal growth
		↓	↓
		death of the organism	←

Nuclear Radiation and its harmful effect

Radiations emitted by **nuclear** substances or wastes (fallout) or from atomic power plant or an atomic explosion cause **nuclear radiation**. Nuclear wastes continue to emit radiation for a very long period.

Radioactive Iodine (^{131}I) and Strontium (^{90}Sr) are two **nuclear wastes** from an atomic explosion and may cause cancer of thyroid and cancer of bone narrow/ respectively. By entering food chain they also get accumulated in high concentration in the body of the top consumer causing harmful effect on the health of both humans and animals.

Nuclear power plants

Nuclear power plants help in generating electrical energy by utilising heat generated by nuclear reactions. India has some of its nuclear power plants at Narora in U.P., Kalpakkam in Tamil Nadu, and Kota in Rajasthan etc.

Disposal of nuclear wastes

It is essential to dispose nuclear wastes carefully as it remains radioactive (emits radiation) for a very long time. Waste is normally packed in sealed lead containers as lead absorbs all radiation. These containers are then dumped in deep pits or in high seas.

Protection against radiation

Exposure to radiation may affect both young and adults. Entry of children and pregnant females is prohibited in the nuclear installations. Nuclear radiation may have the following harmful effects

- Cancer in child
- Male sterility
- Malformation of the growing embryo

People working in the nuclear establishments can be provided protection against radiation by

- Increasing the distance between the source of radiation and the working people.
- Use of lead shields to serve as absorbing material.
- Thick concrete walls around the reactor to work as shields
- Use of protective apron and gloves for people.

Applications of Radiation

Despite all the harmful effects of radiation, their use in various fields for the benefit of mankind is gradually increasing as show in Table 27.6. Almost all our sources of energy originate from **solar radiation**. For example **photosynthetic process** for the formation of food and fossil fuel. Artificially generated radiation are also used for various purposes.

Table 27.6: Applications of Radiation

Field	Use
1. Industry process	Radiation detector for metals, moisture, quality,
2. Nuclear Energy	Power Plants
3. Communications	Radio, TV, Satellite,
4. Medicine	Radiation Tomography (CAT Scan), X ray for anatomy Diathermy to relieve pain by localised heating Artheritis Destruction of cancerous growth Sterilisation of surgical instruments
5. Scientific research	Radiocarbon dating - to determine the age of objects or fossils

INTEXT QUESTIONS 27.5

1. Give one example each of natural and man made radiations
   (i) ....
   (ii) ....
2. List two wastes of atomic explosion.
   (i) ....
   (ii) ....
3. Name the containers which should be used for the disposal of nuclear wastes.
   ....
4. List any two harmful effects of nuclear radiations.
   (i) ....
   (ii) ....

WHAT YOU HAVE LEARNT

- Pollution is the addition of undesirable material in the environment.
- A pollutant is a constituent which when added adversely affects the environment.
- Pollution may be of different types such as Air, Water, Soil, Noise, Thermal or because of radiations.
- Pollutant could be gaseous, particulate or a physical factor.
- Air Pollution turns clear, odourless, air into hazy and/or smelly.
- Air pollution causes a number; of respiratory problems such as anaemia, heart palpitation, choking and eye irritation.
- Plants may show chlorosis, necrosis, stunted growth, leaf and fruit fall due to air pollution.
- Air pollution caused by suspended particular matters may be controlled by use of filter bags, electrostatic precipitators and by planting vegetation.
- Water may be polluted by domestic, agricultural or industrial activities.
- Biodegradable matter present in water causes depletion of oxygen content and death of aquatic life.
- Uncontrolled release of pollutants by the industry has made water in water streams unfit for human consumption.
- Use of non biodegradable pesticides (DDT etc.) gives rise to the phenomenon of biomagnification.

- Soil pollution may be caused due to pesticides, radioactive wastes, domestic wastes etc.
- Noise is unwanted sound which may cause deafness, lack of concentration, high blood pressure and nervous disorders.
- Soil pollution includes addition of substances that reduce the fertility of the soil.
- Waste can he classified into biodegradable (e.g. cow dung, vegetable peels, paper, wood etc.) and non-biodegradable (e.g. aluminium cans, glass bottles, plastics, DDT etc.).
- Recycling of wastes such as cow dung, paper, sewage and rice husk, into useful products help in conservation of resources.
- Ozone provides a protective layer against harmful ultra-violet rays coming from the sun. Excessive use of chemical, such as CFCs used in spray cans, gas used in refrigerators and air conditioners, lead to thinning of the ozone layer.
- Accumulation of high concentration of carbon dioxide has led to the phenomenon of global warming (due to green house effect), and has resulted in increased earth's temperature. The climate has changed.

TERMINAL EXERCISES

1. Which of the following are biodegradable materials?

   Aluminium, wood, fruit peels, DDT, paper, glass, dung
2. Which gaseous pollutant has the ability to absorb infra-red radiations?
3. A ship carrying oil from the gulf region collides with hug rocks and get damaged. It this just news or has some serious consequences? Give your opinion in one sentence.
4. To set up a new industry, a large forest area had to be cut. List four ways in which the environment in that area may be affected.
5. List any three ways in which noise from various sources can affect the well-being of a person. Suggest few methods to control noise pollution.
6. What does 'Global warming' mean ? Name the gas responsible for this phenomenon and why should it be considered an environmental problem.
7. How would you classify the waste generated at home? What is the difference between the different groups? How would you manage this waste so that it cause least pollution?

ANSWERS TO INTEXT QUESITONS

27.1
1. Addition of unwanted substances to the environment which have adverse effects on organisms.
2. Air pollution, water pollution, land polluton, noise pollution.
3. Respiratory problems in humans, chlorosis (loss of chlorophyll in plants).

27.2
1. Soil erosion/leaking of mineral from rock/decay of organic matter (any two)
2. Accumulation in greater concentration of chemicals at higher levels of food chain.
3. eutrophication
4. See table 27.3

27.3
1. Detachment and removal of soil particle by flowing water and blowing wind.
2. Wind erosion, sheet erosiion, Gully erosion.
3. Wind, water

27.4
1. Sewage, kitchen, waste, certain agricultural waste, hay, dung etc. (any two)
2. loud speakers/sound of automobiles/sound from heavy machines/fire works (any two)
3. Nitrogren oxides, methane, carbon dioxide, chlorofluoro carbons. (an two)
4. When harmful gases like SO_2 and NO_x in the atmosphere dissolve in water to form acid during veins.

27.5
1. Solar/cosmic (any one); x-ray/gamma rays (any one)
2. Radioactive Iodine and strontium
3. Lead containers
4. (i) cancer (ii) gene mutations.

28

NUTRITION AND HEALTH

Food is the basic necessity of life. We all know that regular supply of food is essential for human beings in order to keep fit and to carry on all the life processes. We eat a large variety of food according to our taste, availability and body requirement. In this lesson we will learn about nutritional requirement of the body and the problems of health related to specific deficient nutrition.

OBJECTIVES

After completing this lesson you will be able to :

- *define the terms food, nutrition and disease;*
- *explain the biological significance of food;*
- *differentiate between micro- and macronutrients;*
- *list the sources and describe the functions of carbohydrates, fats, proteins, vitamins, minerals, water and roughage;*
- *explain the energy requirement of the body;*
- *emphasise the need of balanced diet especially for growing children, persons in different occupations and lactating mothers;*
- *list the common deficiency diseases PEM, minerals and vitamins; deficiency, obesity, hypervitaminosis, their symptoms and recommended food sources.*

28.1 WHAT IS FOOD

Food is any substance which performs the following functions in the body :

(i) yields enegy for life processes,

(ii) builds up new cells during growth,

(iii) repairs worn out (damaged) tissues,

(iv) aids in production of useful body compounds.

Biological Classification of Food

Food can be classified into three categories based on their functions (Table 28.1)

(i) Energy providing foods

(ii) Body building foods

(iii) Protective/regulatory foods

(i) **Energy providing foods** : These are rich in carbohydrates and fats and provide energy on biological oxidation in the body. Example : cereals, sugar, fats, oils, jaggery, coconut, and groundnuts.

(ii) **Body building foods :** These are rich in proteins and help in the formation of new tissues. Example : legumes, milk, egg, meat, fish, pulses, nuts and oilseeds.

(iii) **Protective/regulatory foods :** These are rich in minerals, vitamins, roughage and water. They help in regulaiton of internal metabolism in the body. Example : green leafy vegetables, fruits, amla, guava, citrus, oranges and water melon.

Table 28.1 The three food groups

Food group	Major nutrients	Food sources
Energy providing food	Carbohydrate and fats	• Cereals (rices, wheatm maize) • Sugar • Fats (oil and ghee) • Jaggery
Body building food	Proteins	• Milk • Legumes • Egg white • Meat (chicken, mutton, fish)
Protective food	Minerals and vitamins	• Green leafy vegetables • Roughage such as fruits, beans and other lagumes. • Amla, guava, citrus, orange, etc.

28.2 NUTRITION

> Nutrition is the sum of the processes by which an organism takes in, metabolises and utilises food substance for its various biochemical activities.

Nutrients are the organic or inorganic substances which help in our survival and in maintaining proper health. A nutrient supplies energy to the body, builds and repairs body tissues and regulates the body metabolism.

On the basis of quantity required by the body, nutrients are classified into two categories :

(i) Macronutrients (ii) Micronutrients

Macronutrients (Nutrients required in a large amount) : Carbohydrates, fats, proteins and water contained in food comprise macronutrients.

Micronutrients (nutrients required in small amount) : Vitamins and minerals form only a small fraction of the total weight of the food.

> One molecule of glucose yields 38 ATP molecules
> 1 ATP gives 34 kJ
> ∴ 1 mole of glucose yields $38 \times 34 = 1292$ kJ upon complete biological oxidation

Let us learn in some detail about these nutrients.

28.2.1 Carbohydrate

Carbohydrates are the chemical compounds made up of carbon, hydrogen and oxgyen. They release energy on biological oxidation with the help of cellular enzymes. They are the cheapest source of energy. Complete biological oxidation of one gram of carbohydrate yields about 18 kilo joules of energy. One kilo calorie of heat is required to raise the temperature of 1 litre of water through 1°C.

1 kilocalorie = 4.18 kJ

1 kilojoule = 1/4.18 × 1000 calories

Carbohydrates in the diet provide about 60-80% of total energy required by our body.

Types of carbohydrates

The three types of carbohydrates that we consume in our food are :

(i) sugars (ii) starch (iii) cellulose (Table 28.2)

Table 28.2 Carbohydrates required in our diet

Carbohydrates			
Sugar		**Starch**	**Cellulose**
Monosaccharides Glucose (found in molasses, honey and sweet fruits like grapes) Fructose (Found in honey and ripe fruits)	Disaccharides Sucrose (found in sugarcane and sugar beet) Maltose (found in sprouted cereals) Lactose (found in milk)	Storage form of carbohydrates (found in cereals, grains, seeds, roots, potato, rice, wheat, barley, maize, nuts etc.)	Found in cellulose of plants, seed coats, fruits, vegetables and cereals

Common sources of carbohydrates

- **Starch**

  Cereals (wheat, rice, maize), millets (bajra, jowar, barley), roots and tubers (sweet potato, tapioca, potato)

- **Sugar**

  Cane sugar, beet root, fruits (banana, mango, sapota or chiku), milk, honey, and cereals.

- **Cellulose**

  Cell walls of fruits, vegetables, and cereals

  During digestion both starch and sugars are absorbed as glucose. The surplus glucose is changed into glycogen which is stored in the liver for subsequent use. (For detail refer to lesson 13)

  Cellulose is a fibrous substance which is not digested by human body. However, it serves as roughage and facilitates bowel (stool) movement.

  A normal person needs about 400-500 grams of carbohydrates daily in the diet. A growing child, a lactating mother and a person doing hard physical work need more carbohydrates than an average person because of their greater energy requirements. The percentage of carbohydrates in different food items is given in table 28.3 below :

Table 28.3 Percentage of carbohydrates present in some common food items

Food	Percentage (per 100 g of food)
Sugar	99.4
Rice	78.2
Wheat flour	69.4
Potato	22.7
Banana	24.7
Mango (ripe)	11.8
Green gram	69.4
Red gram	57.6
Carrots	1.6
Cow's milk	4.4

Functions of carbohydrates

- Lactose sugar promotes growth of intestinal bacteria that facilitate the absorption of calcium.
- Excess carbohydrates are converted into glycogen and fat and serve as reserve sources of energy.
- Cellulose provides faecal bulk and helps in bowel movement.
- Glucose is the only source of energy for the central nervous system.

28.2.2 Fats

Fats are members of lipids. Like carbohydrates, fats are also made up of carbon, hydrogen and oxygen. However fats contain more carbon and hydrogen and less oxygen. Fats are the richest source of energy. Fats are insoluble in water but soluble in solvents like acetone, and benzene. Chemically fats are triglycerides.

One gram of fat on biological oxidation gives about 9.0 kcal (37 kilojoules) of energy.

Sources :

Animal sources : Ghee, butter, fish oil, meat, egg.

Plant sources : Vegetable oil from the seeds of coconut, mustard, sunflower, safflower, milk, nuts, soyabean, cheese.

Functions of fats

- fats are the richest sources of energy. On biological oxidation, one gram of fat provide 37 kJ of energy.
- Form structural components of cell cytoplasm and cell membrane.
- help in absorption of fat-soluble vitamins A, D, E and K
- act as precursor of various hormones.
- can be stored for subsequent use by the body.
- sub-cutaneous fats serve as insulators in the body thus protecting it from cold weather and pressure.
- stored fat provides padding to protect the vital organs of the body from shocks.
- help in the synthesis of vitamin D and steroid hormones in the body.

28.2.3 Proteins

Proteins are extremely large molecules composed of many amino acids. Proteins are complex organic compounds rich in carbon, hydrogen, oxygen, nitrogen and sometimes phosphorous and sulphur also.

Proteins are needed by the body for :

- growth and development
- repair and maintenance
- the synthesis of antibodies, enzymes, and hormones

They can also be used as a source of energy. 1 gram of protein yields about 4 kcal of energy. Building blocks of proteins are the amino acids. You have already learnt in lesson one that there are only about 22 different amino acids of which almost all proteins found in living organisms are made. Nutritionally, amino acids belong to two categories :

(a) **Essential amino acids :** These are the amino acids which can not be synthesised in the animal body and must be supplied with food e.g. leucine.

(b) **Non essential amino acids :** which can be synthesised in the body particularly from carbohydrates and need not be supplied in the diet. e.g. alanine.

Digestion of protein

Like fats, proteins can not be absorbed in the tissue until they are broken down into their amino acids. Digestion of proteins occurs in stomach and small intestine where acids and enzymes break up proteins into amino acids.

Sources :

Animal sources : Milk, egg, fish, bean, meat, and liver. contain adequate amount of essential amino acids.

Plant sources : Whole cereals (wheat and maize), pulses, nuts, grams, and legumes.

Intake of more than one plant protein in the same meal (dal-roti, sambar-idli) can produce a mixture containing all the essential amino acids.

Proteins are structural components of body. For example, protein **keratin** is present in hair and nails. Collagen present in the connective tissue is also an example of protein. Actin and myosin are examples of contractile proteins present in the muscles.

Functions of proteins

- Proteins are required for building and maintaining body tissues.
- Proteins are found in all the enzymes e.g. Trypsin, pepsin and rennin.
- Some proteins function as hormones, to regulate many body functions. For example, insulin is a hormone which regulates blood glucose level in the body.
- Proteins also act as antibodies and protect the body from antigen (foreign agent).
- Transport protein carries different substances from blood to the tissues in the body. Haemoglobin is a transport protein.

28.2.4 Vitamins

Vitamins are complex chemical substances required by the body in very small amounts. They do not yield energy but act as biocatalysts in the body. They are essential for good health and protect the body from various diseases. They are essential for the utilisation of other nutrients that we take in our diet.

Vitamins are grouped into two classes :

(a) Water soluble vitamins are vitamins B complex and C

(b) Fat soluble vitamins are vitamins A, D, E and K

Since vitamins cannot be made in our body except for vitamin D, they need to be supplied through food that contain them. Table 28.4 lists the vitamins and their sources as well as the daily requirements in the body, deficiency diseases and symptoms in 13-15 year old boys and girls.

Table 28.4 Vitamins : their functions, sources and deficiency diseases.

