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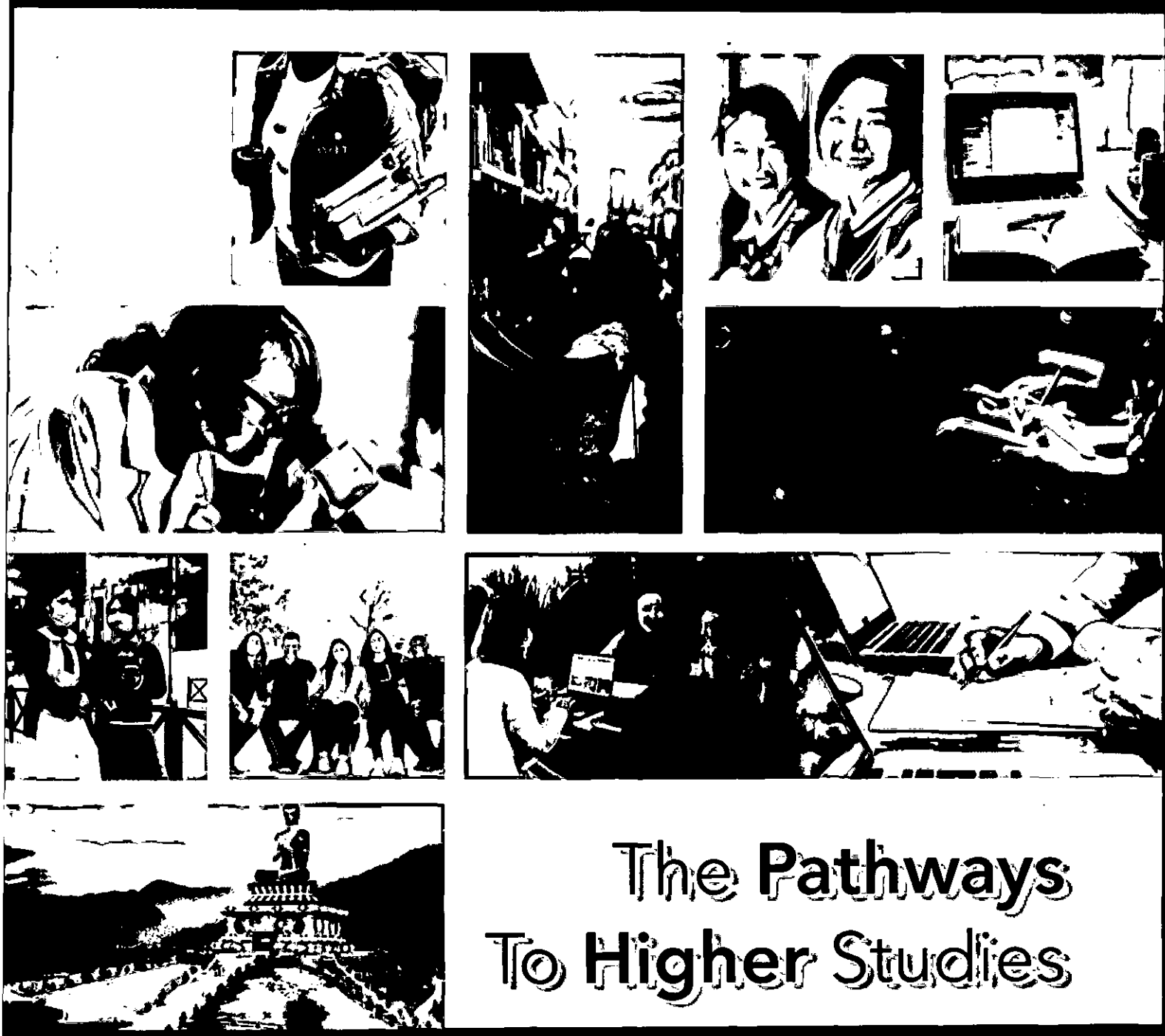


The Pathways To Higher Studies

Biology

Class-XII

BIOLOGY

CLASS 12

Module 1 DIVERSITY AND EVOLUTION OF LIFE

Module Content

1. Origin and Evolution of Life and Introduction to Classification
2. The Kingdoms Monera, Protoctista and Fungi
3. Kingdoms Plantae and Animalia
4. Cell - Structure and Function
5. Tissues and other Levels of Organization

Objective of the module

This module would enable the learner to visualize the origin of life on earth and the vast diversity in the living world, and also to group them together at various classification levels. It also intends to stimulate our learner to understand the concepts and theories of evolution. The module also highlights the cell as the basic unit of life and its organization into various forms of tissues.

1 ORIGIN AND EVOLUTION OF LIFE AND INTRODUCTION TO CLASSIFICATION

Introduction

Origin of life

The universe is about 20 billion years old. The earth was formed about 4.5 billion years ago. The atmosphere was not present on early earth. The earth was covered with water vapor, methane, carbon dioxide and ammonia. The UV rays from the sun split water into hydrogen and oxygen. The oxygen reacted with ammonia and methane to form water, carbon dioxide and other gases. When the earth cooled down further, water vapor fell as rain; to form oceans. Life appeared on earth about 4 billion years back.