Vitamin	Daily requirement	Function	Best food sources	Deficiency diseases	Symptoms
			1. Water Soluble Vitamins		
Vitamin B_1 (Thiamine)	1.3 mg (boys) 1.2 mg (girls)	Carbohydrate metabolism; sharpens appetite; functioning of heart, nerve and muscles	Yeast; liver; milk; cheese; leafy vegetables; meat; whole grain cereals	Beri-beri	Pain in hands and feet. Swelling of body. Paralysis of limbs. Oedema.
Vitamin B_2 (Riboflavin)	1.6 mg (boys) 1.4 mg (girls)	Carbohydrate and protein metabolism; keeps skin healthy;	Milk; liver meat; eggs peas; yeast; whole grains; green leafy vegetables.	Riboflavinosis; photophobia	Retarded growth and mental disorder. Cracking of skin at corners of mouth. Lesions of eyes.
Vitamin B_3 (Niacin)	1.8 mg (boys) 1.5 mg (girls)	Coenzyme for protein, fat and carbohydrate metabo lism. Keeps the skin healthy.	Fish; eggs; meat; legumes; whole grains; leafy vegetables; peanuts; bean; tomato; potato.	Pellagra	Dermatitis (bad skin), diarrhoea (loose motions) dementia (mental disorder).
Vitamin B_{12} (Cyanocobalamine)	0.2-100 mg	Blood formation, Nervous tissue metabolism, Nucleic acid synthesis.	Liver; fish; cheese; milk; eggs; meat.	Pernicious anaemia.	Paleness of skin; breath lessness; retarded growth.
Vitamin C (Ascorbic Acid)	40 mg	Resistance to infections; keeping teeth, gums and joints healthy; healing of cuts and wounds; maintenance of connective tissue.	Amla, cabbage; tomatoes, lemon; orange; mangoes; chillies, guava, pineapple; sprouted grams.	Scurvy	Bleeding gums; pain in joints; general weakness.
			2. Fat Soluble Vitamins		
Vitamin A (Retinol)	750 mg	Maintenance of vision and skin; Essential for synthesis of visual pigment	Milk, cheese, butter, eggs codliver oil, carrots mangoes papaya, yellow pumpkin spinach, sweet potato	Night blindness. Xerophthalmia or keratinol acid. Dry skin	Cannot see in dimlight, (night blindness); Retarded keratinization of epithelia

Notes

Vitamin D (Calaciferol)	200 IU	Keeps teeth and bones healthy, absorption of calcium and phosphorus	Milk; cheese; egg yolk; cod liver oil, fish; butter; expo sure to sunlight.	Rickets in children; (Fig. 28.1) Osteomalacia in adults	Failure of growing bones to calcify; bow legs pigeon chest; softening of bones Painful bones; spontaneous fracture.
Vitamin E (Tocopherol)	Trace	antioxidant; ageing vitamin	Grains vegetable oil, green leafy vegetables, nuts, liver	reproduction failure in males and females	Sterlity in males, miscar-riage, or death of embryos during pregnancy in females.
Vitamin K (Phylloqu-inone)	Trace amount	Clotting of blood	Green leafy vegetables; soyabean; tomatoes.	Faulty blood clotting; haemorrhage.	Delayed blood clotting.

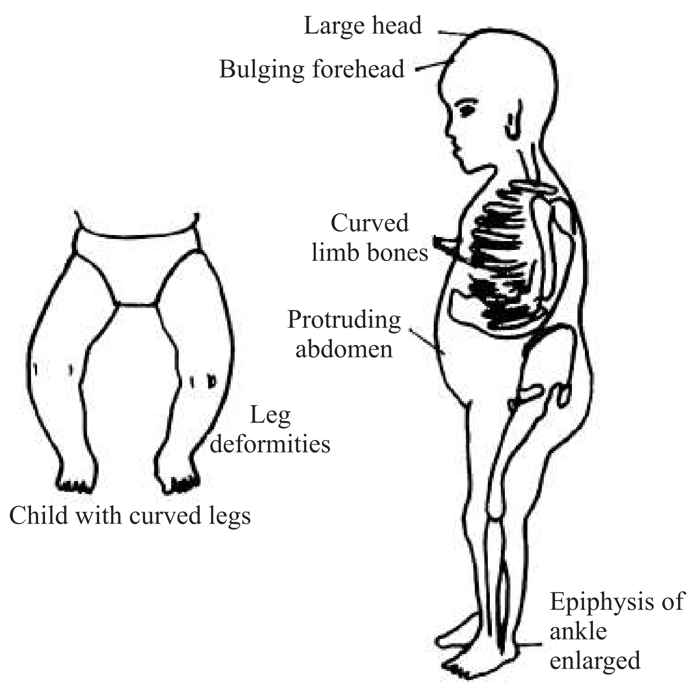


Fig. 28.1 Child with rickets

28.2.5 Minerals

Minerals are micronutrients required in varying amounts for proper functoning, normal growth and keeping good health of our body. They are inorganic elements, occuring in the form of their salts e.g. calcium, potassium, sodium, phosphorus, iron etc. They do not supply energy to our body but are essential for protection against diseases and also have role in body functions.

Minerals	
Required in larger amounts	**Required in trace amounts**
Calcium, Phosphorus Sodium Potassium, Sulphur Chloride, Magnesium.	Iron, Iodine, Zinc, Chromium Cobalt, Copper, Fluoride, Manganese, Molybdenum Selenium, and Boron

Functions

Minerals perform the following functions :

- Essential for development of bone and teeth e.g. calcium, phosphorus.
- Regulate the fluid balance and acid alkalinity of body fluids e.g. sodium, potassium, chloride.
- Iron is major component of haemoglobin, which helps in transport and release of oxygen.
- Iodine is required for the synthesis of thyroid hormone thyroxine, which regulates the rate of oxidation energy sources within cells.
- Zinc, coper and magnesium regulate a host of vital reactions in our body.

Table 28.5 Lists the minerals, their sources, function, deficiency diseases and symptoms

Table 28.5 Minerals required by and in our body, their sources and functions

Minerals	Functions	Food sources	Deficiency diseases	Symptoms
1. Calcium	Formation of bones and teeth, necessary for nerve, teeth and muscles	Milk and milk products; fish; meat; beans; green leafy vegetables; brocolli, tapioca; cereals.	Rickets; Oesteomalacia loss of teeth	Softening of bones; deformities; pain in bones; enamel.
2. Iron	Formation of haemoglobin; acts as carrier of oxygen.	Liver; green leafy vegetables; eggs, spinach; groundnuts; cereals; jaggery.	Anaemia.	Loss of weight; pale appearance; tiredness; loses of appetite.
3. Phosphorus	Formation of bones and teeth	Milk; cereals; green leafy vegetables; nuts, bajra meat.	Rickets and Oesteomalacia;	Softening of bones; bowlegs; pigeon chest.

4.	Iodine	Metabolic control of hormone thyroxine; controls growth and mental ability.	Iodized salt; sea food; fish; green leafy vegetable	Goitre (Fig. 28.2)	Enlargement of thyroid gland; retarding of physical and mental growth.
5.	Sodium and Potassium	Maintenance of normal water balance in the body; associated with conduction of nerve impulse.	Common salt; meat; poultry; fish; fruits; cereals; egg; spinach; pulses; potato; yoghurt.	High blood pressure; Oedema; Osmotic pressure disturbed.	Severe malnutrition; high blood pressure; fatigue; loss of appetite; vomiting.

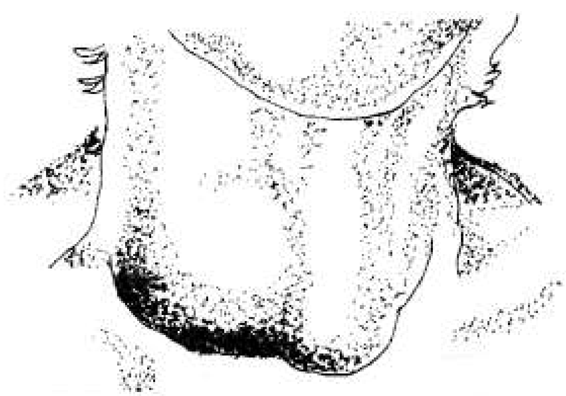


Fig. 28.2 Patient with goitre

28.2.6 Water

Water is an important constituent of our diet. 75% of an infant body and 60% of an adult body is nothing but water. Various functions of water are as follows.

- essential for the transport and digestion of food material.
- excretes wastes.
- maintains the body temperature.
- acts as solvent in various reactions in the body.

Sources of water

Water is replenished by :

- drinking of plain water or of tea, coffee, milk and fruit juices.
- eating fruits, vegetables and fish.
- some amount of water comes as a by-product of oxidation of glucose in the body.

28.2.7 Roughage

Roughage is the fibre present in some food items like fruits and vegetables. Though roughage is not a food, it forms an important part of our diet. Roughage consists mainly of cellulose.

Function

- It helps in bowel movement.
- It cleans our digetive tracts and protects the body from digestive ailments.
- It prevents constipation.
- It helps in retaining water in the body.
- It helps in maintaining optimum levels of blood sugar and cholesterol.

INTEXT QUESTIONS 28.1

1. Define nutrition and nutrients

   ....

2. Name the various nutrients of food.

   ....

3. Differentiate between macronutrients and micronutrients

   ....

4. Name the following :

   (i) two water soluble vitamins

   ....

   (ii) two sources of roughage

   ....

   (iii) two sources of proteins

   ....

5. If equal amount of sugar and butter are consumed, which one will provide more energy?

   ....

28.3 ENERGY REQUIREMENTS OF THE BODY

Our body needs energy to carry on various activities of life. We get this energy by eating food.

The energy requirement of an individual depends on various factors like age, sex, amount of work done (occupation), special needs like pregnancy and lactation. The average daily requirements of our body for different age groups are given below.

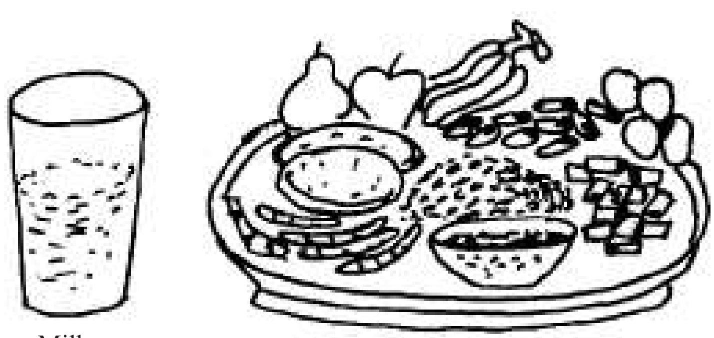
Table 28.6 Energy requirements of body

Group	Sex	Age/Profession	Required calories
Infants	-	0-12 months	100-120/kg body weight
Children	-	2-6 years	1200-1800
		7-12 years	1800-2000
Adolescent	Boys	13-15years	2500
	Girls	13-15 years	2200
Adult	Man	Sedentary work	2400
		Moderate physical work	2800
		Heavy physical work	4000
	Woman	Moderately active	2400
		Pregnancy (later half)	3300
		during lactation (upto 1 year)	3700

Growing children, persons engaged in hard physical work (labourers), pregnant women, lactating mothers, sportsman, persons recovering from illness and persons working in cold weather require more energy.

28.4 BALANCED DIET

You have studied that our balanced diet consists of all the nutrients in varying amounts. (Fig. 28.3)



Milk

Apple, chapati, green vegetables, eggs paneer, dal, rice, banana

Fig. 28.3 Sample of a balanced meal.

To maintain proper health, one needs the right type of food in right quantity. The need generally varies with age, sex, type of work and state of body, (See Table 28.6).

A balanced diet is one that contains all essential nutrients in suitable proportion and amount to provide necessary energy and keeps the body in a healthy state.

A balanced diet has the following qualities :

- it meets the nutrient requirement of the body,
- it consists of different types of food items,
- it provides adequate amount of energy,

The box given below shows recommended dietary requirements according to age, sex and different physical activities.

Recommended dietary requirements (in gram) according to age, sex and different physical activities

Food items	Adult man			Adult woman			Children		Boys	Girls
	Seden-tary	Moderate Work	Heavy Work	Sede-tary	Moderate Work	Heavy Work	1-3 years	4-6 years	10-12 years	10-12 years
Cereals,	460	520	670	410	440	570	175	270	420	380
Pulses	40	50	60	40	45	50	35	35	45	45
Leafy vegetables	40	40	40	100	100	50	40	50	50	50
Other vegetables	60	70	80	40	40	100	20	30	50	50
Roots and tubers	50	60	80	50	50	60	10	20	30	30
Milk	150	200	250	100	150	200	300	250	250	250
Oils and fats	40	45	65	20	25	40	15	25	40	35
Sugar and jaggery	30	35	55	20	20	40	30	40	45	45
Fruits	20	30	30	30	30	30	5	10	10	10

28.4.1 Balanced diet for special needs

Balanced diet varies with age, occupation, and state of health. Under special conditions more food is required by an individual. Let us learn about it.

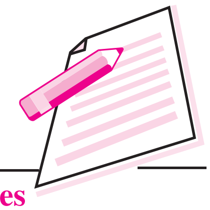
1. Nutritional needs for growing children

Growing children need more food in proportion to their body weight. They need –

(i) extra protein to make new tissues for growth,

(ii) more calcium and phosphorous for formation of bones and red blood cells,

(iii) vitamin A for development of healthy eyesight,



Notes

(iv) vitamin C for general health, and

(v) vitamin D for healthy bones.

2. Nutritional needs for persons in different occupations

Persons doing hard physical work like rickshaw pullers, labourers, carpenters, mill workers. require food which is rich in energy (carbohydrates and fats). Similarly, athletes also require diet of high energy value.

3. Nutritional needs during pregnancy and lactation

A pregnant women has to feed the developing embryo, therefore, she has special need for extra nutrients.

The pregnant women and lactating mothers should take,

(i) extra protein for tissue growth

(ii) more calcium and phosphorus to form bones of the baby

(iii) more iron for making sufficient blood of the baby

(iv) more carbohydrates for herself because extra energy is required to carry out all the building processes linked with embryo.

Similarly, nursing mothers (who breast feed their babies), also need a special diet to take care of their additional requirements of lactation (milk formation). So their diet should contain more proteins, calcium and vitamins.

4. Nutritional needs depending upon the state of health

The persons recovering from illness need more proteins, minerals and vitamins in their diet to repair the damage caused by the ailment. If there is loss of blood due to surgery or an accident the patient needs more of proteins and iron to make up for the loss of blood.

28.5 WHAT IS HEALTH AND DISEASE?

According to the World Health Organisation (WHO), health is defined as:

Health is a state of complete physical, mental, and social well being and not merely absence of disease or infirmity.

Disease :

Disease is a malfunctioning process related to a certain part of the whole body in which normal functions are disturbed or damaged. Disease literally means not at ease (dis = not)

Deficiency diseases :

The diseases which occur due to deficiency of one or more nutrients (proteins,carbohydrates, vitamins and minerals) in our diet are called **deficiency diseases**.

Malnutrition : The condition resulting from lack of nutrients in the diet is called malnutrition.

A large number of people in our country suffer from malnutrition. Malnutrition affects the health of the children adversely as it results in physical and mental retardation.

The deficiency diseases are of three types :

- Protein Energy Malnutrition (PEM)
- Mineral deficiency diseases.
- Vitamin deficiency diseases.

Let us learn in some detail about some of these diseases:

28.5.1 Protein energy malnutrition (PEM)

Generally the growing children suffer from protein energy malnutrition as the required amount of proteins needed for their growth and development is not available. A number of children in the age group of 1-5 years suffer from this disease. PEM is due to two reasons :

(a) Lack of proteins or carbohydrates or both in the diet.

(b) More intake of carbohydrates than proteins.

Protein energy malnutrition results in two diseases :

(i) Marasmus, and

(ii) Kwashiorkor

Marasmus

It is caused due to the deficiency of carbohydrates, fats and proteins. It usually affects infants below the age of one year (Fig. 28.4a)

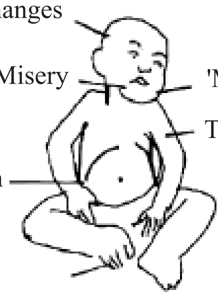


Fig. 28.4(a) A child suffering from marasmus

Symptoms

– wasting of muscles reduces the child to skin and bones.

– folded skin.

– sunken eyes, thin face, thinning of limbs and abdominal walls.

- retarded physical and mental growth.
- ribs become prominent (Pigeon chest).
- Oedema and skin pigmentation are absent.

Kwashiorkor

This disease develops when mothers stop feeding their babies with breast milk and the child is given traditional family food having low protein in it. (Fig. 28.4b)

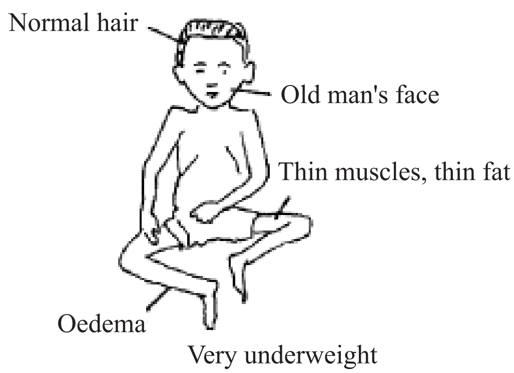


Fig. 28.4(b) A child suffering from kwashiorkor

Symptoms :

A child suffering from Kwashiorkor disease shows the following symptoms

- under weight
- has protruding bellly
- the skin is dark and scaly
- has enlarged liver
- has anaemia
- suffers from repeated diarrhoea
- stunted growth
- loss of appetite
- hair becomes reddish
- swelling of legs and feet due to retention of water by the cell (oedema)

Cure : The child suffering from kwashiorkor and marasmus can recover if adequate protein and carbohydrate rich food is given.

28.6 MINERAL DEFICIENCY DISEASES

Common deficiency diseases of iron, calcium and iodine are given below:

Anaemia (Iron deficiency) : Iron is important for the formaiton of the respiratory pigment **haemoglobin** present in blood. Deficiency of iron results in reduction of red blood cells. This reduces the oxygen carrying capacity of blood.

A person suffering from Anaemia becomes pale, tires easily, loses appetite and loses weight.

Cure : This disease can be cured by eating food stuff rich in iron and vitamin B12, e.g. eggs, meat, liver, milk, green leafy vegetables, such as spinach and fruits like apple, banana, guava (Iron tablets and tonics can also supplement the food).

Deficiency of calcium, phosphorus and vitamin D

Calcium : Chief constituent of bones and teeth, regulates heart beat and muscle contraction, helps in the clotting of blood. Calcium metabolism is closely related to that of phosphorus and vitamin D.

Deficiency of calcium causes : Rickets in children and Osteomalacia in adults.

Rickets (See Figure 28.2)

(i) The bones become soft, get deformed or bend easily,

(ii) bow legs (bent legs),

(iii) pigeon chest,

(iv) loss of teeth enamel (outer shiny layer in teeth), and

(v) tender (soft) bones that tend to fracture easily.

Osteomalacia :

The persons suffering from osteomalacia show

(i) softening of bones

(ii) pain in bones which tend to fracture easily.

Cure : Rickets and osteomalacia can be prevented by giving diet rich in calcium like milk, cod liver oil, egg yolk, and green leafy vegetables.

Goitre

Iodine is essential for the synthesis of thyroxine (hormone produced by thyroid gland). Iodine deficiency causes thyroid gland to enlarge and swell, this is called goitre. (Fig. 28.3).

Symptoms

The person suffering from goitre has

(i) protruding eyes,

(ii) stunted growth,

(iii) puffy appearance

(iv) irregular heart beat

(v) low intelligence

(vi) deficiency of iodine results in another disease called cretinism

Cure : Use of iodised table salt and eating sea food, and fish.

Cretinism

The person suffering from cretinism shows stunted growth, retarded mental growth, delayed puberty and low metabolic rate.

28.7 VITAMIN DEFICIENCY

If the diet is deficient in one or more vitamins like A, B complex, C, D, E and K, it leads to a variety of diseases as given in table 28.3

INTEXT QUESTIONS 28.2

1. Define malnutrition.

   ....

2. What is PEM ? Name two diseases caused due to PEM.

   ....

3. A person has low haemoglobin content, tires easily and looks pale. Name the disease he is suffering from.

   ....

4. Give two food items which can prevent vitamin D deficiency.

   ....

28.8 OBESITY AND EXCESSIVE INTAKE OF FOOD

If a person continues to eat more food than required by his body, he soon becomes overweight and bulky. Excess of carbohydrates and fats instead of providing energy get accumulated in the body.

The overweight and bulkiness of a person's body due to accumulation of carbohydrate and fat is called obesity.

Causes of Obesity

(i) Overeating

(ii) Insufficient exercise

(iii) Hormonal imbalance (deficiency of thyroxine) or other metabolic disturbances.

Harmful effects

An obese person tends to have high cholesterol (fatty substance) deposited in blood arteries. This leads to **hypertension** (high blood pressure) **atherosclerosis** (hardening of arteries), **coronary attack** (heart attack), diabetes and respiratory problems.

Methods to prevent obesity

The obese person should be very careful about diet. Some suggestions are :

(i) avoid fried food

(ii) not to take carbohydrate rich foods

(iii) not to take saturated fats like ghee and vansaspati hydrogenated vegetable oils. Instead, take unsaturated fats like oils, and that too in as little quantity as possible.

(iv) take regular physical exercise.

(v) eat green leafy vegetables (to add roughage).

(vi) if suffering from hormonal imbalance, take the advise of a physician

Effects of excessive intake of Iron

It leads to a condition called hemosiderosis (large deposits of iron in the liver). This may cause

(i) Constipation and diarrhoea
(ii) Nausea and vomitting
(iii) Heart burn
(iv) Epigastric pain

Effect of excessive intake of vitamins (Hyper vitaminosis)

Some persons tend to take vitamins in excess amounts. An excessive intake of water solouble vitamins (vitamins B complex and C) may not cause any harm to the body because they are excreted out through urine. Intake of fat soluble vitamins (vitamin A and D) can be toxic (poisonous) to the body which may lead to certain diseases.

The disease caused by presence of vitamins in excessive quantities in the body is called **hypervitaminosis.**

Hypervitaminosis A

Excess vitamin A accumulation in liver is toxic. This results in

(i) loss of hair
(ii) drowsiness
(iii) painful swelling of long bones
(iv) loss of appetite,
(v) nausea and vomitting.

Hypervitaminosis D

Excess of vitamin D leads to high calcium absorption in the intestine. This results in :

(i) deposition of calcium in soft tissues of body like kidney,

(ii) drowsiness,

(iii) nausea,

(iv) loss of weight.

So we find that both, deficiency and excess of nutrients is harmful to the body.

INTEXT QUESTIONS 28.3

1. List any two causes of obesity.

   (i) ....

   (ii) ....

2. Suggest two methods to prevent obesity

   (i) ....

   (ii) ....

3. Mention two symptoms of excessive intake of Iron.

   (i) ....

   (ii) ....

4. Define hypervitaminosis. Name two vitamins which when taken regularly in diet cause hypervitaminosis.

   (i) ....

   (ii) ....

WHAT YOU HAVE LEARNT

- Food is required for the proper growth and development of the body.
- Food provides nutrients required for a healthy body.
- Carbohydrates, fats, proteins and water are macronutrients whereas vitamins and minerals are micronutrients. In addition, roughage is also as important component of our diet.
- Food has six major components
- Food can be classified into three types : Energy giver-carbohydrates and fats, body building-proteins, protective/regulatory-minerals and vitamins.
- The requirement of energy and different nutrients for the body are needed according to age, sex and profession as well as state of the body.
- A balanced diet provides proper amount of carbohydrates, fats, proteins, minerals, water and vitamins in food.
- A balanced diet is essential for proper growth and health of an individual.
- Malnutrition is the lack of essential nutrients or food elements in the diet. It results in deficiency diseases.
- an excessive intake of fat solutble vitamins A and D results in hypervitaminosis.
- An excessive intake of food for prolonged periods results in obesity. An obese person suffers from cardiovascular diseases, respiratory problems and diabetes.

TERMINAL EXERCISES

1. Differentiate between
   (i) Marasmus and Kwashiorkor.
   (ii) Rickets and Osteomalacia
   (iii) Essential and non-essential amino acids
   (iv) Body-building and protective foods.
   (v) Water soluble vitamins and fat soluble vitamins.
2. Give reasons why do children of 1-5 years develop **PEM**.
3. Why one should include more than one type of proteins in the meals?
4. What is the importance of water in the diet ?
5. What is a balanced diet ? Why does a pregnant women or a nursing mother needs special diet ?
6. Why should food contain roughage ? Name two sources of roughage in our diet.
7. Why is polishing of rice not advisable ? If a person always consumes polished rice, what is he likely to suffer from ? Give two sysmptoms.
8. State **four** important functions of food.
9. If a child is not able to see in dim light, which two food stuffs will you advise him to eat. Give reasons.
10. Name **two** sources rich in
    (i) Vitamin A (ii) Calcium (iii) iron
    (iv) Vitamin B12 (v) starch (vi) Glucose
11. What are minerals ? Name any two minerals and their sources.
12. What are deficiency diseases ? Name two diseases caused by the deficiency of protein and carbohydrates. Also write the symptoms of these deficiency diseases.

ANSWERS TO INTEXT QUESTIONS

28.1 1. Nutrition : Sum of the processes by which an organism takes in, metabolises and utilises food substances.

Nutrients : Substances which help in maintaining proper health and are required for the survival of an individual.

2. (a) Carbohydrates, fats, proteins, minerals, vitamins and water.

3. Nutrients required in large quantities are called macronutrients such as carbohydrates fats, proteins and water.

   Nutrients required in small amounts are micronutrients e.g. minerals and vitamins
4. (i) Water soluble-vitamin B and C (ii) leafy vegetables, fruits, (iii) milk, fish.
5. Butter

28.2

1. The condition resulting from lack of essential nutrients in diet is malnutrition
2. Protein Energy Malnutrition; Marasmus, Kwashiorkor
3. Anaemia
5. milk, cod liver oil, egg yolk, exposure to light (Any two)

28.3

1. Over eating, lack of exercises, hormonal imbalance.
2. Avoid fried food, carbohydrates, take regular exercise, eat green leafy vegetable (Any two).
3. Constipation, Diarrhoea, epigastric pain (any two).
4. Excess presence of vitamins in the body. vitamin A and D.

29

SOME COMMON HUMAN DISEASES

In the previous lesson you have read about the diseases due to nutritional deficiencies. In this lesson, you will learn about diseases caused due to other reasons.

OBJECTIVES

After completing this lesson, you will be able to :

- *define a disease and learn its types;*
- *differentiate between parasite and pathogen;*
- *differentiate between infection and infestation;*
- *list the symptoms, causative agents, prevention and control of influenza, measles, polio, hepatitis, tuberculosis, diphtheria, leprosy, malaria, filariasis and dengue.*
- *identify certain diseases that are caused due to improper functioning of some organs of the body system;*
- *describe the causes, symptoms and prevention and cure for hypertension;*
- *list the symptoms of and methods for diagnosing coronary heart disease and suggest preventive measures;*
- *describe the cause, the symptoms, preventive and curative methods of diabetes mellitus and osteoporosis;*
- *recognize cancer as a cell-regulation disorder;*
- *define and differentiate between benign and malignant tumors;*
- *interpret the category of allergies as immune system related disorders;*
- *define the special category of sexually transmitted diseases;*

- *list the causative agents, symptoms, prevention and control of syphilis, gonorrhea and AIDS;*
- *define drug abuse and its prevention.*

29.1 DISEASES

29.1 What is a disease?

Any malfunctioning process which interferes with the normal functioning of the body is called a disease. In other words, disease may be defined as a disorder in the physical, physiological, psychological or social state of a person caused due to nutritional deficiency, physiological disorder, genetic disorder, pathogen or any other reason.

29.1.1 Types of Diseases

The diseases may be classified into two broad categories (Table 29.1).

Table 29.1 Classification of human diseases

- Diseases
  - Congenital diseases (Present since birth)
  - Acquired diseases (Develop after birth)
    - Communicable diseases (Spread from infected person to healthy person
    - Non-communicable diseases (do not spread from a diseased person to a healthy person)
      - Degenerative diseases (caused due to malfunctioning of vital body organ)
      - Deficiency diseases (caused due to lack of nutrients in diet)
      - Allergies (caused due to hypersensitivity of the body to certain foreign substances)
      - Cancer (caused due to uncontrolled growth of cells/ tissues)
      - Other diseases (caused due to various physical agents or any other reason)

A. Congenital disease : The disease which is present from birth (e.g. hole in the heart in infants). They are caused by some genetic abnormality or metabolic disorder or malfunctioning of an organ.

B. Acquired disease : The disease which may occur after birth during one's lifetime.

Acquired diseases may generally be classified into :

(i) **Infectious diseases :** The diseases which can be transmitted from diseased healthy person person to e.g. measles.

(ii) **Degenerative diseases :** The diseases caused by the malfunction of some vital organs of the body e.g. heart failure.

(iii) **Deficiency diseases :** These are caused due to nutritional deficiency such as that of minerals or vitamins in the diet e.g. anaemia (Fe), Beri- beri (vitamin B). You have read about such diseases in an earlier lesson 27.

(iv) **Cancer :** This is an abnormal, uncontrolled and unwanted growth of cells. e.g. breast cancer.

Acquired diseases are studied under two categories (Table 29.2).

(i) **Communicable diseases :** The diseases which can be transmitted from an infected person to a healthy person.

(ii) **Non-communicable diseases :** These diseases do not spread from an affected person to a healthy person.

Table 29.2 Differences between communicable and non-communicable diseases

Communicable diseases	Non-communicable diseases
1. Caused by some biological agents or pathogens, such as viruses, bacteria, protozoans and helminths (worms).	Caused due to some specific factor, such as malfunctioning of some vital organ, and deficiency of nutrients.
2. Spread from one person to another through contact, water, air, and food, etc.	Do not spread from one person to another by contact.
3. The concern of the diseases involves the society as these are related to community health.	The concern of the disease is restricted to the individual only.

29.1.2 Modes of Spread of Communicable Diseases

Communicable diseases spread from the infected person to a healthy person in the following ways.

Direct transmission

The pathogens of diseases infect a healthy person directly without an intermediate agent. It can take place by various means such as,

(i) **Direct contact between the infected person and the healthy person :** Diseases like small pox, chicken pox, syphilis, gonorrhoea spread through direct contact.

(ii) **Droplet infection :** The infected person throws out tiny droplets of mucus by coughing, sneezing or spitting. These droplets may contain the pathogen. By inhaling the air containing the droplets, a healthy person may get the infection. Diseases like common cold, pneumonia, influenza, measles, tuberculosis and whooping cough spread through droplet infection.

(iii) **Contact with soil** contaminated with disease-causing viruses and bacteria.

(iv) **Animal bite :** Viruses of rabies are introduced through the wound caused by the bite of rabid animals, especially dogs. The virus is present in the saliva of the rabid animals.

Indirect transmission

The pathogens of certain diseases reach the human body through some intermediate agents. It can take place by various means, which are as follows :

(i) **By vectors such as houseflies, mosquitoes, and cockroaches.** Examples: Houseflies carry the causative organisms of cholera on their legs and mouth parts from the faeces and sputum of infected persons to food and drinks and contaminate them. When this contaminated food is taken by a healthy person, he gets the infection. Similarly, mosquitoes carry virus of dengue and malarial parasite which causes malaria.

(ii) **Air-borne :** The pathogens may reach humans with air and dust. The epidemic typhus spreads by inhalation of dried faeces of infected fly.

(iii) **Object borne (Fonite borne) :** Many diseases are transmitted through the use of contaminated articles, such as clothes, utensils, toys, door handles, taps, syringes and surgical instruments.

(iv) **Water borne :** If potable water (drinking water) is contaminated with pathogens of diseases such as cholera, diarhhoea, hepatitis or jaundice, it reaches a healthy person upon consuming such water.

29.2 SOME IMPORTANT TERMS TO REMEMBER

Pathogen : A living organism which causes a disease.

Parasite : An organism which gets food and shelter from host.

Host : The living body on or inside which the disease-producing organism takes shelter.

Infestation : Presence of a large number of parasitic organisms on the surface of body of the host or on the clothings.

Vector : It is an organism which harbours a pathogen and may pass it on to another person to cause a disease (Mosquitoes harbour malarial parasite and transmits it to humans).

Carrier : It is an organism which itself does not harbour the pathogen but physically transmits it to another person (Housefly is the carrier of cholera germs).

Reservoir : An organism which harbours pathogens in large numbers that do not cause any suffering to it.

Epidemic : Spreading of a disease among a large number of people causing a huge loss of life in the same place for some time e.g. plague.

Endemic : A disease which is regularly found among a particular group of people e.g. goitre, restricted to a certain locality or a country.

Pandemic : A disease which is found all over the world e.g. AIDS.

Interferon : Type of proteins produced by infected cells of the body when attacked by a virus, which act to prevent the further development of the same virus.

Inoculation : Introduction of antigenic material inside the body to prevent suffering from a disease.

Vaccination : Injection of a weak strain of a specific bacterium (Vaccine) in order to secure immunity against the corresponding disease. It is also called immunisation.

Incubation period : The period between entry of pathogen inside a healthy body and appearance of the symptoms of the disease.

Symptoms : Specific morphological or physiological expressions which appear on the deseased organism and help in the identification of the disease.

INTEXT QUESTIONS 29.1

1. Define the term disease. ....
2. Give appropriate terms for
   (i) the kind of disease which is present from birth.. ....
   (ii) disease caused by malfunctioning of vital organs. ....
3. Name any two communicable and any two non-communicable diseases in humans
   ....
4. What does infestation mean?
   ....

29.3 COMMUNICABLE DISEASES (INFECTIOUS DISEASES)

The diseases which spread from one diseased person to another through contaminated food, water or contact or through insecticides, and animals are called the communicable diseases. These are caused by different causative agents (pathogens).

29.3.1 Diseases caused by viruses

1. Chicken pox

Pathogen : Chicken pox virus (voricella)

Mode of transmission : By contact or through scabs

Incubation period : 12-20 days

Symptoms

(i) Fever, headache and loss of appetite

(ii) Dark red-coloured rash on the back and chest which spreads on the whole body. Later, rashes change into vesicles.

(iii) After few days these vesicles start drying up and scabs (crusts) are formed.

(v) These scabs start falling (infective stage)

Prevention and cure

There is no vaccine against chicken pox as yet. But precautions must be taken as follows:

(i) The patient should be kept in isolation.

(ii) Clothings and utensils, used by the patient should be sterilised.

(iii) Fallen scabs should be collected and burnt.

One attack of chicken pox gives life long immunity to the person recovered from this disease.

2. Measles

Pathogen : Virus (*Rubeola*)

Mode of transmission : By air

Incubation period : 3-5 days

Symptoms

(i) Common cold

(ii) Appearance of small white patches in mouth and throat.

(iii) Appearance of rashes on the body.

Prevention and cure

(i) The patient should be kept in isolation.

(ii) Cleanliness should be maintained.

(iii) Antibiotics check only the secondary infections which can easily recur.

3. Poliomyelitis

Pathogen : Polio Virus

Mode of transmissions : Virus enters inside the body through food or water.

Incubation period : 7-14 days

Symptoms

(i) The virus multiplies in intestinal cells and then reaches the brain through blood.

(ii) It damages brain and nerves and causes infantile paralysis.

(iii) Stiffness of neck, fever, loss of head support.

Prevention and Cure

Polio vaccine drop (oral polio vaccine, OPV) are given to children at certain intervals.

Pulse polio programme is organised in our country to give polio vaccine to children.

4. Rabies (also called hydrophobia)

Pathogen : Rabies virus

Mode of Transmission : Bite by a rabid dog.

Incubation period : 10 days to 1-3 months depending upon the distance of bite from Central Nervous System (CNS), that is the brain or spinal cord.

Symptoms

(i) Severe headache and high fever.

(ii) Painful contraction of muscles of throat and chest.

(iii) Choking and fear of water leading to death.

Prevention and Cure

(i) Compulsory immunisation of dogs.

(ii) Killing of rabid animals.

(iii) Anti-rabies injections or oral doses are given to the person bitten by a rabid animal.

5. Hepatitis

Pathogen : Hepatitis B virus.

Mode of Transmission : Mainly through contaminated water.

Incubation Period : Generally 15-160 days.

Symptoms

(i) Bodyache.

(ii) Loss of appetite and nausea.

(iii) Eyes and skin become yellowish, urine deep yellow in colour (due to bile pigments).

(iv) Enlarged liver.

Prevention and Cure

(i) Hepatitis B vaccine is now available in India.

(ii) Proper hygeine is to be observed.

(iii) Avoid taking fat rich substances.

6. Influenza

Influenza, commonly known as ‘flu’ is an illness caused by viruses that infect the respiratory tract. Compared to common cold, influenza is a more severe illness.