Panspermia: Early Greek thinkers thought that units of life (called spores) were transferred to different planets including earth. Panspermia is a hypothesis which says that life came from outside the earth, i.e., from another celestial body.

Spontaneous Generation: Some thinkers believed that life came out of decaying and rotting matter; like straw, mud, etc. But Louis Pasteur disproved this theory by proving that life comes only from pre-existing life.

Oparin and Haldane proposed that the first form of life came from pre-existing non-living organic molecules; like RNA, protein, etc. They proposed that formation of life was preceded by chemical evolution. Diverse organic molecules were formed form inorganic constituents during the course of chemical evolution.

Experiment by Miller and Urey: They created an atmosphere in laboratory; similar to what existed on the earth about 4 billion years ago. A closed tank was filled with CH_4, H_2, NH_3 and water vapor. They created electric discharge at 800°C in the tank. Miller observed the formation of amino acids. Observations by some others showed formation of sugars, nitrogenous bases, pigments and fats. These experiments proved the hypothesis of Oparin and Haldane. Thus, chemical evolution became an accepted theory of origin of life.

The first non-cellular forms of life could have originated about 3 billion years ago; in the form of giant molecules, e.g., RNA, protein, polysaccharides. The first cellular form of life possibly did not come into existence till about 2000 million years ago. Thus, first form of life gradually evolved from non-living molecules. This is the most accepted theory on origin of life on earth.

Charles Darwin's Theory

Any population has built in variation in characteristics. The characteristics which enable an organism to survive better in natural conditions would enable the organism to outbreed others.

Darwin proposed the concept of survival of the fittest. Here, fitness ultimately means reproductive fitness. Organisms which are better fit in an environment leave more progeny than others.

Darwin proposed the concept of natural selection. More progeny results in better chances of survival. Such organisms are selected by nature

EVOLUTION

Evidences For Evolution

Paleontological Evidence: Remains of hard parts of life forms; found in rocks; are called fossils. A study of fossils in different sedimentary layers indicates the geological period in which they existed. This shows the period in which a particular organism existed on the earth.

Homologous Organs: Organs which are similar in structure but serve different purposes in different organisms are called homologous organs. For example; forelimbs of humans and dogs have similar structure; in terms of constituent bones. But forelimbs of humans serve different functions than those of dogs. This indicates that humans and dogs have evolved from a common ancestor. Homology is based on divergent evolution.

Analogous Organs: Organs which are different in structure but serve similar function are called analogous organs. For example; wings of bats and wings of butterfly are different in structure but they are meant for flight in both organisms. Analogy is based on convergent evolution.

Artificial Breeding: Many plants and animals have been artificially bred by man since ages. The intensive breeding program has created numerous breeds in a single species, e.g., various breeds of dogs. If man could create new breeds within hundreds of years then nature could create new species over millions of years.

Dark Winged Moths: A collection of moths made before industrialization in England showed that there were more white-winged moths than dark-winged moths. The collection after industrialization showed that there were more dark-winged moths than white-winged moths. The tree trunks became dark due to pollution. So, white-winged moths could be easily spotted by predators. Dark wings gave survival advantage. Hence, number of dark-winged moths increased rapidly. This gives another proof that evolution can happen and has happened.

Development of Resistance: Doctors use various antibiotics to control infections. Over a period of time, bacteria develop resistance against an antibiotic. This also shows that evolution can happen. This also shows that evolution is not a direct process; in the sense of determinism.

ADAPTIVE RADIATION

The process of evolution of many varieties from a single variety of organism in a given geographical area is called adaptive radiation. It happens within a short span of time.

Darwin's observation on finches of the Galapagos Islands showed interesting insights. Finches of that island show a wide variety; in terms of types of beaks; suited to different eating habits. Darwin proposed that all the varieties evolved on the island itself. From the original see-eating features, many other forms (with altered beaks) arose. This shows adaptive radiation.

Another example of adaptive radiation is seen in Australian marsupials. Different types of marsupials evolved from one ancestral stock; within the Australian island continent. Placental mammals in Australia also exhibit adaptive radiation.

Examples of marsupial mammals: Marsupial mole, numbat, marsupial mouse, spotted cuscus, flying phalanger, Tasmanian tiger cat, Tasmanian wolf.

Examples of placental mammals of Australia: Mole, anteater, mouse, lemur, flying squirrel, bobcat, wolf.

The rate of appearance of new forms is linked to the life cycle or lifespan. Microbes can multiply rapidly to become millions of individuals within hours. So, a new species can emerge in a microbe within a short time. But life cycle of a complex animal can be from a couple of months to many years. Origin of a new species in such animals would take millions of years.

MECHANISM OF EVOLUTION

HARDY-WEINBERG PRINCIPLE

As per Hardy Weinberg Principle, "Allele and genotype frequencies in a population will remain constant from generation to generation in the absence of other evolutionary influences. These influences include mate choice, mutation, selection, genetic drift, gene flow, and meiotic drive."

The gene pool remains a constant. The total genes and their alleles in a population make the gene pool. Sum total of all the allelic frequencies is 1.

Let us assume there are two alleles A and a of a gene. Let us assume that p represents the frequency of allele A and q represents the frequency of allele a.

Frequency of diploid AA individuals in population = p^2

Frequency of diploid aa individuals in population = q^2

Frequency of diploid Aa individuals in population = 2pq

Hence, $p^2 + 2pq + q^2 = 1$

When frequency differs from expected values, the difference (direction) indicates the degree of evolutionary change. Thus, disturbance in Hardy-Weinberg Equilibrium would then be said to result in evolution.

Factors that affect Hardy-Weinberg Equilibrium: Gene migration or gene flow, Genetic Drift, Mutation, Genetic Recombination and Natural Selection.

Evolution: The change in inherited traits in biological population over subsequent generations is called evolution. Scientists have proven that life evolved in the form of simple unicellular organisms on this earth; and all the organisms which are present today have evolved from a common ancestor. The idea of evolution is based on the premise of a common ancestry.

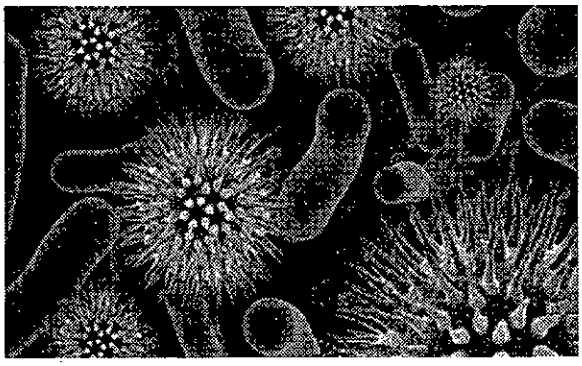
Speciation: The process of origin of a new species is called speciation. A species is a group of organisms in which most of the characters are similar and members of a species are able to breed among themselves. Speciation can happen if two groups of the same species are somehow prevented from interbreeding for several generations. This can happen because of geographical segregation or because of some genetic changes. Evolution of new species, because of geographical segregation is called genetic drift.

ORIGIN AND EVOLUTION OF MAN

- Dryopithecus and Ramapithecus existed around 15 mya. Ramapithecus was more man-like, while Dryopithecus was more ape-like.
- Man-like primates existed in eastern Africa around 3 to 4 mya.
- Australopithecines probably lived in East African grasslands around 2 mya.
- Homo habilis is an example of Australopithecines. Scientists still differ if Homo habilis should be kept under Australopithecines or among hominids. Its brain was of 650-800 cc capacity.
- Homo erectus existed about 1.5 mya. Its brain's capacity was 900 cc.
- Neanderthal lives near east and central Asia between 100,000 to 40,000 years back. The brain capacity of Neanderthal was 1400 cc.
- Modern Homo sapiens arose in Africa between 75,000 to 10,000 years back

2 THE KINGDOMS MONERA, PROTOCTISTA AND FUNGI

Introduction



(1) Bacteria are the sole members of the Kingdom Monera.

(2) Bacteria are grouped under four categories based on their shape: the spherical Coccus, the rod-shaped Bacillus, the comma-shaped Vibrium and the spiral Spirillum.

(3) Compared to many other organisms, bacteria as a group show the most extensive metabolic diversity.

(4) They may be photosynthetic autotrophic or chemosynthetic autotrophic. Some of the bacteria are autotrophic, i.e., they synthesise their own food from inorganic substrates.

(5) The vast majority of bacteria are heterotrophs, i.e.; they do not synthesise their own food but depend on other organisms or on dead organic matter for food.

Characteristics of Monera

Monera (Monos - single) includes prokaryotes and shows the following characters:

- They are typically unicellular organisms (but one group is mycelial).
- The genetic material is naked circular DNA, not enclosed by nuclear envelope. Ribosomes and simple chromatophores are the only subcellular organelles in the cytoplasm.
- The ribosomes are 70 S.
- Mitochondria, plastids, Golgi apparatus, lysosomes, endoplasmic reticulum, centrosome, etc., are lacking.
- Sap vacuoles do not occur. Instead, gas vacuole may be present.

- The predominant mode of nutrition is absorptive but some groups are photosynthetic (holophytic)and chemosynthetic.
- The organisms are non-motile or move by beating of simple flagella or by gliding. Flagella, if present, are composed of many, intertwined chains of a protein flagellin. They are not enclosed by any membrane and grow at the tip.
- Moneran cells are microscopic (1 to few microns' in length).
- Most organisms bear a rigid cell wall (Peptidoglycan).
- Reproduction is primarily asexual by binary fission' or budding.
- Mitotic apparatus is not formed during cell division.

Did You Know?

- Monera is a kingdom of prokaryotes. Therefore, it is also known as procaryota.
- It includes the most primitive form of life which developed from an early stock known as progenote.
- Being the earliest forms of life, monerans are adapted to all types of habitats.