Causes

Influenza is caused by a virus which attacks our body’s cells, resulting in various effects depending on the strain of the virus.

There are many strains of influenza virus. The virus mutates all the time and new variations (strains) arise. This constant changing enables the virus to evade the immune system of its host. Unfortunately immunity against one strain (which is conferred by exposure or immunisation) does not protect against other strains. A person infected with influenza virus develops antibodies against that virus; as the virus changes, the antibodies against the virus do not recognize the changed virus, and influenza can recur, caused by the changed or mutated virus.

Symptoms

Typical symptoms of influenza include:

(i) fever (Usually 100° F to 103° F in adults and often even higher in children).

(ii) respiratory tract infection symptoms such as, cough, sore throat, running nose, headache, pain in the muscles, and extreme fatigue.

Although nausea and vomiting and diarrhoea can sometimes accompany Influenza infection, especially in children, gastrointestinal symptoms are rarely prominent.

Most people who get flu, recover completely in 1 to 2 weeks, but some people develop serious and potentially life-threatening complications, such as pneumonia.

Treatment and Control

(i) Much of the illness and death caused by influenza can be prevented by annual influenza vaccination. Influenza vaccine is specifically recommended for those who are at high risk for complications with chronic diseases of the heart, lungs or kidneys, diabetes, or severe forms of anaemia.

(ii) The persons suffering from influenza should

- drink plenty of fluids
- take symptom relief with paracetamol, aspirin (not in children under the age of 16) or ibuprofen as recommended by the doctor.
- Consult doctor immediately for treatment.

7. Dengue

Dengue is an acute fever caused by virus. It is of two types: (i) Dengue fever, (ii) Dengue hemorrhagic fever.

Dengue fever is characterized by an onset of sudden high fever, severe headache, pain behind the eyes and in the muscles and joints.

Dengue hemorrhagic fever is an acute infectious viral disease. It is an advanced stage of dengue fever. It is characterized by fever during the initial phase and other symptoms like headache, pain in the eye, joint pain and muscle pain, followed by signs of bleeding, red tiny spots on the skin, and bleeding from nose and gums.

How does Dengue spread?

Dengue spreads through the bite of an infected *Aedes aegypti* mosquito. The transmission of the disease occurs when a mosquito bites an infected person and subsequently bites a healthy person. In doing so, it transmits blood containing the virus to the healthy person and the person becomes infected with dengue. The first symptoms of the disease occur about 5 to 7 days after the infected bite.

Aedes mosquito rests indoors, in closets and other dark places, and is active during day time. Outside, it rests where it is cool and shaded. The female mosquito lays her eggs in stagnant water containers such as coolers, tyres, empty buckets, in and around homes, and other areas in towns or villages. These eggs become adults in about 10 days.

Incubation period

The time between the bite of a mosquito carrying dengue virus and the start of symptoms averages 4 to 6 days, with a range of 3 to 14 days.

Diagnosis

Diagnosis is made through blood tests by scanning for antibodies against dengue viruses. In addition the blood platelet counts also get drastically reduced in the infected person.

Symptoms

Symptoms of Dengue fever

(i) Sudden onset of high fever, generally 104-105 °F (40 °C), which may last 4-5 days.

(ii) Severe headache mostly in the forehead.

(iii) pain in the joints and muscles, body aches.

(iv) Pain behind the eyes which worsens with eye movement.

(v) Nausea or vomiting.

Symptoms of Dengue hemorrhagic fever

These include symptoms similar to dengue fever, plus other symptoms such as:

(i) Severe and continuous pain in the abdomen.

(ii) Rashes on the skin.

(iii) Bleeding from the nose, mouth, or in the internal organs.

(iv) Frequent vomiting with or without blood.

(v) Black stools due to internal bleeding.

(vi) Excessive thirst (dry mouth).

(vii) Pale, cold skin, weakness.

Prevention

Following steps can be taken to prevent spread of dengue fever:

(i) Avoid water stagnation for more than 72 hours so that the mosquitoes do not breed there.

(ii) Prevent mosquito breeding in stored water bodies, like ponds, and wells.

(iii) Destroy discarded objects like old tyres and bottles, as they collect and store rain water.

(iv) Use mosquito repellents and wear long sleeved clothes to curtail exposure.

(v) Use mosquito nets, also during daytime.

(vi) Avoid outdoor activities during dawn or dusk when these mosquitoes are most active.

(vii) Patients suffering from dengue fever must be isolated for at least 5 days.

(viii) Report to the nearest health centre for any suspected case of Dengue fever.

Treatment for dengue and dengue hemorrhagic fever

There is no specific treatment for dengue fever. Persons with dengue fever should rest and drink plenty of fluids. Dengue hemorrhagic fever is treated by replacing lost fluids. Some patients need blood transfusions to control bleeding.

INTEXT QUESTIONS 29.2

1. How does chicken pox spread?

   ....

2. Mention the most obvious symptom of measles.

   ....

3. Which organ system of the body is affected by the polio virus?

   ....

4. Name the causative organism of hydrophobia.

   ....

5. Which mosquito spreads dengue?

   ....

29.3.2 Diseases caused.by Bacteria

1. Tuberculosis

Pathogen : A bacterium (*Mycobacterium tuberculosis*).

Mode of Transmission : airborne-discharged through sputum, cough and sneeze, of the infected person.

Incubation period : 2-10 weeks during which the bacteria produce a toxin, tuberculin.

Symptoms

(i) Persistent fever and coughing.

(ii) Chest pain and blood comes out with the sputum.

(iii) General weakness.

Prevention and Cure

(i) Isolation of patient to avoid spread of infection.

(ii) BCG vaccination is given to children as a preventive measure.

(iii) Living rooms should be airy, neat and with clean sorroundings.

(iv) Antibiotics be administered as treatment.

2. Typhoid

Pathogen : A Bacillus rod-shaped bacterium (*Salmonella typhi*)

Mode of transmission : Through contaminated food and water

Incubation period : About 1-3 weeks

Symptoms

(i) Continuous fever, headache, slow pulse rate.

(ii) Reddish rashes appear on the belly.

(iii) In extreme cases, ulcers may rupture resulting in death of the patient.

Prevention and Cure

(i) Anti-typhoid inoculation should be given.

(ii) Avoid taking exposed food and drinks.

(iii) Proper sanitation and cleanliness should be maintained.

(iv) Proper disposal of excreta of the patient.

(v) Antibiotics should be administered.

3. Cholera

It often breaks out among people in crowded areas and the areas with poor sanitary conditions.

Pathogen : Comma shaped bacterium (*Vibrio cholerae*)

Mode of transmission : Contaminated food and water. Housefly is the carrier.

Incubation period : 6 hours to 2-3 days.

Symptoms

(i) Acute diarrohoea and watery stool.

(ii) Muscular cramps.

(iii) Loss of minerals through urine.

(iv) Dehydration leads to death.

Prevention and cure

(i) Cholera vaccination should be given.

(ii) Electrolytes (Na, K, sugar) dissolved in water should be given to the patient to check dehydration (In market it is available as ORS–oral rehydration solution).

(iii) Proper washing and cooking of food.

(iv) Proper disposal of vomit and human excreta.

(v) Flies should not be allowed to sit on eatables and utensils.

4. Diphtheria

This disease generally occurs in children of 1-5 years of age.

Pathogen : Rod-shaped bacterium (*Cornybacterium diphthereae*)

Mode of Transmission : Through air (droplet infection)

Incubation period : 2-4 days

Symptoms

(i) Slight fever, Sore throat and general indisposition.

(ii) Oozing semisolid material in the throat which develops into a tough membrane. The membrane may cause clogging (blocking) of air passage, resulting into death.

Prevention and cure

(i) Immediate medical attention should be given.

(ii) Babies should be given DPT vaccine.

(iii) Sputum, oral and nasal discharges of the infected child should be disposed off.

(iv) Antibiotics may be given under doctor's supervision.

(v) Isolation of the infected child.

5. Leprosy

Pathogen : A bacterium (*Mycobacterium leprae*)

Mode of transmission : Prolonged contact with the infected person. Nasal secretions are the most likely infectious material for family contacts.

Incubation period : 1-5 years

Symptoms

(i) Affects skin.

(ii) Formation of nodules and ulcer.

(iii) Scabs and deformities of fingers and toes.

(iv) Infected areas lose sensation.

Prevention and Cure

(i) The children should be kept away from parents suffering from leprosy.

(ii) Some medicine may arrest the disease and prevent from spreading.

INTEXT QUESTIONS 29.3

1. Name the causative bacterium of (i) TB (ii) Typhoid (iii) Cholera.

   ....

2. State the most obvious symptom of diphtheria.

   ....

3. What is the mode of transmission of leprosy.

   ....

29.3.3 Diseases caused by protozoans

1. Malaria

Pathogen : Malarial parasite (different species of *Plasmodium*)

Mode of transmission : By bite of female *Anopheles* mosquitoes

Incubation period : Approximately 12 days

Symptoms

(i) Headache, nausea and muscular pain.

(ii) Feeling of chilliness and shivering followed by fever which becomes normal along with sweating after some time.

(iii) The patient becomes weak and anaemic.

(iv) If not treated properly secondary complications may lead to death.

Prevention and cure

(i) Fitting of double door and windows (with "Jali" i.e. wire mesh) in the house to prevent entry of mosquitoes.

(ii) Use of mosquito net and mosquito repellents.

(iii) No water should be allowed to collect in ditches or other open spaces to prevent mosquito breeding.

(iv) Sprinkling of kerosene oil in ditches or other open spaces where water gets collected.

(v) Antimalarial drugs to be taken.

2. Amoebiasis (Amoebic dysentery)

Pathogen : *Entamoeba histolytica*

Mode of transmission : Contaminated food and water

Symptoms

(i) Formation of ulcers in intestine.

(ii) Feeling of abdominal pain and nausea.

(iii) Acute diarrhoea and mucus in stool.

Prevention and cure

(i) Proper sanitation should be maintained.

(ii) Vegetables and fruits must be properly washed before eating.

(iii) Antibiotics may be given to the patients.

29.3.4 Diseases caused by worms (helminths)

1. Filariasis

Pathogen : Filarial worm (*Wuchereria bancrofti*)

Mode of transmission : Bites of mosquitoes - *Aedes* and *Culex.*

Symptoms

(i) Fever

(ii) Collection of endothellial cells and metabolites in the wall of lymph vessels.

(iii) Swelling takes place in certain parts of the body like legs, breasts, and scrotum.

(iv) Swelling of legs which appear as legs of elephant, so this disease is also called elephantiasis (Fig. 29.1)

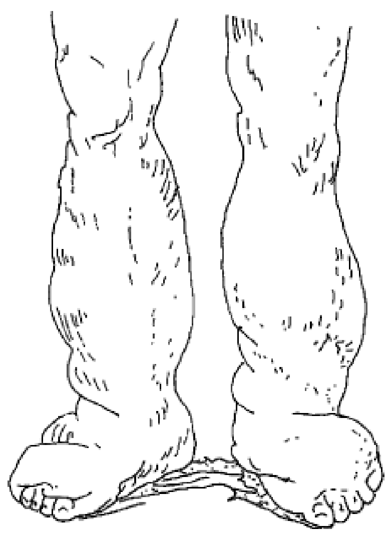


Fig. 29.1 Patient suffering from Elephantiasis.

Prevention and cure

(i) Mesh doors and windows in the house to check the entry of mosquitoes.

(ii) The water collected in tanks or other articles should be properly covered.

(iii) Sprinkling of kerosene in ditches.

(iv) Drugs may be administered.

INTEXT QUESTIONS 29.4

1. Which mosquito carries stages of life history of the malarial parasite?

   ....

2. Which protozoan causes amoebic dysentery?

   ....

3. Name the disease cause by *Wuchrareria bancrofti*.

   ....

29.4 NON-COMMUNICABLE DISEASES

1. Diabetes mellitus

The disease can be diagnosed by blood test or urine test.

Causes

(i) Less secretion of insulin hormone from the pancreas.

(ii) Mental stress

(iii) Through heredity from parents to children.

Symptoms

(i) More glucose in blood.

(ii) Excessive and frequent passing of urine.

(iii) Feeling thirsty and hungry frequently.

(iv) Reduced healing capacity of injury.

(v) General weakness of the body.

(vi) In extreme cases diabetic coma can take place making the patient unconscious.

Prevention and cure

(i) Control the excessive weight of the body.

(ii) A regulated and controlled diet is to be taken.

(iii) The food should not contain sugar and much carbohydrates.

(iv) Injection of insulin before meals, if required (only on doctor's prescription).

2. Cardio vascular diseases

Common Causes

(i) Deposition of cholesterol (a kind of fat) in the walls of coronary arteries which restrict the flow of blood to the heart muscles. This leads to heart attack.

(ii) Due to reduced blood supply, and reduced oxygen available to the muscles, heart's efficiency is affected.

(iii) Due to stress and strain.

(iv) Obesity (over weight).

(a) Hypertension : (high blood pressure)

Symptoms

(i) Persistent high blood pressure (BP)

(ii) It may damage the arteries of kidney.

(iii) In extreme cases the arteries may burst or blindness may be caused.

(iv) It may also cause paralysis.

Prevention and Cure

(i) Do not build up mental tension.

(ii) Low fat diet should be taken.

(iii) Weight of the body must be kept under control.

(iv) Good eating habits should be cultivated

(v) Medicines may be taken as per doctor's advice.

(b) Coronary heart disease

Symptoms

(i) Severe pain in the chest gasping for breathe.

(ii) Intense nausea and vomiting.

(iii) Lot of sweating takes place.

(iv) Blood clot may be formed within the blood vessels.

Prevention and Cure

(i) A diet low in saturated fats may control the formation of cholesterol.

(ii) Sound eating habits should be developed.

(iii) Over weight should be checked.

(iv) Avoid smoking, alcoholic drinks and drugs.

(v) Take treatment under a qualified doctor.

(vi) Electrocardiogram (ECG) can diagnose the disease.

(vii) By-pass surgery is performed in extreme cases.

3. Osteoporosis

Osteoporosis is an age dependent disorder with loss of the normal density of bone. The bones become fragile and are easily fractured. Bones that are affected by osteoporosis can fracture with only a minor fall or injury. Elderly men and women are most susceptible because of hormonal changes which occur with advancing age.

Symptoms

(i) The persons suffering from osteoporosis may not know about their condition for a long time, because osteoporosis doesn't cause clear cut symptoms and one may not realise till a bone fracture.

(ii) The symptoms of osteoporosis are related to the location of the fracture.

(iii) Fractures of the spine can cause severe 'band like' pain that radiates around from the back to the side of the body. Repeated spine fractures can cause chronic lower back pain, as well as curving of the spine, which gives the individual a hunched-back appearance.

(iv) Some patients with osteoporosis develop stress fractures of the feet while walking or stepping off. Hip fractures typically occur as a result of a fall. With osteoporosis, hip fractures can occur upon even minor accidents. Hip fractures may take a very long time to heal because of poor bone quality.

Treatment

(i) Patients suffering from osteoporosis are generally treated with vitamin D and calcium supplements. In addition they are advised bed rest so that the condition does not worsen.

(ii) Changes to lifestyle and diet are also recommended. The patients are advised to take calcium either via dietary means or via supplements in the form of tablets. Since body absorbs about 500 mg calcium at a given time, the calcium intake should be spread throughout the day.

(iii) Exercise also helps to protect persons from the risk of getting osteoporosis. However, it is important to do exercises for osteoporosis under the guidance of a professional physiotherapist.

4. Cancer

1t is the uncontrolled and unwanted growth of cells.

Cause

(i) No definite cause has been arrived at so far. However, it is found that body has proto-oncogenes. These are activated by some substances or stimulus, which convert these into active cancer-causing oncogenes.

(ii) Heavy smoking and alcoholism.

(iii) Chewing of tobacco.

(iv) Consistent irritation of skin or repeated injury at the same point.

Cancer is a kind of tumorous growth. Tumours can be classified into two categories :

(a) Benign tumour

It remains confined to the place of origin and does not spread to other body parts. It is relatively harmless.

(b) Malignant tumour

It spreads to other parts of the body and growth is rapid. This is serious and may cause death of the patient.

Symptoms

(i) Persistent lump or thickening in tissues, specially in tongue, breast and uterus.

(ii) Any irregular bleeding or blood-tinged discharge from any body opening.

(iii) Any sore that does not heal quickly.

(iv) Change in the form of mole or wart.

(v) Persistent hoarseness in voice, cough or difficulty in swallowing.

Prevention and cure

(i) Cancer check up should be done once a year.

(ii) Treatment should be taken under medical advice.

(iii) Avoid smoking, taking alcohol and chewing of tobacco.

(iv) Observe regularity in life style to keep body healthy.

5. Allergy

(i) Includes a group of non-infectious diseases.

(ii) No definite cause is known

(iii) It is believed that they occur due to hypersensitiviness of certain individuals to foreign matter (allergens) which may enter inside the body.

(iv) Symptoms may be sneezing, gasping, running of eyes, irritation of throat or trachea.

(v) Allergens may be pollen grains, feathers, some animals or insects, drugs, medicines and odour.

INTEXT QUESTIONS 29.5

1. Why is diabetes called a hereditary disease?

   ....

2. What happens to the blood pressure in persons with hypertension?

   ....

3. State one point of difference between malignant and benign tumour.

   ....

29.5 SEXUALLY TRANSMITTED DISEASES

The diseases that are transmitted through sexual contact are known as sexually transmitted diseases. Sexually transmitted diseases are those diseases that are transmitted via the mucous membrane and secretions of the sexual organ, throat and the rectum. Syphilis, gonorrhoea, and AIDS are some sexually transmitted diseases.

29.5.1 AIDS (Acquired Immuno Deficiency Syndrome)

It is a pandemic disease. The word "immuno deficiency" signifies that the immune system becomes very weak. It is a disease of cell-mediated immune system of the body.