Bacteria Shape

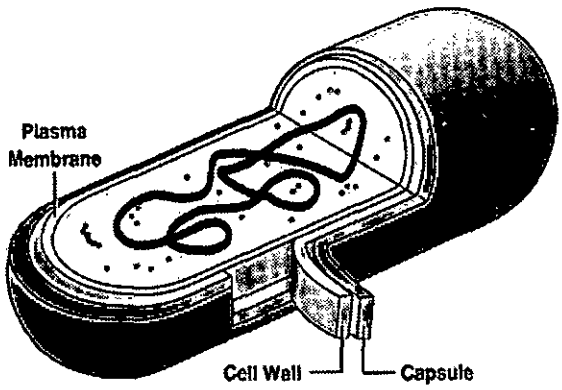
- **Cocci:** They are oval or spherical in shape. They are called micrococcus when occur singly as in Micrococcus, diplococcus when found in pairs as in Diplococcus pneumoniae, tetra coccus in fours, streptococcus when found in chains as in Streptococcus lactis staphylococcus when occurring in grape like clusters as in Staphylococcus aureus and Sarcine, when found in cubical packets of 8 or 64, as in Sarcina.
- **Bacilli:** They are rod-shaped bacteria with or without flagella. They may occur singly (bacillus), in pairs (diplobacillus) or in chain (streptobacillus).
- **Vibrios:** These are small and ‹comma or kidney› like. They have a flagellum at one end and are motile, vibrio bacteria has curve in its cell e.g., Vibrio cholerae.
- **Spirillum:** They are spiral or coiled like a corkscrew. The spirillar forms are usually rigid and bear two or more flagella at one or both the ends e.g., Spirillum, Spirochaetes etc.
- **Filament:** The body of bacterium is filamentous like a fungal mycelium. The filaments are very small e.g., Beggiota, Thiothrix etc.
- **Stalked:** The body of bacterium possesses a stalk e.g., Caulobacter.
- **Budded:** The body of bacterium is swollen at places e.g., Rhodomicrobiu

Structure of Bacteria

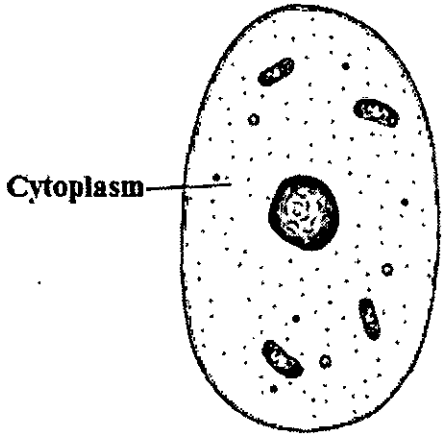
(1) **Capsule:** In a large number of bacteria, a slimy capsule is present outside the cell wall. It is composed of polysaccharides and the nitrogenous

substances (amino acids)are also present in addition. This slime layer becomes thick, called, capsule. The bacteria, which form a capsule, are› called capsulated or virulent bacteria. The capsule ‹is usually found in parasitic forms e.g., Bacillus, anihracis, Diplococcus pneumoniae, Mycobacterium tuberculosis.

(2) **Cell wall:** All bacterial cells. are covered by a strong, rigid cell wall. Therefore, they are classified under plants. Inner to the capsule cell wall is present. It 'is made up of polysaccharides, proteins and lipids. In the cell wall of bacteria there are two important sugar derivatives i.e., NAG and NAM (N-acetyl glucosamine and N-acetyl muramic acid) and besides L or D - alanine, D-glutamic acid and diaminopimelic acid are also found.



(3) **Plasma membrane:** Each bacterial cell has plasma membrane situated just internal to the cell wall. It is a thin, elastic and differentially or selectively r permeable membrane. It is composed of large amounts of phospholipids, proteins and some amounts of polysaccharides but lacks sterols. It is characterised by possessing respiratory enzymes.



(4) **Cytoplasm:** The cytoplasm is a complex aqueous fluid or semifluid ground substance (matrix)consisting of carbohydrates, soluble proteins, enzymes, co-enzymes, vitamins, lipids, mineral. salts and nucleic acids. The organic matter is in the colloidal state. The cytoplasm is granular due to presence of a large number of ribosomes. Ribosomes in bacteria are found› in the form of polyribosome. Membranous organelles such as mitochondria,

endoplasmic reticulum, Golgi bodies, lysosomes and vacuoles are absent. In some photosynthetic bacteria the plasma membrane gives rise to large vesicular thylakoids which are rich in bacteriochlorophylls and proteins.

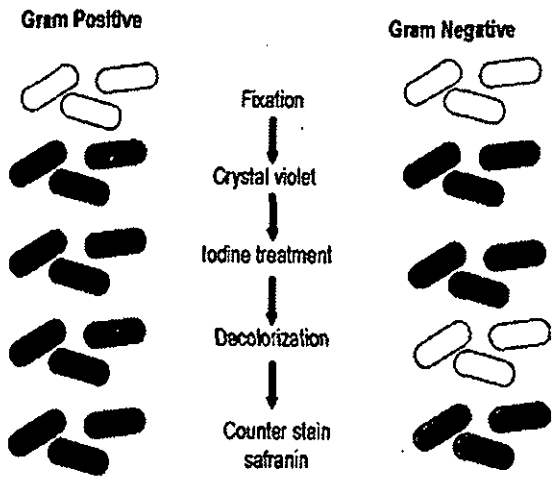
(5) **Nucleoid:** It is also known as genophore, naked nucleus, incipient nucleus. There is nuclear material DNA which is double helical and circular. It is surrounded by some typical protein (polyamine) but not histone proteins. Histones (basic proteins)are altogether absent in bacteria. This incipient nucleus or primitive nucleus is named as nucleoid or genophore.

(6) **Plasmid:** In addition to the normal DNA chromosomes many bacteria (e.g., E.coli)have extra chromosomal genetic elements or DNA. These elements are called plasmids. Plasmids are small circular double stranded DNA molecules. The plasmid DNA replicates independently maintaining independent identity and may carry some important genes. Plasmid terms was given by Lederberg (1952). Some plasmids are integrating into the bacterial DNA chromosome called episomes.

(7) **Flagella:** These are fine, thread-like, protoplasmic appendages which extend through the cell wall and the slime layer of the flagellated bacterial cells. These help in bacteria to swim about in the liquid medium. Bacterial flagella are the most primitive of all motile organs. Each is composed of a Single thin fibril as against the 9+2 fibrillar structure of eukaryotic cells. The flagellum is composed entirely of flagellin protein.

(8) **Pili or Fimbriae:** Besides flagella, some tiny or small hair-like outgrowths are present on bacterial cell surface. These are-called pili and are made up of pilin protein. They measure about O.5-2mm in length and 3-5mm in diameter. These are of 8 types I, II, III, IV, V, VI, VII, and F types. I to F are called sex pili. These are present in all most all gram -ve bacteria and few gram +ve bacteria. Fimbriae take part in attachment like holding the bacteria to solid surfaces. The function of pili is not in motility but they help in the attachment of the bacterial cells. Some sex pili acts as conjugation canals through which DNA of one cell passes into the other cell.

Staining of Bacteria



(1) **Simple staining:** The coloration of bacteria by applying a single solution of stain to a fixed smear is termed simple staining. The ells usually stain uniformly.

(2) **Gram staining:** This technique was introduced by Hans Christian Gram in 1884. It is a specific technique which is used to classify bacteria into two groups Gram +ve and Gram -ve. The bacteria are stained with weakly alkaline solution of crystal violet. The stained slide of bacteria is then treated with 0.5 percent iodine solution. This is followed by washing with water or acetone or 95% ethyl alcohol. The bacteria which retain the purple stain are called as Gram +ve. Those which become decolourised are called as Gram -ve

Differences Between Gram +ve Bacteria and Gram -ve Bacteria

S.No.	Gram +ve Bacteria	Gram -ve Bacteria
1.	They remain coloured blue or purple with gram stain even washing with absolute alcohol or acetone.	The bacteria di not retain the stain when washed with absolute alcohol.
2.	The wall is single layered. Outer membrane is absent.	The wall is two layered. Outer membrane is present.
3.	The thickness of the wall is 20-80nm.	It is 8-12nm.
4.	The lipid content of the wall is quite low.	The lipid content of the wall is 20-30%.
5.	The wall is straight.	The wall is wavy and comes in contact with plasmalemma only at a few places.
6.	Merein or mucopeptude content is 70-80%	It is 10-20%.
7.	Basal body of the flagellum has two rings of swellings.	Four rings of swellings occur in the basal body.
8.	Mesosomes are more prominent.	Mesosomes are less prominent.
9.	The bacteria are more susceptible to antibiotics.	They are more resistant to antibiotics.
10.	Fewer pathogenic bacteria belong to Gram+ve group.	Most of the pathogenic bacteria are Gram* ve.
11.	Porins are absent.	Porins or hydrophilic channels occur in outer membrane of cell wall.
12.	Cell wall contains teichoic acids.	Teichoic acids are absent.

Nutrition in Bacteria

On the basis of mode of nutrition, bacteria are grouped into two broad categories. First is autotrophic and second is heterotrophic bacteria.

- **Autotrophic bacteria:** These bacteria are able to synthesize their own food from inorganic substances, as green plants do. Their carbon is derived from carbon dioxide. The hydrogen needed to reduce carbon to organic form comes from sources such as atmospheric H2, H2S or NH3.
- **Heterotrophic bacteria:** Most of the bacteria cannot synthesize their own organic food. They are dependent on external organic materials and require at least one organic compound as a source of carbon of their growth and energy. Such bacteria are called heterotrophic bacteria. Heterotrophic bacteria are of three types Parasites, Saprotrophs and Symbionts.

Archaebacteria

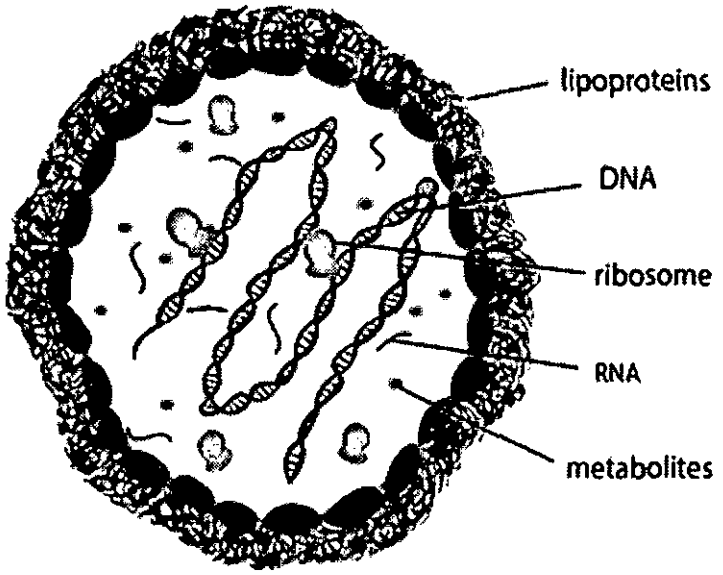
They are a group of most primitive prokaryotes which are believed to have evolved immediately after the evolution of the first life.