Lymphocytes are the main cells of the immune system i.e. T-lymphocytes and B-lymphocytes. 'Helper T' lymphocytes play a great role in regulating the immune system. Damages to or destruction of 'Helper' lymphocytes leads to the development of a cellular immune deficiency which makes the patient susceptible to wide variety of infections.

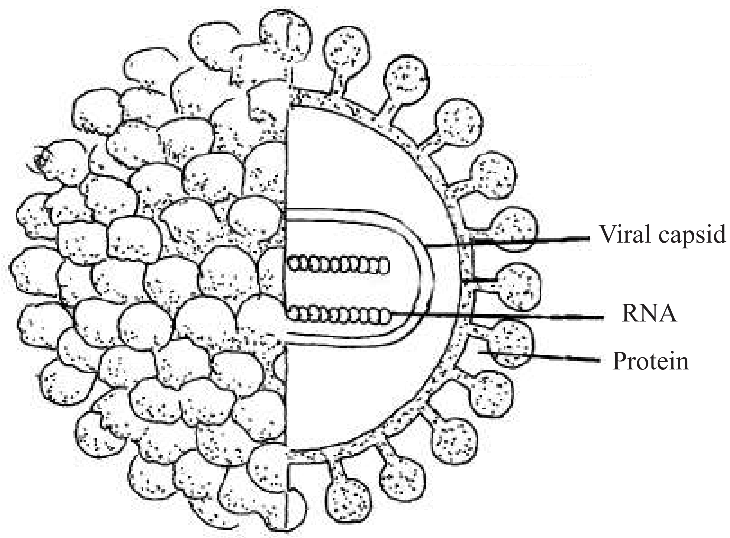


Fig. 29.2 Human Immunodeficiency Virus (HIV)

Mode of transmission : AIDS may be transmitted through any of the following means :

(i) Sexual contact with the affected person. In India, the most common route of HIV transmission is through unprotected heterosexual sex.

(ii) Using the same syringe that was used for affected person.

(iii) Blood transfusion which contains human immuno deficiency virus.

(iv) Organ transplantation of the affected person.

(v) Artificial insemination.

(vi) From mother to new born baby during the process of giving birth.

Incubation period : The average period is 28 months though it may range between 15 to 57 months

Symptoms : The sufferer may show one or more of the following symptoms :

(i) A type of lung disease develops (tuberculosis).

(ii) A skin cancer may be observed.

(iii) Nerves are affected.

(iv) Brain is badly damaged with the loss of memory, ability to speak and to think.

(v) The number of platelets (thrombocytes) becomes less which may cause haemorrhage.

(vi) In severe cases the patient shows swollen lymph nodes, fever and loss of weight. A full blown (disease at its peak) AIDS patient, may die within three years.

Prevention and cure

No medicine or vaccine is known to be available against HIV infection. Therefore, care has to be taken through following measures:

(i) There should not be any sexual contact with the person who has HIV infection or STI. Since STI causes some damage to the genital area and mucous layer, and thus facilitates the entry of HIV into the body.

(ii) Use disposable syringe and needle.

(iii) The blood to be transfused to the needy person, should be free from HIV germ.

(iv) Prostitution and homosexuality should be avoided.

(v) Condom should always be used during intercourse.

Control

AIDS can be detected by ELISA test.

There are three points which may be important to control STD.

(i) **Partner notification :** Identification of potential infected contact, examination and treatment.

(ii) **Education of STD :** This should be a part of general education.

(iii) **Screening for STD :** Serological screening of groups, such as, blood donors, women before giving birth.

Facts about HIV transmission

- HIV is a weak virus and hard to get infected with. It cannot be transmitted through air or water outside the human body.
- A person cannot get AIDS by hugging or sneezing of an infected person, insect bites (including mosquito), sharing the same comb, plates, glass, handkerchiefs, knives or cutlery.
- A person cannot get AIDS by using public toilets, swimming pools, showers and telephones.
- HIV cannot be transmitted by being near to someone, touching someone or working with someone who is suffering from AIDS.

INTEXT QUESTIONS 29.6

1. How is HIV transmitted? Mention any three ways of infection.

....

2. Mention any two methods to prevent AIDS.

....

3. Write full form of HIV.

....

4. Give any two symptoms of AIDS.

....

5. Mention three general points the knowledge of which may control STD.

....

29.5.2 Syphilis

Causative organism

Treponema pallidum (a long corkscrew bacteria)

Mode of spread

Sexual contact with the infected person

Incubation period

Symptoms of the disease occur in about 10-90 days after contraction, but generally noticed in 3-4 weeks after getting infected with the bacteria.

Symptoms

Symptoms of syphilis occur in stages. The common symptoms of syphilis include.

(i) Fever, and sores on the skin, in the throat and urinogenital areas especially vagina or penis, anus, rectum and mouth. Sores are firm, round and often painless.

(ii) Rashes on hands, feet and palms.

(iii) White patches in the mouth.

(iv) Acne-like warts in the groin area.

(v) Hair fall in patches from infected areas.

(vi) The last three symptoms can be very serious. They often become internal and affect organs like brain, nerves, liver, eyes, blood vessels, bones and joints, which show up after about 10 years of getting the infection. It can lead to paralysis, blindness, dementia and sterility.

Prevention and cure

(i) Having sexual intimacy with only one person.

(ii) Avoiding prostitution and homosexuality.

(iii) Practising abstinence, and use condoms.

(iv) Taking appropriate medical treatment, and maintaing personal hygience.

29.5.3 Gonorrhoea

Gonorrhoea is a sexually transmitted disease that often involves urethra, vagina or penis, cervix, anus, and throat, as its target sites.

Causative organism

A gonococcus bacterium, *Neisseria gonorrhoeae*. It grows and multiplies quickly in warm moist areas of the body, such as the cervix, rectum and mouth.

Modes of spread

Having multiple sex partners increases the risk of contracting it. Any kind of unprotected sex is always a risk. Any kind of contact of sores with an infected person is also risky.

Incubation period

About 2-5 days after getting infection.

Symptoms

(i) Inflammation of mucous membrane in the urinogenital tract.
(ii) Burning sensation while passing out urine and urethral discharge.
(iii) Rectal discomfort.
(iv) Pain in the joints.
(v) Rashes on palms, Mild sore throat
(vi) In females, it may cause sterility

Prevention and cure

(i) Having sexual contact with only one person.
(ii) Avoiding prostitution and homosexuality.
(iii) Taking antibiotics, such as penicillin injection or appropriate medicines at the appropriate time as per Doctor's advice.

In males, gonorrhoea primarily affects the urethra, anus, throat, joints and eyes. Most victims of this disease are teenagers and young adults. One of the advanced complications of gonorrhoea is gonococcal septicemia (blood poisoning).

29.6 DRUG ABUSE AND ITS PREVENTION

What is a drug

A drug is a chemical substance that changes the way our body and mind work. A pharmaceutical preparation or a naturally occurring substance used primarily to alter the physical or mental functioning of an individual, is called a drug.

What is drug abuse

When drugs are taken for medical reasons to treat or cure disease both physical and mental, they are called *medications or therapeutic drugs.*

Drug abuse occurs when drugs are taken without medical reasons and without medical supervision, especially when they are taken in an amount, strength, frequency, or manner that damages the physical and mental functioning of the individual. Cough syrups, pain killers, and tranquillizers are some common medicines that are often abused.

Drug abuse also occurs when certain chemicals that have no medical use or benefits are taken, such as sniffing glue and solvents. The extent of drug abuse depends on the quantity of the drug being taken, and the method and frequency of its consumption. Drug abuse leads to many serious physical, emotional, and social problems.

What are the effects of drug abuse?

Drug abuse leads to a number of short-term and long-term effects that are detrimental to health:

- *Short-term effects :* These are the effects that appear instantly or a few minutes after the intake of drugs. The effects include a sense of well-being and a pleasant drowsiness.
- *Long-term effects :* Constant and excessive use of drugs over a long period can cause both physical and mental damage and illness. This includes failure in academic studies, employment, and interpersonal relationship; financial ruin; increased risk of contracting STIs; and increased risk of being involved in vehicular accidents. Addicts stop thinking of everything in life except when and how they will get their next drug dose. They will do anything for the dose, including committing crimes such as theft and in certain case even murder.

Some Basic Facts

Teenagers sometimes try a smoke or drink just to see how it feels, but they do not start using drugs on a regular basis. What is the harm in trying drugs just to see how it feels?

Ideally, there is no need to try out a smoke or drink.

But there is a great difference between " trying out" smoking or drinking as compared to drugs.

Smoking and drinking once only or very occasionally does not always lead to addiction. But drugs are very powerful chemicals that can cause profound alterations in the metabolism of the body and in the chemistry of the brain. Even a single dose of a powerful drug can start the addiction process. When one's mind and body becomes addicted to drugs, stopping drugs produces very unpleasant and distressing mental and physical symptoms. This makes the addict persist with the usage of the drug. Addicts cannot give up their habit unless they get medical treatment and counselling.

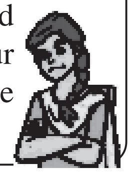
You should not boast about your strong will power and assume that you can experiment with drugs without becoming addicted. ALWAYS KEEP AWAY from drugs. Do not allow yourself to succumb to pressure by friends and acquaintances. If you remain firm in your resolve, you can prevent your life from being ruined.

Notes

Some Basic Facts

What are Reproductive Tract Infections (RTIs)?

RTIs are infections of the upper and lower reproductive tracts of both sexes. Agents of infection include bacteria, viruses, and protozoa. Not all RTIs are sexually transmitted; some may occur due to an imbalance of the bacteria normally found in the reproductive tract and poor personal hygiene.

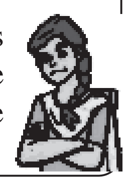


Some Basic Facts

Is it possible for a person to have an RTI (Reproductive Tract Infection) without knowing about it?

Symptoms of RTIs in men are visible, and hence they become aware that their sexual organs have been infected.

However, RTIs in women sometimes can be *asymptomatic*. This means that signs or symptoms are not experienced even though the infection is active. Hence women often do not know that they have RTI.



INTEXT QUESTIONS 29.7

1. Name the pathogen that causes syphilis.

   ....

2. Mention any two symptoms of the disease gonorrhoea.

   ....

3. Give the main method of checking syphilis.

   ....

WHAT YOU HAVE LEARNT

- Diseases are broadly classified into two categories–Acquired (Occur after birth) and congenital (present from birth).
- Infectious diseases are transmitted from a diseased person to a healthy person and degenerative diseases are due to malfunctioning of some organs.
- Cancer is uncontrolled growth of cells.

- Acquired diseases are studied in two categories of communicable and non-communicable diseases.
- Communicable diseases are transmitted and may be caused by virus, bacteria, protozoa or helminths (worms).
- Non-communicable diseases are not transmitted from a diseased person to a healthy person.
- diseases which spread by sexual contact are called sexually transmitted diseases (STD).
- AIDS is caused by HIV.
- Gonorrhoea is caused by a bacterium (*Neisseria gonorrhoeae*). Syphilis is caused by a long, corkscrew bacterium (*Treponema pallidum*).

TERMINAL EXERCISES

1. What is a disease? How does it differ from disorder?
2. Name the two categories of acquired diseases.
3. Explain the term (i) parasitism (ii) reservoir.
4. Give two symptoms of coronary diseases and of typhoid.
5. What precautions should be taken to prevent malaria?
6. Name the pathogen that causes diphtheria and the one, that causes cholera.
7. Mention the four types of acquired diseases.
8. Differentiate between :
   (i) Communicable and non-communicable diseases
   (ii) Pathogen and vector
   (iii) Syphilis and gonorrhoea
   (iv) HIV and AIDS
   (v) Benign and malignant tumours
9. How does polio virus enter human body? How does it paralyse limbs?
10. A nursing mother is given an immunization for BCG and DPT to the baby. What are the diseases against which she would be protected?
11. Give the cause, symptoms and treatment of haemorrhagic dengue fever.
12. Give full form of STD.
13. Mention any two sympotms of syphilis.
14. State the means by which we may prevent and cure gonorrhoea.
15. What does the term AIDS stand for?
16. Write four possible symptoms of AIDS.
17. Mention three general points which may control sexually transmitted diseases.

ANSWERS TO INTEXT QUESTIONS

29.1 1. Any condition which interfers with the normal functioning of the body.

2. (i) congenital (ii) degenerative
3. Refer text.
4. Presence of large number of organisms on the surface of body.

29.2 1. Contact or scabs

2. Appearance of rashes on the body
3. Nervous system
4. Rabies virus
5. *Aedes aegypti*

29.3 1. (i) *Mycobacterium tuberculosis*

(ii) *Salmonella typhi*

(iii) *Vibrio cholerae*

2. Oozing semisolid material in the throat, form a membrane which blocks the air passage.
3. Prolonged contact with patient.

29.4 1. Female *Anopheles*

2. *Entamoeba histolytica*
3. Elephantiasis or Filariasis

29.5 1. It is passed down from parents to offspring.

2. The blood pressure remains persistently high.
3. Benign tumor does not spread to other parts of the body, whereas malignant tumor cells spread to other parts of the body.

29.6 1. Any three points mentioned under "mode of transmission"

2. Give any two points written under "prevention and cure".
3. Human immunodeficiency virus.
4. Mention any two points given under "symptoms."
5. (i) Partner-notification.

(ii) Education of STD.

(iii) Screening for STD.

29.7 1. *Treponema pallidum*

2. (i) Swelling of mucous membrane of urinogenital tract.

(ii) Burning sensation during passing of urine.

3. (i) Prostitution and homosexuality should be avoided.

(ii) Certain medicines may check the diseases.

MODULE - V
EMERGING AREAS IN BIOLOGY

30

BIOTECHNOLOGY

At home we prepare food items such as yoghurt (curd), cake, bread, idli and dosa by the action of microorganisms, such as the bacteria and fungi. Brewers use yeast (fungus) to make beer. Antibiotics such as penicillin are obtained from certain fungi. Nowadays, biological processes such as fermentation by microorganisms is being used in industry on a commercial scale for making food, drinks, drugs (medicines) and industrial chemicals. Modern techniques in biotechnology are programming microorganisms for this task. In this lesson, you will learn about use of microorganisms in industries.

OBJECTIVES

After completing this lesson, you will be able to:

- *appreciate the importance of biotechnology in human welfare;*
- *explain the use of biotechnology in industry;*
- *list the microbes used in the industry and the products manufactured through their use;*
- *explain fermentation and outline the process of making alcohol by using microorganisms;*
- *describe the process of making yoghurt and cheese on a large scale;*
- *explain the contribution of microorganisms in making antibiotics and vaccines;*
- *define genetic engineering and mention its utility;*
- *define transgenic organisms, mention the steps in their production and cite a few examples of transgenic plants and animals;*
- *explain the process and importance of gene therapy;*
- *explain bioremediation and biopesticides.*

30.1 BIOTECHNOLOGY

The word **biotechnology** has come from two words, **bios** (meaning biology) and **technology** (meaning technological application). Thus **biotechnology is defined as the industrial application of living organisms and their biological processes such as biochemistry, microbiology, and genetic engineering, in order to make best use of the microorganisms for the benefit of mankind.**

Biotechnology is applied in many areas to produce foods and medicines, in the development of new diagnostic tools, gene therapy, and DNA finger-printing for forensic purposes.

30.1.1 Applications of Biotechnology

1. Health and medicine

Fighting infectious diseases : Biotechnology is used extensively in the study of infectious diseases such as SARS (Severe Acute Respiratory Syndrome), and influenza. As a result more effective pharmaceuticals have been developed.

Development of vaccines and antibiotics : Using technology, microorganisms are used to develop antibiotics and vaccines to cure diseases. For example, bacteria *Bacillus polymysea* is used to produce polymyxin B (antibiotic used to cure urinary tract infections), fungus *Penicillium notatum* is used to produce penicillin (used to cure pneumonia, and many other bacterial infections.)

Treating genetic disorders : Disease can occur when genes become defective due to mutations. With advancements in biotechnology, in the near future it will be possible to use gene therapy to replace an abnormal or faulty gene with a normal copy of the same gene. It may be used to treat ailments such as heart disease, inherited diseases such as SCID, and Thalassaemia.

In forensic science : A lot of New techniques have been developed such as **DNA fingerprinting**, besides having a number of other applications which have facilitated the speedy identification of the criminals.

2. Environment

Cleaning up and managing the environment : Cleaning up the environment using living organisms is called **bioremediation**. Naturally occurring, as well as genetically modified microorganisms, such as bacteria, fungi and enzymes are used to break down toxic and hazardous substances present in the environment.

3. Agriculture

Biotechnology has also made possible the production of crops improved disease resistan; herbicide-toleran and insecticide-resistan. Plants with improved nutritional value for livestock have also been obtained through biotechnology.

Control of pests : One application of biotechnology is in the control of insect pests. The genetic make-up of the pest is changed by causing some mutations. These pests become sterile and do not reproduce further.

Manufacturing and bio-processing : With the help of new biological techniques it has become possible to grow, the plants that produce compounds for use in detergents, paints, lubricants and plastics on large scale.

Food and drinks : Biotechnology, has also made the processing of foods and their products easier. Preservation and storing of food for consumption later has become easy and cheap with the help of biotechnology. Seedless grapes and seedless citrus fruits have been developed using biotechnology.

4. Industry

Biotechnology has been used in the industry to produce new products for human consumption. Food additives have been developed which help in the preservation of food. Microorganisms are used in the mass production of items such as cheese, yoghurt, and alcohol.

30.1.2 Industrial Microorganisms and Their Industrial Products

Important microorganisms used in industries include

- yeasts (fungi)
- moulds (fungi)
- bacteria
- filamentous bacteria (*actinomycetes*)

Microbes are used in the manufacture of several products. Some of these are

- alcohol-containing beverages
- proteins
- vitamins, steroids and enzymes
- yoghurt (curd)
- antibiotics and monoclonal antibodies
- biogas

> The progress in gene manipulation and genetic engineering has introduced the use of cultured mammalian cells and 'hybridomas' in the industries. Hybridomas are created by fusion of cells belonging to organisms of different species.