They have been placed in a separate subkingdom or domain of archaea by a number of workers (e.g., woese, 1994).

Archaebacteria are characterised by absence of peptidoglycan in their wall. Instead, the wall contains protein and non-cellulosic polysaccharides.

It has **pseudomurein** in some methanogens.

Mycoplasma (PPLO)



Mycoplasmas are **mollicutes** are the simplest and the smallest of the free-living prokaryotes.

They discovered in pleural fluid of cattle suffering from pleuropneumonia (no card and roux, 1898).

The organisms are often called MLO's (pleuropneumonia like organisms).

The size ranges from 0.1-0.15um. a cell wall is absent. Plasma membrane forms the outer boundary of the cell.

Due to the absence of cell wall the organisms can change their shape and are pleomorphic.

Cyanobacteria

(Blue green algae, Cyanophyceae, Myxophyceae)

- Cyanobacteria or blue – green algae are gram (=) photosynthetic prokaryotes which perform oxygenic photosynthesis.
- Photosynthetic pigments include chlorophyll a, carotenoids and phycobilins.
- Food is stored in the form of cyanophycean starch, lipid globules and protein granules.
- Cyanobacteria evolved more than 3 billion years back.
- They added oxygen to the atmosphere and paved the path for evolution of aerobic forms, including aerobic bacteria.

Difference Between Bacteria and Cyanobacteria

S.No.	Bacteria	Cyanobacteria
1.	The cells are comparatively smaller.	The cells are comparatively larger.
2.	The cell wall is 1-2 layered.	The cell wall is four layered.
3.	Plasmodesmata and pores do not occur in cell walls.	They are often present.
4.	They exhibit lesser structural elaboration.	They show higher degree of morphological complexity as well as structural elaboration.
5.	Bacteria are both autotrophic and heterotrophic.	Cyanobacteria contain chlorophyll a as found in eucaryotic autotrophs.
6.	Autotrophic bacteria possess bacteriochlorophyll.	Cyanobacteria contain chlorophyll a s found in eukaryotic autotrophs.
7.	Photosynthesis is anoxygenic.	Photosynthetic is oxygenic.
8.	Photoautotrophic bacteria do not contain phycobilin's.	They possess accessory water-soluble photosynthetic pigments known as phycobilin's.
9.	Flagella may be present.	Flagella are absent.
10.	Carbohydrate reserve food is glycogen.	Carbohydrate reserve food is a special starch known as cyanophycean starch.

EXERCISE

Multiple Choice Questions

1. Kingdom Monera comprises the –
   (a) Plants of economic importance
   (b) All the plants studied in botany
   (c) bldiryotic organisms
   (d) Plants of Thallophyta group
2. According to Whittaker kingdom Monera includes
   (a) Unicellular eukaryotes
   (b) Prokaryotes & akaryotes
   (c) Slime moulds & protozoa
   (d) Multicellular & eukaryotes
3. Kingdom of unicellular eukaryotes –
   (a) Monera
   (b) Protista
   (c) Fungi
   (d) Plantae
4. Engler and Prantl created metachlarnydae to include –
   (a) Polypetalous dicots
   (b) Gamopetalous dicots
   (c) Gamopetalous monocots
   (d) Gymnosperm

Answer

1. (c) 2. (b) 3. (b) 4.(b)

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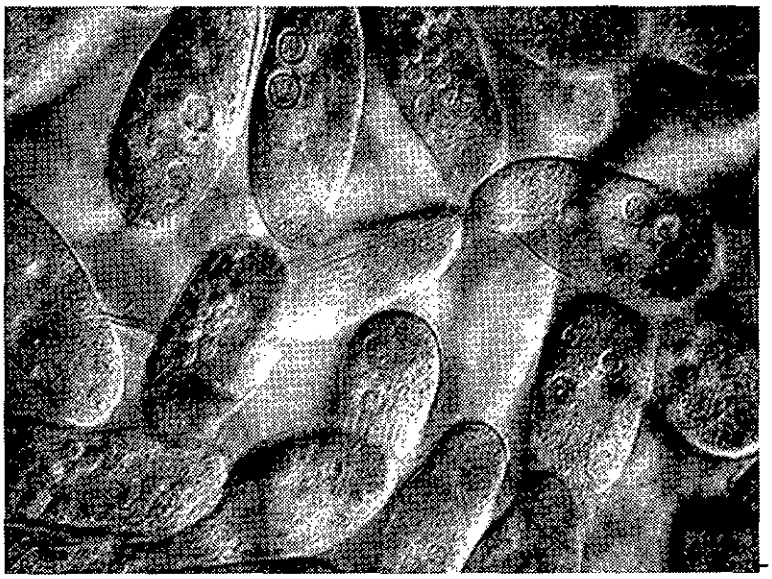
Kingdom Protista