30.1.3 Production of Alcohol – Containing Beverages

> **Fermentation**
>
> Fermentation is a process by which carbohydrates such as sugar are converted into alcohol.
>
> $$\text{Glucose} \xrightarrow[\text{enzyme}]{\text{yeast}} \text{Ethyl alcohol + Carbon-dioxide + ATP}$$
>
> Yeast is capable of fermenting sugar to alcohol. Fermentation is an energy yielding process.

In the mid nineteenth century, Louis Pasteur showed that fermentation by the yeast *Saccharomyces cerevisiae* yields beer and buttermilk. Presently yeast is being used on a large scale for brewery and bakery.

Bakers use yeast to leaven (raise) dough to make bread. Yeast is also grown on molasses and is packed and sold. Yeast is used to raise cakes and bread while baking.

Alcoholic beverages are manufactured by fermentation of sugars by the yeast, *Saccharomyces cerevisiae*. It is called **Brewer's yeast**. The source of carbohydrate fermented by yeast gives the beverage its specific flavour. For example :

– Wine is obtained by fermentation of grapes. Grapes are fermented by *S. cerevisiae* and its soluble sugars (glucose and fructose) are converted into CO_2 and ethyl alcohol.

– Fermentation is carried out in large tanks called bioreactors.

– Barley malt is fermented to yield beer.

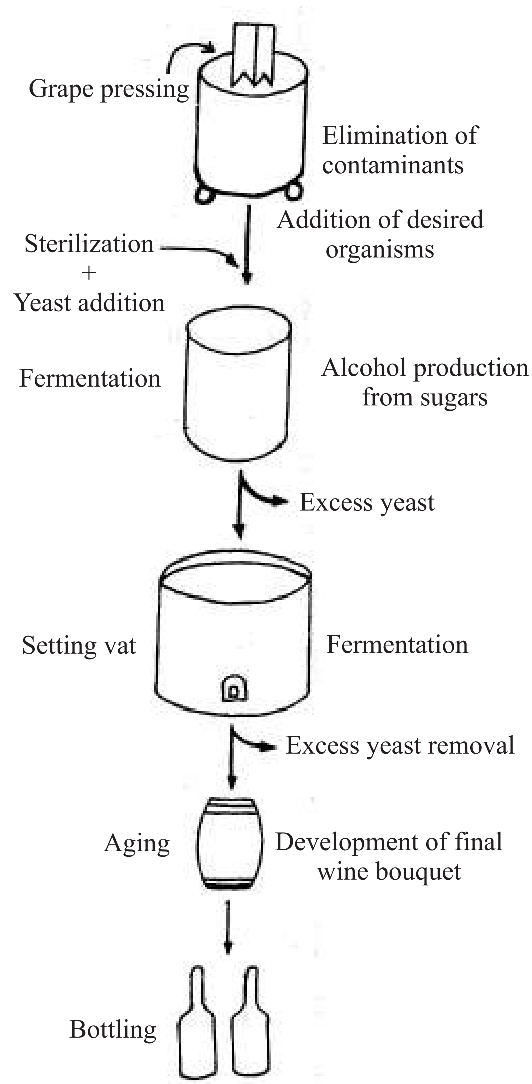


Fig 30.1 Obtaining wine from *grapes by fermentation by* Yeast

Steps taken for fermentation

(i) Fermenter or tank and the nutrient medium are sterilised by steam under pressure (autoclave).

(ii) The correct strain of yeast is selected.

(iii) The yeast is inoculated into the medium. Inoculation can be done in two ways:

(a) Yeast can be grown as a layer on the surface of nutrient medium. This is called **support growth system**.

(b) Cells or mycelia are suspended in a liquid medium. This is called **suspended growth system**.

(iv) Care is taken to maintain the right temperature, pH, oxygen and carbon-dioxide concentration.

(v) The medium is stirred and left to ferment.

(vi) The sugar in the medium gets fermented by enzymes released by yeast.

(vii) The fermented product is taken out (Fig. 30.1).

Some alcohols manufactured by yeast fermentation are : Ethyl alcohol, butanol and glycerol. The same method also yields **lactic acid** and **acetic acid** (vinegar) by using specific bacteria.

The yeast extract left after removal of the beverage can be used as animal feed. It is also a rich source of vitamins.

INTEXT QUESTIONS 30.1

1. Name three different kinds of microorganisms used in the manufacture of industrial products.

   ....

2. Name three products obtained in industries by using microorganisms.

   ....

3. Name two alcohols produced through fermentation by yeast.

   ....

4. Name the two methods of inoculation of yeast in the medium.

   ....

5. Match the items given in columns A with those given in column B.

	Column A		Column B
1.	Bioreactor	(a)	Butanol
2.	Steaming under pressure	(b)	Fermentation tank
3.	Alcohol	(c)	Autoclave

30.2 YOGHURT AND CHEESE MAKING

At home we add a bit of yoghurt (starter) to milk and it sets. The milk becomes yoghurt or curd due to the milk curdling enzymes released by the increasing population of bacteria, *Lactobacillus* present in the starter. (Table 30.1) On a commercial scale, making of yoghurt as well as cheese utilises **Rennet** tablets for this purpose. Rennin is the milk curdling enzyme obtained from the calf stomach. However, this method is popular any more.

Whether by bacteria or by "rennin", when milk is 'curdled', milk protein casein, separates from the liquid which is called whey. *Lactobacillus* convert lactose in the milk into lactic acid which lowers the pH. Lowered pH causes souring which is essential for preservation.

Butter can be made by violently shaking (churning) sour milk. The fat globules separate and form butter. A starter culture of *Streptococcus cremosis,* and *Leuconostoc is* added to the milk when butter, yoghurt or cheese are made.

Table 30.1 Fermenting microbes used for dairy products

Fermented product	Fermenting microorganism	Description
Yoghurt	*Streptococcus thermophilus* and *Lactobacillus bulgarians*	Product made from low or non-fat milk and stabilisers like gelatin added.
Butter	*Lactococcus lactis*	Cream is incubated till the desired acidity is achieved followed by churning, washing and salting

30.2.1 Microorganisms and antibiotics

In 1928, Alexander Fleming accidentally discovered that one microorganism can inhibit the growth of another organism. Selman Waksman 1942 coined the term antibiotic (anti: opposed to, biotic: living organism)

> Antibiotic is a substance produced by a microorganism such as bacteria or fungi which inhibits the growth of another microorganism. Antibiotics are generally small molecules with a molecular weight less than 2000 Da. They are not enzymes. The antibiotic interferes with the vital metabolic processes of the pathogenic bacterium and prevents its growth and reproduction.

Wide-spectrum and narrow-spectrum antibiotics

Modern medicines have found a specific antibiotic for almost every different pathogen. *Streptomyces* bacterium yields some of the most widely used antibiotics like Chloramphenicol, Erythromycin, Tetracycline etc. These are called '**broad spectrum antibiotics**' and can be used against more than one kind of pathogenic bacterium. Streptomycin and Penicillin are **narrow spectrum antibiotics** used against few pathogenic bacteria.

Drawbacks of antibiotics

Use of antibiotics was a big step in curing infectious diseases which offered a safe, sure and relatively inexpensive cure. But even now we find many people suffering from bacterial diseases. The reasons for this are:

1. Some people are allergic to a particular antibiotic.
2. Some disease causing bacteria undergo mutation and become resistant to a particular antibiotic to which they were sensitive earlier.

Sources of antibiotics

Some of the common antibiotics and their source organisms are given in table 30.2.

Table 30.2 Major antibiotics and their sources

Antibiotic group	Source
Tetracyclin	*Streptomyces sp*
Chlorotetracycline	*Streptomyces auriefaciens*
Chloramphenicol	*S. venezuelae*
Cycloheximide	*S. griseus*
Streptomycin	*S. griseus*
Cephalosporin	*Cephalosporium acremonium*
Penicillin	*Penicillium chrysogenum*

30.3 VACCINATION

In 1790, Edward Jenner observed that milkmaids did not get smallpox as they were exposed to a milder disease cowpox. Jenner infected a boy with cowpox germs and after two months with small pox germs. The boy did not get small pox. Jenner proposed that if mild or attenuated (weakened) germs were introduced into the body, they would not cause the disease. He gave the term **vaccine** (latin *vacca* : cow) or vaccination, for the weakened germ and its protective inoculation.

Today, the principle of vaccination has been extended to prevent attack of many diseases. When vaccines are made from attenuated disease causing bacteria, they are termed as “first generation vaccines”. The “second generation vaccines” have been produced by genetic engineering or recombinant DNA technology about which you shall study in the next section. Second generation vaccines for Hepatitis B virus and *Herpes* virus are already in use. Vaccines synthesised from chemicals are called “third generation vaccines”.

30.4 PRODUCTION OF VITAMINS

Vitamins are nutrients required in very small amounts for essential metabolic reactions in the body. They are produced using biotechnology. Vitamin C was the first vitamin to be produced during a fermentation process by using bacteria. B_{12} or cyanocobalamin and B_2 or Riboflavin were obtained from liver extract. The production of B_{12} involved fermentation by propionic bacteria. In nature B_2 is found in cereals, vegetables and yeast but the yield of B_2 can be enhanced hundred to three hundred fold by using microbes.

30.5 PRODUCTION OF BIOGAS

Biogas is a new conventional source of fuel. Its use can save fossil fuel (coal, kerosene, and petrol) which are fast getting depleted.

Biogas is made from organic waste including faecal matter. Cowdung or faeces have lignocellulose. The energy used as fuel comes from methane (CH_4). Cowdung forms the primary source of biogas. In India cowdung is available in plenty in villages and small scale methane generating plants have been designed.

Any biodegradable substance (which can be decomposed by bacteria) can be fermented anaerobically (in the absence of oxygen) by methane-producing (methanogenic) bacteria. Cowdung or faeces are collected and put in a biogas digester or fermenter (a large vessel in which fermentation can take place). A series of chemical reactions occur in the presence of methanogenic bacteria (CH_4 generating bacteria) leading to the production of CH_4 and CO_2.

While generating biogas, few parameters have to be taken into account. These are as follows:

1. Fermentation should be in an anaerobic environment and no free oxygen should be present.
2. pH in the fermenter should be close to neutral, around 6.8 to 7.6
3. Methanogenic bacteria are to be used for fermentation.

Several kinds of reactors have been designed. One side of the reactor is for input, that is, for introducing cowdung or faecal matter into the reactor. Whiel other side of the reactor has an outlet for removal of biogas: The material is left behind is called **slurry**. The gas gets stored above the slurry level. Slurry forms excellent manure.

Advantages of biogas

1. Biogas is a fuel used to cook food, and light lamps.
2. Slurry left after biogas production forms a soil conditioner (manure).
3. Biogas is much cheaper than LPG (Liquefied Petroleum Gas) which we commonly use these days in our houses.

INTEXT QUESTIONS 30.2

1. Name the bacterium responsible for curdling of milk.

   ....

2. Who discovered antibiotic?

   ....

3. What do you mean by second generation vaccines?

   ....

4. Which was the first vitamin to be produced by fermentation?

   ....

5. Which bacteria cause the production of biogas?

   ....

30.6 GENETIC ENGINEERING

An engineer fixes a machine to make it work efficiently. Body is like a machine and genes, the nucleotide sequences in DNA have the information for products to run this machine. With progress in molecular biology, techniques have been developed by which a scientist can now manipulate genetic material, replace genes or replace gene products in the body, make identical copies of these genes and store them in a gene library. This is called **genetic engineering**.

30.6.1 Importance of genetic engineering

You know that **diabetes mellitus** is a genetic disorder. A diabetic patient lacks a gene which has the information for synthesis of insulin, therefore such a person cannot secrete insulin. Take another example. A person suffering from **Thalassemia** lacks the gene for haemoglobin and can survive only through frequent blood transfusions. A person suffering from sickle cell anemia has an altered gene whose product makes the red blood corpuscles abnormal on exposure to oxygen because they contain faulty haemoglobin.

Humans suffering from genetic disorders such as those cited above have now hope in genetic engineering. Genetically engineered copies of DNA can be produced and stored in gene libraries to be used when required.

In the previous sections of this lesson you have studied about the use of microbes to produce various products on a commercial scale. Currently bacteria are being genetically manipulated to act as biological factories to produce various kinds of proteins such as enzymes, hormones, and antibodies through genetic engineering. Researchers have isolated genes which can be used to produce effective vaccines.

Workers have also developed bacterial strains, through genetic manipulation, which can degrade harmful environmental pollutants.

30.6.2 Recombinant DNA technology

Genetic engineering may be defined as construction and utilisation of new DNA molecules that have been engineered by recombinant DNA techniques. **The technique of genetic engineering is in the production of recombinant DNA.** Recombinant DNA, as the name suggests, involves cutting a piece of original DNA and inserting in its place a different segment of DNA having desred characters. The recombined or recomposed DNA is then copied multifold inside bacterial cells and stored in a gene library for use when required. The multiple copies of the gene are termed **cloned DNA or cloned genes.**

Causing genetic change by artificially manipulating DNA is genetic engineering.

Clone is a group of genetically identical cells. Such cells are descendents of a single cell. When a bacterium with recombinant DNA divides several times, it provides a clone containing a specific segment of DNA from another species.

The production of genetically identical individuals or genetic material from a single cell is called cloning.

Recombinant DNA technology resulted from the two discoveries made while experimenting with bacteria :

(i) presence of plasmids or extra chromosomal DNA fragments in the bacterial cell which replicate along with bacterial DNA and can be used as a vector for carrying foreign DNA.

(ii) presence of specific restriction enzymes which attack and cut DNA at specific sites.

30.6.3 Tools and steps in recombinant DNA technology

Recombinant DNA technology is a "cut and paste" technology. Specific nucleotide sequences are cut from the DNA of humans, other animals or plants and "pasted" into plasmids. DNA of the plasmid carrying nucleotide sequence of another organism is the recombinant DNA. It is then inserted into bacteria. Bacteria divide repeatedly and a clone of bacteria with the recombinant DNA is obtained.

Five requirements for recombinant DNA technology are:

(i) Cell culture

(ii) Restriction endonuclease enzyme

(iii) Plasmids

(iv) Ligases

(v) Host bacteria

(i) Cell culture : Cultured cells of an animal or plant (or even a bacterium) carrying the required gene (nucleotide sequence of DNA) in its nucleus.

(ii) The enzyme Restriction endonuclease : Restriction endonucleases cut short specific DNA sequences. There are many different restriction endonucleases found in bacteria. Each of these enzymes very specifically recognises a particular DNA sequence (usually 4 to 6 bases) and cuts it. These enzymes are the "molecular scissors". They either cut both the strands at the same place or at different places so that the two DNA strands hang out at the two ends. Two cuts at the two ends of a DNA segment releases the cut part as the restriction fragment. The ends are single stranded and called sticky ends.

Thus a piece of DNA containing a particular gene can be obtained by selecting a particular restriction endonuclease.

(iii) Plasmids : Plasmids are extra chromosomal DNA molecules in a bacterial cell which have sequences matching those of the required gene and can be similarly cut by the same restriction enzymes. Plasmids can readily enter bacteria, yeast or other speedily reproducing cells.

(iv) DNA ligase : It is an enzyme called 'joining enzyme' since it joins two DNA fragments, both of which have having sticky ends. Ligase is the "molecular glue".

(v) Host Bacteria : Host bacteria are the bacteria whose plasmid is used for carrying foreign DNA.

Sequences of steps in recombinant DNA technology:

1. Specific restriction enzyme is selected.
2. Cell culture with required gene in the cells is obtained.
3. Restriction enzyme cuts the DNA at two ends of the specific gene and a restriction fragment is obtained (Fig. 30.2 a, c)
4. Same restriction enzyme cuts a matching DNA sequence from a plasmid (Fig. 30.2 b, d)

5. Ligase joins the restriction fragment in the place vacated by the cut DNA segment of the plasmid. The plasmid becomes a *recombinant plasmid* containing a foreign DNA fragment (Fig. 30.2 e, f). Its DNA is the *recombinant DNA*. Since plasmids can carry foreign DNA, they are called **clonal vectors**. Bacteriophages (viruses) can also function as clonal vectors.
6. The recombinant plasmids are then placed with the comptent cells to enter the bacteria.
7. Bacteria divide. Recombinant plasmids replicate along with bacterial DNA.
8. A large population of bacteria (more than a million) containing recombinant DNA can be obtained in less than ten hours.
9. Multiple identical copies of DNA fragments inserted into plasmids or bacteriophage (bacterial virus) are then obtained and preserved in a DNA library.
10. These DNA fragments are the cloned DNA.

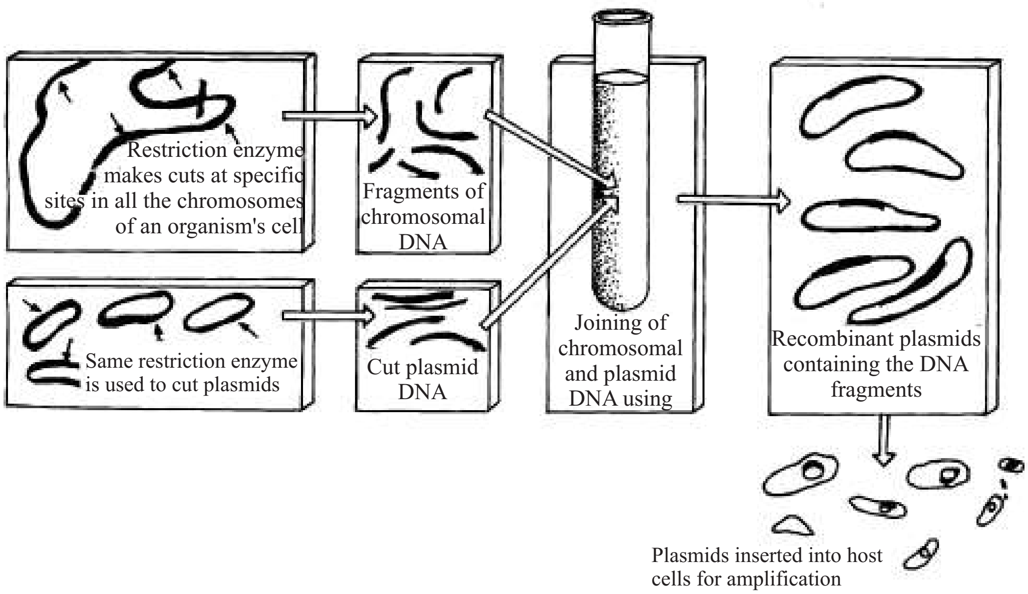


Fig. 30.2 Steps in formation of multiple copies of recombinant DNA for DNA library

INTEXT QUESTIONS 30.3

1. Define genetic engineering.

   ....

2. What is a clone?

   ....

3. What do you mean by the term recombinant DNA?

   ....

4. Where are plasmids found?

....

5. Why are restriction enzymes called “molecular scissors”?

....

6. Name the enzyme which joins DNA fragments.

....

7. What is a clonal vector?

....

8. What do you mean by transgenic organism?

....

30.6.4 Applications of genetic engineering

1. Protein manufacture

You would recall from earlier section of this lesson that bacteria and yeasts have been used for centuries to produce cheese, and alcohol, and more recently antibiotics. Currently, plasmids in bioengineered bacteria carry some human genes and these genes are expressed to give large quantities of human proteins which are clinically useful. The development of recombinant DNA technology and gene cloning has generated a new industry for manufacturing proteins. Earlier valuable proteins could be obtained from eukaryotes in small amounts and at heavy expense, but now these can be produced in large quantities. For example, until sometime back, growth hormone was available only in tiny amounts and was extremely expensive as it had to be extracted from endocrine glands of certain animals. Today, it can be made available in large quantities through recombinant DNA technology. In 1982 production of human insulin became the first commercial success of recombinant DNA technology.

There are several proteins of therapeutic (medical) value which are available now through recombinant DNA technology. These are cloned human gene products approved for use or being developed. Following table 30.3 gives the names and uses of some of these:

Table 30.3 The names of proteins and their uses

Protein	Used in
1. Insulin	Diabetes mellitus
2. Growth hormone	Pituitary dwarfism
3. Erythropoietin	Anaemia
4. Interferons	viral infections
5. Interleukin 2	Cancer
6. Clotting factor VIII	Haemophilia A
7. Clotting factor IX	Haemophilia B
8. Monoclonal antibodies	Infectious diseases
9. Tissue Plasminogen factor	Heart attack

2. **Enzymes** have also been produced from cloned genes. The following table 30.4 gives the names of such enzymes and their uses:

Table 30.4 The names of enzymes and their uses

Enzymes	Used in
Proteases	manufacture of detergents, meat tenderisers.
Amylases	manufacture of beer, bread and textiles
Glucoisomerases	to make corn syrup, which is sweeter than sucrose and used to flavour soft drinks

Enzymes are fragile and have to be entrapped in gel and encapsulated in small artificial cells.

3. Antibiotics

Since the discovery of Penicillin in 1920s, more than 6000 antibiotics have been isolated from various microorganisms and have resulted in an enormous improvement in human health. Research is in progress to genetically engineer biosynthetic pathways for the synthesis of antibiotics. Novel antibiotics have also been obtained through genetic manipulation.

4. Vaccines

Bioengineered vaccines have been developed for rabies and hepatitis B. A gene for the antigen protein is inserted into a plasmid and the bacteria containing recombinant DNA then generate large quantities of the protein. The protein is added to the vaccine. Antibodies immediately form against the antigen when vaccinated.

INTEXT QUESTIONS 30.4

1. Name any two proteins and two enzymes obtained by recombinant DNA technology.

   (i) .... (ii) ....

2. How is recombinant DNA technology useful for pharmaceutical companies?

   ....

3. Name any two diseases for which bioengineered vaccines have already been developed.

   (i) .... (ii) ....

30.8 TRANSGENE AND TRANSGENIC

Genetic engineering has made possible production of organisms of one species carrying genes of another species. The foreign gene is called a **transgene.** The plant or animal carrying it is termed as **transgenic.**

Genetically engineered organisms carrying foreign genes are termed transgenics.

1. Usefulness of transgenic organisms

1. For a better yield desirable traits can be introduced or increased in agricultural plants and domestic animals, especially the cattle.
2. Valuable products can be produced by transgenic plants and animals.
3. Transgenic plants and animals can be used for investigating biological processes such as gene expression.

2. Methodology for production of transgenics

There are two methods which are mostly used for generating transgenics:

(i) Microinjection of foreign DNA into pronuclei of fertilised eggs.

(ii) Retroviral vector method. Infection of pre-implantation embryos with retroviruses carrying foreign DNA.

The first method has the following steps:

(i) Collection of oocytes from the animal killed in slaughter house or surgically removed from female parent.

(ii) In-vitro maturation of oocytes.

(iii) In-vitro fertilisation with male semen.

(iv) Eggs (oocytes) to be centrifuged to concentrate yolk which in normal cells prevents male pronuclei from being seen under the dissecting microscope.

(v) Microinjection of "input DNA" into male pronuclei (Fig. 30.3). Usually hundred to thousand copies of the gene of interest are injected.

(vi) In-vitro development of embryos.

(vii) Non-surgical implantation of one embryo into a recepient foster mother.

(viii) Screening of DNA of the offspring of foster mother for presence of transgenes.

(ix) Offspring with the transgenes are the transgenic organisms.

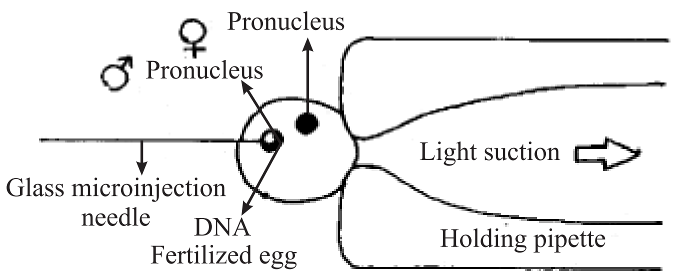


Fig. 30.3 Microinjection of input DNA into male pronucleus

In the **second method** called the **retroviral vector method,** DNA required to be transferred into the female is introduced through the retrovirus which infects the cells of an early stage embryo before implantation into a receptive female.

Transgenic plants

By recombinant DNA techniques, plant breeders can now directly modify the DNA of plants. They can add genes from other species to the plant. The most popular method for doing this is to produce a transgenic plant by the use of *Agrobacterium tumefaciens.* It is a soil bacterium which has a natural "genetic engineering" system. It has a plasmid which can be inserted into plant cells. *Agrobacterium tumefaciens* causes galls (tumours) (Fig. 30.4) in several plants. The information for production of galls is present on a plasmid, (T_i) in the bacterium. A segment of DNA from the plasmid can be transferred into plant cell. In the T_i plasmid, gall forming genes can be removed and substituted by desired genes. The plasmid can then be used to transform plant cells. Such foreign genes in the chromosomes of transformed plant cells can be expressed normally (Fig. 30.4).

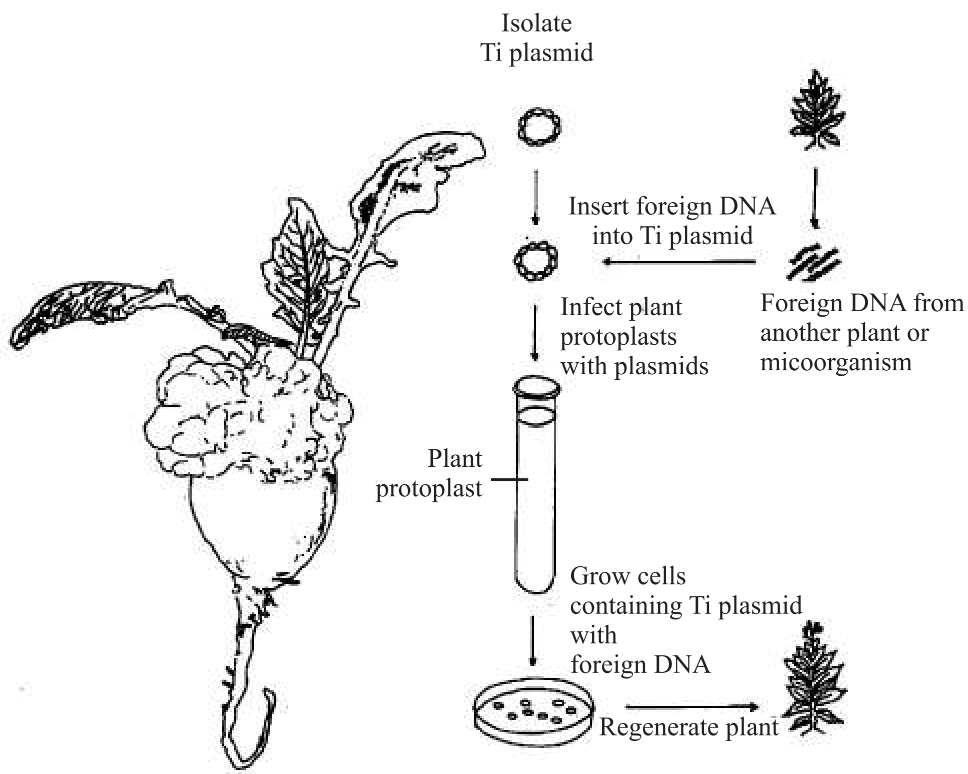


Fig. 30.4 Gall caused on turnips by bacteria carrying T1 plasmid

Examples of transgenic plants

(i) Cotton which can resist attack by worms.

(ii) Corn and soyabean which are more tolerant to drought and pesticides.

Transgenic plants can also serve as factories to produce medically and commercially useful proteins. Serum albumin is used in preparations given to patients with burn injuries and others for replacement of body fluid. Genetically altered potato and tobacco plants can yield serum albumin.

Transgenic animals

Mice : It is difficult to generate transgenic animals as animal cells do not accept plasmids. Transgenic mice are, however, routinely produced in the laboratories throughout the world by microinjecting foreign DNA. Gene for growth hormone from rats was microinjected into mouse eggs. These mice grew larger than their litter mates. This was because rat gene got integrated into mouse DNA and was being expressed. (Fig. 30.5).

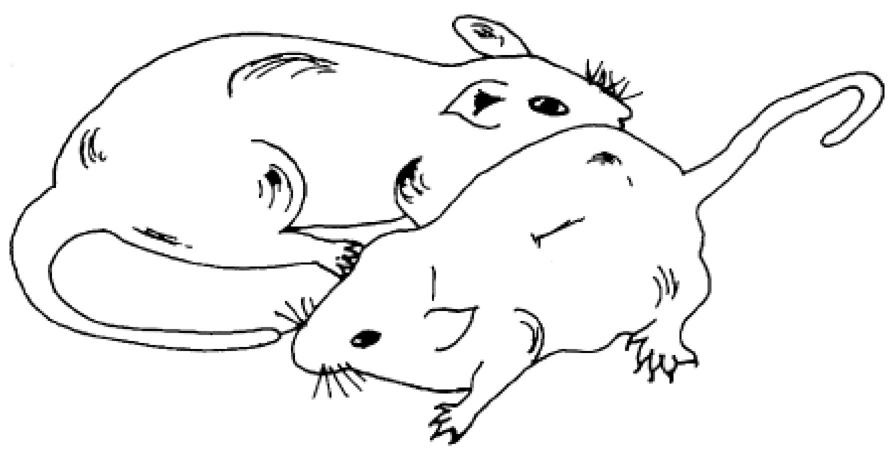


Fig. 30.5 Transgenic mouse compared to normal mouse

Goats : Transgenic goats have been developed from a fertilised egg injected with recombinant DNA consisting of goat gene sequences spliced with human genes for tPA (tissue plasminogen activator). Goat milk contains this factor which dissolves blood clots. This has proved very useful for heart attack (coronary thrombosis) and stroke patients.

Cattle : Transgenic livestock have the potential to produce large quantities of drugs faster and at much cheaper rates than from bacteria which have to be cultured in huge industrial vessels.

Chinese hamster : Blood clotting factor VIII genes have been inserted in chinese hamster ovary cells. This factor saves the patients suffering from haemophilia A. Blood clotting factor has also been generated through recombinant DNA technology in Chinese hamster. This eliminates the need to get it from human blood alongwith remov of the the risk of transmitting AIDS.

30.8.1 Bioremediation (remedy through organisms)

Genetically engineered bacteria can clean up pollutants from the environment. This is called **Bioremediation**. The transformed bacteria metabolically breakdown toxic pollutants into harmless compounds.

Mercury resistant bacteria process metallic mercury (which damages the nervous system) into a nontoxic compound.

INTEXT QUESTIONS 30.5

1. Define the term transgenic.

   ....

2. Name the gall producing bacterium and the plasmid which can be conveniently used to produce transgenics.

   ....

3. What is bioremediation?

   ....

30.9 HUMAN GENE THERAPY

Many people are born with and suffer from diseases such as sickle cell anaemia, haemophilia, severe combined immuno deficiency (SCID), and colour blindness. Such diseases are caused due to genetic defects. These genetic defects are hereditary. It has been estimated that around 2000 children in India alone are born every day with genetic disorders. Let us learn about the methods of removal and correction of genetic defects.

30.9.1 Gene function

Genes play a number of different roles in the proper functioning of an organism by (a) controlling synthesis of enzymes involved in biochemical reactions, (b) regulating their synthesis such that the right enzyme appears at the right time. Sometimes genes may not function properly due to some irregularity or defect in their structure. This may lead to genetic disorders. A defective gene may appear in an individual in the following two ways:

(i) Certain defective genes are inherited and the defect runs in the family. For example : Colour blindness, haemophilia, sickle cell anaemia.

(ii) A gene becomes defective all of a sudden due to mutation during early development. For example : Albinism (non-heritable).

A gene mutation may alter the synthesis or activity of an enzyme needed for the normal completion of chemical reactions or for the normal functioning of an organism.

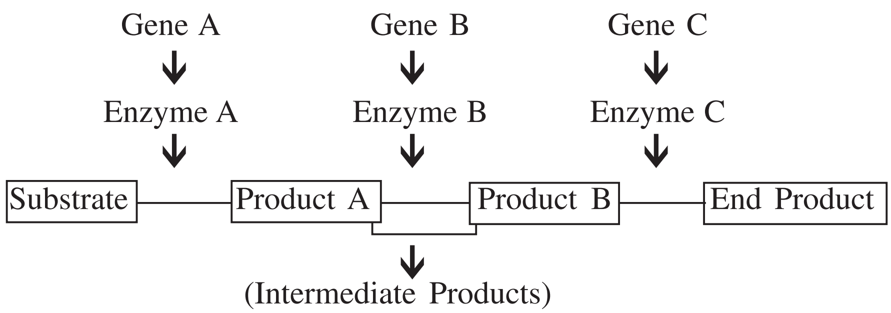
The consequences are :

(i) accumulation of the metabolic substances that are toxic, or

(ii) deficiency of a compound that is important for normal cell functioning.

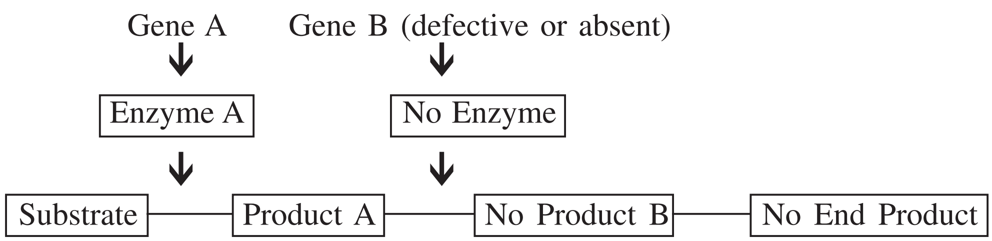
There are mutations that can lead to disorders in any part of the body, including muscles, eyes, liver, bones, kidneys, nerves, and blood system. Under normal conditions, genes work in total harmony completing their specific job of converting a raw material into a finished product, by synthesising the specific enzyme.

Normal gene functioning



Defective Gene Functioning

Sometimes, absence of a gene or defect in a single gene may result in defective metabolism and a desired product may never be formed, rather a harmful product may be obtained.



The absence of enzyme B results in accumulation of unuitilised product A and end product is not produced.

You will be alaimed to know that a number of human disorders are caused due to single gene defects. Following table 30.5 gives an idea of some such diseases, caused due to the missing or defective gene products, and the symptoms, of the diseases.

Table 30.5 Some Common Single Gene Defects

Disease	Gene Product	Symptoms
(i) Severe Combined Immuno Deficiency syndrome (SCID)	Absence of adenosine deaminase	Loss of immunity, T lymphocytes and B lymphocytes in low count.
(ii) Haemophilia	Absence of blood clotting factor VIII	Defective blood clotting, chronic bleeding in joints.
(iii) Sickle Cell anaemia	defective β chain of haemoglobin	damage to heart, spleen, kidney, liver and brain
(iv) Phenylketonuria (PKU)	Accumulation of aminoacid phenyl alanine in blood	Severe mental .retardation, albinism (lack of pigmentation)

30.9.2 Gene therapy

Most of the genetic disorders may result in serious complications, health problems and untimely death. Techniques are being developed to replace defective genes or manipulate them to remove the genetic disorder. Such treatment is called **Gene Therapy**.

Gene Therapy thus may be defined as a technique in which a patient (sufferer) is given healthy genes to replace the defective ones inherited from the parents, or to enhance the action/reaction of the genes they already have.