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

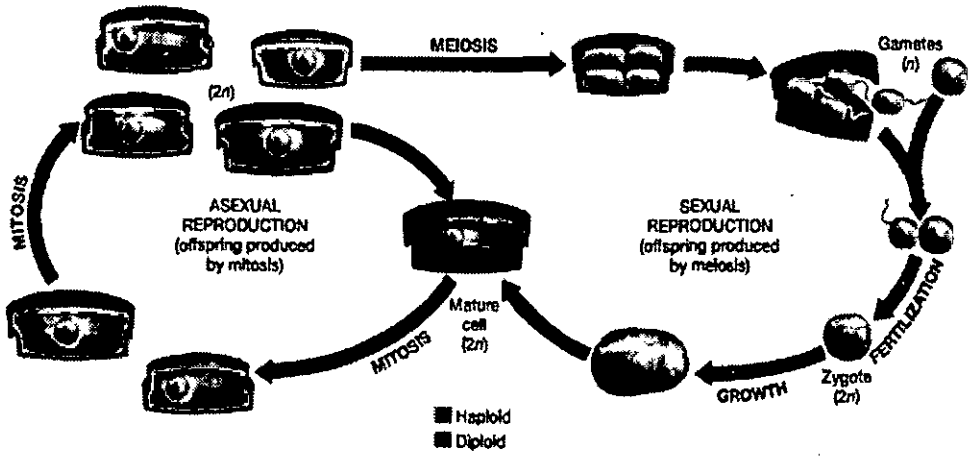
- Members of Protista are primarily aquatic.
- This kingdom forms a link with the others dealing with plants, animals and fungi.
- Being eukaryotes, the protistan cell body contains a well-defined nucleus and other membrane-bound organelles.
- Some have flagella or cilia.
- Protists reproduce asexually and sexually by, process involving cell fusion and zygote formation.
- It may be photosynthetic, holotrophic, saprotrophic, parasitic and symbionts. Some have **mixotrophic nutrition (holotrophic + saprobic)**.
- The photosynthetic, floating protists are collectively called phytoplankton.
- The free-floating, holozoic protozoans are collectively termed zooplankton.
- Unicellular protists have been broadly divided in to three major groups:
  (a) Photosynthetic Protists: **Example:** Dinoflagellates, Diatoms, Euglenoids
  (b) Consumer Protists: **Example:** Slime moulds or Myxomycetes
  (c) Protozoan Protists: **Example:** *Zooflagellate*, Sarcodina, Sporozoa, Ciliata

Life Cycles in Protists

"The sequence of events between any given phase in one generation and that similar phase in the next succeeding generation constitute a life cycle."

Two types of life cycle are found in protists:

(a) Life Cycle Showing Zygotic Meiosis:



It occurs in some dinoflagellates (**Example:** *ceratium, gymnodinium;* von stosch, 1973) and cellular slime moulds.

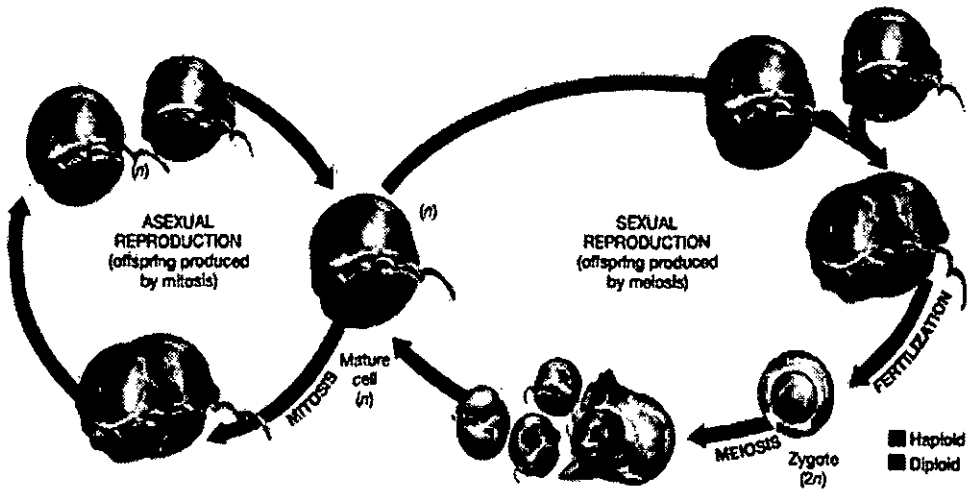
The zygote is 2n that divides by meiosis (also called zygotic meiosis) and produces vegetative cells with 1n chromosome number.

These cells divide repeatedly by mitosis and all the resulting daughter cells maintain the 1n number of chromosomes.

Some of the vegetative cells produce gametes.

When these gametes combine in fertilization, a zygote is formed and the life cycle is completed.

(b) Life Cycle Showing Gametic Meiosis:



This is found in the majority of protozoan protists, diatoms and acellular slime moulds.

The organism spends most of its life cycle in the 2n condition.

The gametes are only 1n (haploid) that are produced by meiosis (also called **gametic meiosis**).