Replacement and alteration of defective gene is called Gene therapy.

Human gene therapy in a broad sense is the addition of functional normal gene or genes to the genetic material contained in the human cell. This is with the aim of correcting an inherited defect.

The ultimate goal is to let 'protein assembling unit' of the cell make desired proteins needed for the normal functioning of an individual. It is like supplying a patient with the necessary gene product formed within the cells by the patient's own body.

INTEXT QUESTIONS 30.6

1. What causes the alteration of normal functioning of a gene ?

   ....

2. Name two single gene disorders in human beings.

   ....

3. State which cells have a low count in Severe Combined Immuno Deficiency (SCID).

   ....

4. Define gene therapy.

   ....

30.9.3 Approach to human gene therapy

There are two basic approaches to human gene therapy:

(i) Somatic gene therapy, and

(ii) Germ-line gene therapy.

(i) Somatic (body cell) gene therapy

Once a normal gene has been cloned, it can be used to correct a genetic defect. Body cells are targeted for genetic transformation (defective gene transformed to normal). This approach helps in the correction of a genetic defect confined to a specific organ or tissue.

(ii) Germ line (sex cell) gene therapy

In this approach, cells of germinal epithelium or gametes or zygote are genetically modified to create an individual that will carry remedial gene(s) in the following generation. Presently all research on human gene therapy is directed towards correcting gene defects in somatic cells (non-sex cells). Somatic gene therapy can be grouped under the broad categories of :

(a) Ex-vivo gene therapy,

(b) In-vivo gene therapy, and

(c) Antisense gene therapy.

(a) Ex-vivo (outside the body) gene therapy:

This type of therapy usually involves the use of cells (with defective gene) taken from the patient. After the gene alteration when the same cells are transfused (transferred back), no immunological response takes place. The steps involved in the procedure are :

1. Isolating the cells with gene defects from a patient.
2. Growing the isolated cells in culture.
3. Altering the genome of the isolated cells with remedial gene.
4. Selecting, growing and testing the altered cells.
5. Transplanting or transfusing the altered cells back into the patient (Fig. 30.6).

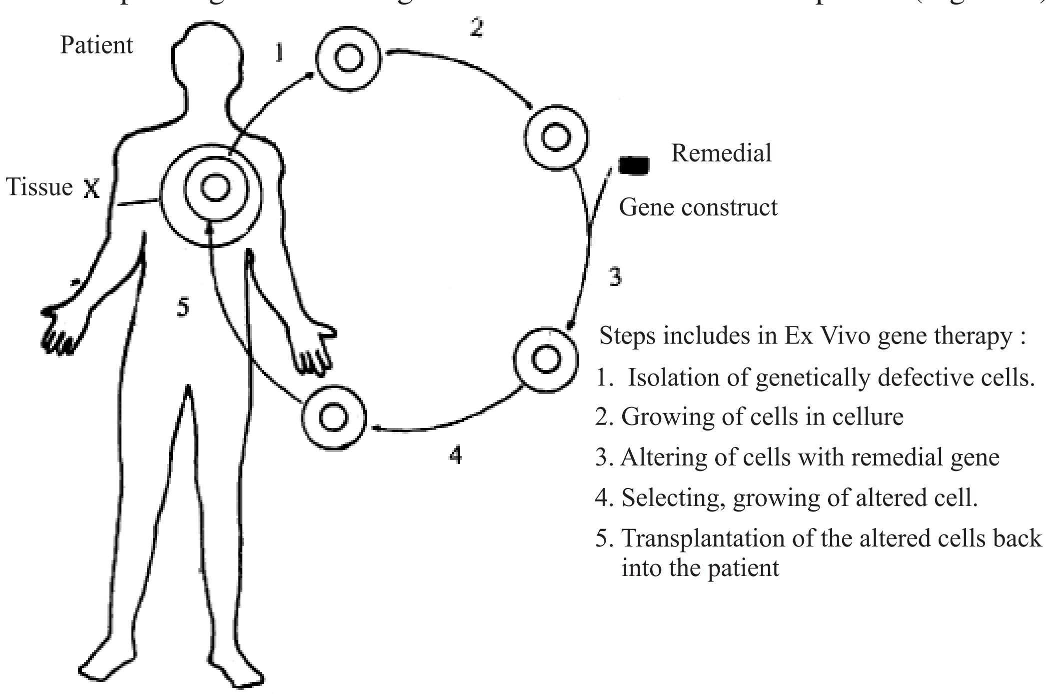


Fig. 30.6 Steps in the Ex-vivo gene therapy

Vectors such as retrovirus is used for the integration of normal gene in the host genome. Stem cells of the bone marrow are continuously producing new cells. If such cells are taken and put back after alteration, to remove genetic defects, these cells can divide and differentiate into various important cells such as B cells and T cells, macrophages, red blood cells, platelets and bone cells.

Genetically engineered stem cells on transplanting back into the patient's body result in a continuous supply of the required gene product. The technique can be used in the treatment of the following genetic disorders:

(i) Severe Combined Immuno Deficiency (SCID).

(ii) Sickle cell anaemia.

(iii) Thalassaemia

(iv) Certain tumours.

(b) In-vivo (within the body) gene therapy

This type of gene therapy includes direct delivery of a remedial gene into the cells of a particular tissue of the patient. Adenovirus, a double stranded DNA virus, is being used as a vehicle for transferring the remedial gene, (Fig. 30.7). The viruses used are weak enough to cause any disease. The tissue specific virus integrates with the host genome and can only infect dividing cells and not the other healthy cells.

This therapy may become useful in the treatment of cancer, Alzheimer's disease and Parkinsons's disease.

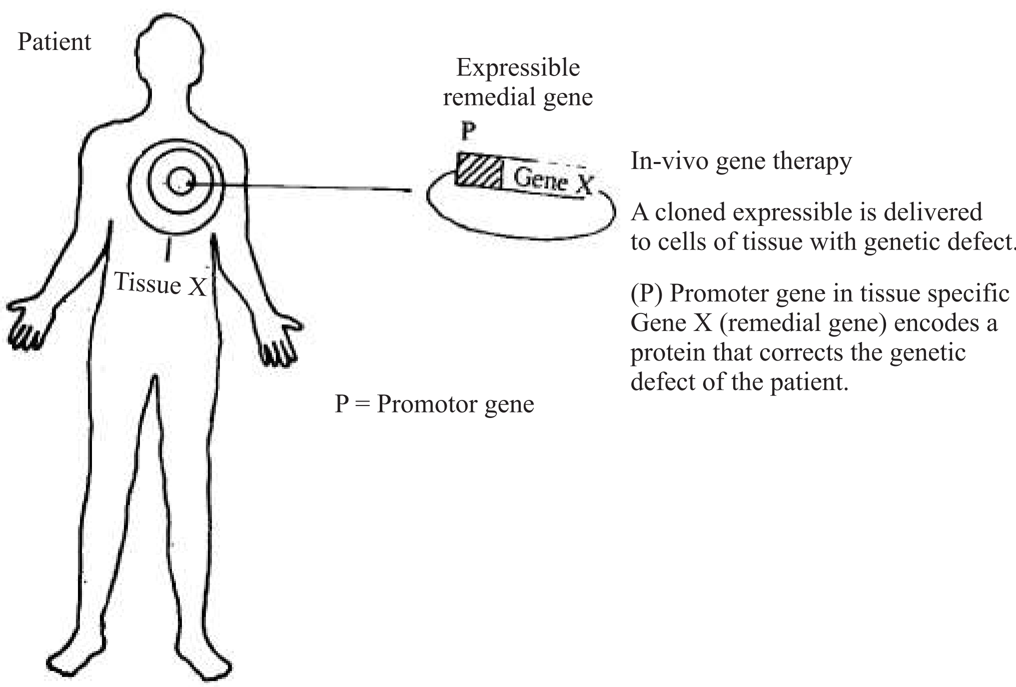


Fig. 30.7 Steps in In-vivo gene therapy

(c) Antisense Therapy

You have learnt the steps involved in protein synthesis, transcription and translation.

This therapy is designed to prevent or lower the expression of specific gene thus limiting the amount of translation of protein from the over producing gene.

This therapy involves the introduction of nucleic acid sequence that is complementary to all or part of m-RNA (messenger RNA formed in the target cell) into the cells overproducing the gene product (Fig. 30.8). This therapy will prove useful in certain human genetic diseases and cancers where too much of a gene product or its continuous presence changes the normal functioning of the cell. It has been tried for treatment of malignant glioma or brain tumour. Tlaur-save tomato with a long shelp life has been produced by this technique.

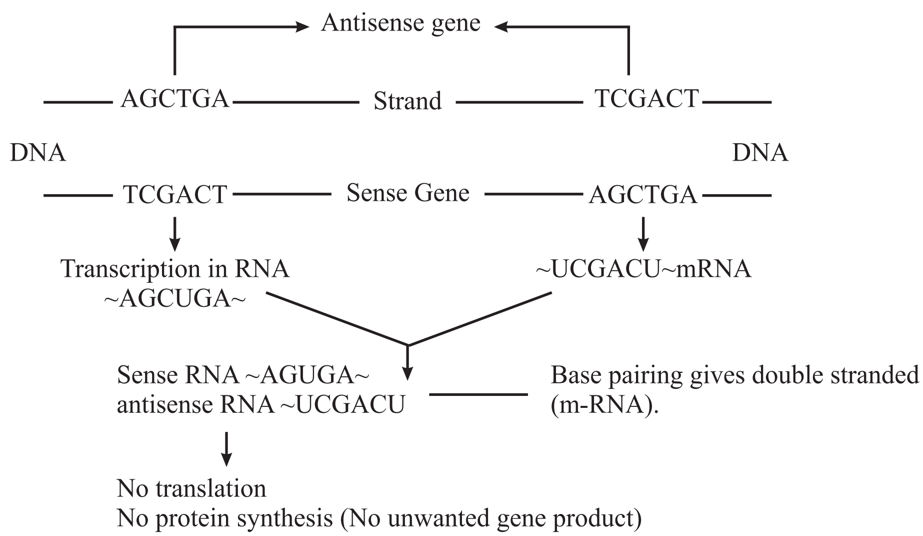


Fig. 30.8 Antisense gene therapy

Antisense gene therapy

An expressible gene is cloned in its reverse (order) orientation and is introduced into a cell. The RNA thus transcribed forms the antisense sequence of normal mRNA. When the antisense RNA base pairs with the mRNA, translation of the mRNA is prevented. The antisense RNA does not contain signals for the initiation of translation.

30.9.4 Gene Therapy—How Far?

The possibility of being able to genetically engineer humans has always been the aim of certain researchers. Somatic cell gene therapy is in its early stages of becoming a mode of treatment for a number of genetic and other diseases such as

(i) AIDS

(ii) Haemophilia

(iii) Atherosclerosis

(iv) Leukaemia

(v) Lung cancer

(vi) Severe Combined Immuno Deficiency-SCID

Germ line gene therapy is not being currently practised. Any manipulation in the genetic material of sex cells may introduce unforeseen characters with alarming consequences in the offspring. Gene therapy is thus not only risky but an expensive and time consuming technique available only in few advanced countries.

Gene therapy has the following limitations

(i) Research is limited to only somatic cells. Treated individuals can not pass the genetic improvement to offspring.

(ii) There could be a possibility of random integration of DNA into a human chromosome leading to inactivation or activation of a normal gene. This may result in either deficiency of an important enzyme or uncontrolled cell division leading to cancerous growth.

(iii) The Procedure Planned has to meet strict safety standards in animal trials.

(iv) Target diseases have to be limited to those that involve known defects in a single gene, and the normal gene must be cloned and be available for transplant.

INTEXT QUESTIONS 30.7

1. State the two approaches to human gene therapy.

   ....

2. Name the three categories of somatic cell gene therapy.

   (a) .... (b) .... (c) ....

3. Name any two genetic diseases that can be treated by somatic gene therapy.

   (i) .... (ii) ....

4. What is the direct delivery of the corrected gene into the tissue of the patient by the use of Adenovirus called?

   ....

WHAT YOU HAVE LEARNT

- Biotechnology is the application of scientific knowledge by industries that produce biological products like food supplements, enzymes, and drugs.
- Yeasts (Fungi), moulds (Fungi) and bacteria are important microorganisms used in industries.
- Yoghurt, alcoholic beverages, antibiotics, vaccines and biogas can be obtained on a commercial scale by the use of microorganisms.
- Fermentation is a process by which sugar is converted into alcohol and CO_2 by yeast.
- Fermentation by the yeast *Saccharomyces* yields beer and that by **Lactobacillus,** yields butter milk.

- In fermentation on large scale, bioreactor and nutrient medium are sterilised by autoclaving. Yeast is inoculated into the medium by support growth system or suspended growth system.
- Yoghurt is made from milk set by a bacterium *Lactobacillus*. Rennet tablets made from calf stomach or ficin from sap of fig trees are used for setting milk into curd.
- Bacteria also yield antibiotics as was discovered by Alexander Fleming. Waksman gave the term antibiotic.
- An antibiotic attacks and terminates a vital step in the metabolic pathway of the pathogenic bacterium which then stops growing.
- Vaccines are prepared (a) from weakened or attenuated germs (first generation vaccines), (b) by recombinant DNA technology (second generation vaccines), or (c) synthetically (third generation vaccines).
- Vitamins may also be generated through fermentation.
- Biogas is made by the action of methanogenic bacteria on waste matter such as the faeces of humans or of cattle.
- Genetic engineering is defined as construction and use of DNA molecules engineered by recombinant DNA technology.
- Recombinant DNA (r-DNA) technology resulted from the discovery of (i) plasmids, and (ii) restriction enzymes.
- Tools of r-DNA technology are cell culture, restriction enzymes, plasmids, ligase and host bacteria.
- Recombinant DNA technology may be used to obtain proteins commercially such as insulin, clotting factors, monoclonal antibodies, enzymes, antibodies and vaccines.
- Genetically engineered organisms carrying foreign genes are called transgenics.
- Transgenic plants may be obtained by using the T_1 plasmid of the bacterium *Agrobacterium tumefaciens*.
- Transgenic animals are produced by microinjection of foreign DNA into fertilised eggs or by using retrovirus for introducing foreign DNA into early embryonic stages.
- Genetically engineered bacteria can clean up pollutants from environment. This is called bioremediation.
- A mutated gene in a cell may result in some form of genetic disorder/disease. Sickle cell anaemia, Haemophilia, SCID are some single gene human disorders.
- Addition of a normal functioning gene to the defective cells to correct the genetic disease is called gene therapy.
- Treatment which is applied to body cells excluding germ line cells is called somatic gene therapy.

- There are three main therapeutic approaches to gene therapy : (a) ex-vivo gene therapy, (b) in-vivo gene therapy, and (c) antisense gene therapy.
- Ex-vivo gene therapy includes addition of corrected genes through retroviral cloning vectors.
- In-vivo gene therapy includes direct delivery of corrected genes into the tissues by use of adenovirus.
- Antisense therapy is designed to prevent or lower the expression of gene in order to have less accumulation of a gene product.
- Gene therapy has certain limitations such as (i) somatic cell gene therapy can not rectify the defect in subsequent generation, (ii) random integration of DNA from outside may interfere with normal gene, (iii) strict safety standards are to be maintained, (iv) proper clones of requisite genes have to be available.

TERMINAL EXERCISES

1. Define biotechnology.
2. How are alcoholic beverages produced by fermentation? Mention the steps in the process.
3. How can you make cheese and curd on a large scale?
4. What are antibiotics? Name five antibiotics and their sources.
5. How are different generations of vaccines produced?
6. Describe the steps in the production of biogas and mention the precautions to be taken.
7. Enumerate in a sequence the steps in recombinant DNA technology.
8. Describe the uses of genetic engineering.
9. How can a transgenic animal be obtained?
10. Write a note on bioremediation.
11. Define the term gene therapy. Under what condition does it become necessary to opt for such a therapy ?
12. What is meant by human somatic gene therapy? How does it differ from the germ line gene therapy? Which of the two have been successful so far and why?
13. Discuss in brief the different types of somatic gene therapy.

ANSWERS TO INTEXT QUESTIONS

30.1 1. Fungi, yeast, bacteria

2. Alcohol/antibiotics/curd/cheese/vitamins/vaccines/biogas (any three)
3. Ethanol/Butanol/Glycerol (any two)

4. Support growth system and suspended growth system
5. 1-b, 2-c, 3-a

30.2 1. *Lactobacillus*
2. Alexander Fleming
3. Vaccines produced by the use of recombinant DNA technology
4. Vitamin C
5. Methanogenic bacteria

30.3 1. Construction and use of novel DNA molecules obtained by recombinant DNA technology.
2. Clone is a collection of genetically identical cells obtained by asexual division of a cell.
3. When a fragment of foreign DNA is inserted in DNA of a phage or plasmid, DNA of the latter is called r-DNA.
4. In bacteria
5. Because they can cut specific sequences of DNA. (6) Ligase.
7. A phage or plamid which can carry foreign DNA and divide along with the bacterium whose part it is.

30.4 1. (i) Insulin, Growth hormone (ii) Proteases, Amylases
2. Antibiotics, vaccines and proteins of clinical value can be manufactured abundantly.
3. Rabies and hepatitis B

30.5 1. An organism containing foreign DNA in its genome
2. *Agrobacterium tumefaciens* and T_1 plasmid.
3. Bioremediation is removal of pollutants in the environment by the use of genetically engineered bacteria.

30.6 1. Mutation
2. Haemophilia, Sickle cell anaemia, SCID (Any two)
3. B-cells and T-cells
4. Replacement and alteration of defective gene is called gene therapy.

30.7 1. Somatic and Germ line cells
2. In-vivo gene therapy, Ex-vivo gene therapy and Anti-sense gene therapy
3. Thalassamia, certain types of cancer
4. In-vivo gene therapy