The gametes fuse to form zygote that grows to form the diploid individual.

Major Groups of Protists

Chrysophytes

This group includes diatoms and golden algae (desmids).

They are found in fresh water as well as in marine environments.

They are microscopic and float passively in water currents (plankton).

In diatoms the cell walls form two thin overlapping shells, which fit together as in a soap box.

The walls are embedded with silica and thus the walls are indestructible. Thus, diatoms have left behind large amount of cell wall deposits in their habitat; this accumulation over billions of years is referred to as **'diatomaceous earth'**.

Being gritty this soil is used in polishing, filtration of oils and syrups.

Diatoms are the chief 'producers' in the oceans.

Did You Know?

- Silicon is present in the frustule of diatoms.
- Auxospones are formed by diatoms.
- Noctiluca dinoflagellate is called 'night light'.
- Diatoms are emploid as a source of water glass or sodium silicate.
- Ganobacteria term was coined by **IBCN** (1978).

Dianoflagellates

- These organisms are mostly marine and photosynthetic.
- They appear yellow, green, brown, blue or red depending on the main pigments present in their cells.
- The cell wall has stiff cellulose plates on the outer surface.
- Most of them have two flagella; one lies longitudinally and the other transversely in a furrow between the wall plates.
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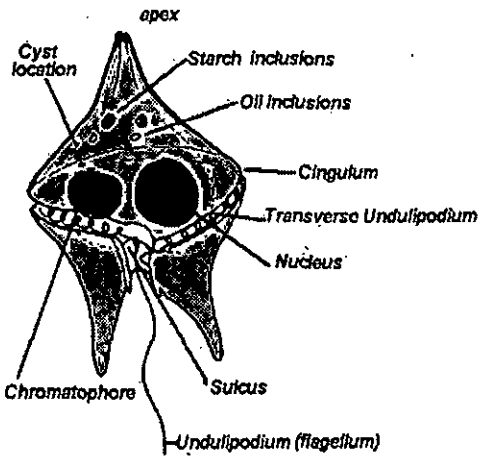


- Very often, red dianoflagellates (**Example:** Gonyaulax) undergo such rapid multiplication that they make the sea appear red (red tides).
- Toxins released by such large numbers may even kill other marine animals such as fishes.
- Dinoflagellates reproduce asexually through cell division or by the formation of zoospores and cysts.
- The cell division starts from posterior end. During cell division, centromeres and spindle are not seen. The spindle is replaced by cytoplasmic microtubules.
- During mitosis, the chromosomes break up into pairs of chromatids. The nuclear envelops and nucleolus persists during, division.
- If sexual reproduction occurs, it is isogamous or anisogamous.
- Two cells conjugate by a conjugation canal where the two amoeboid gametes fuse to form a diploid zygote.
- Life cycle involves zygotic meiosis (**Example:** Ceratium, Gymnodinium etc.) or gametic meiosis (**Example:** Noctiluca).

Did You Know?

- Dinoflagellates, due to **spinning** caused by activity of transverse flagellum (in cingulum/annulus) and longitudinal flagellum (in sulcus), represent whirling whips.
- Dinoflagellates with bioluminescence/phosphorescence due to light producing protein luciferin are called **fire algae**. e.g., Noctiluca, Pyrocystis, Pyrodinium etc.
- **Leeuwenhock** (1674, 1675, 1681) was first to observe and sketch protozoan protists including Vorticella and Giardia.
- Acellular organisms do not contain cellular structure e.g., viruses or not considered as cells but as complete organisms e.g., protists.
- Wall-less multicellular protoplasm of acellular slime moulds having branched veins and with process of cyclosis are called **phaneroplasmodium**.
- Dinoflagellates symbionts in other protists and invertebrates are called zooxanthellae.
- Some dinoflagellates produce blooms or red tides. e.g. Gonyaulax, Gymnodinium etc.

Euglenoids

- Majority of them are fresh water organisms found in stagnant water.
- Instead of a cell wall, they have a protein rich layer called pellicle which makes their body flexible.
- They have two flagella, a short and a long one. The two flagella join with each other at a swelling called paraflagellar body. An orange red

coloured eye-spot or stigma is located at the base of flagellum attached to the membrane of reservoir at the level of paraflagellar body.

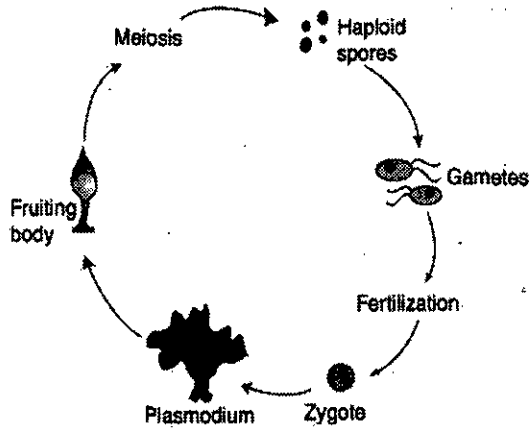
- **Both paraflagellar body; and eye spot act as photoreceptors and direct the organism towards the optimum light.**
- Though they are photosynthetic in the presence of sunlight, when deprived of sunlight they behave like heterotrophs by predating on other smaller organisms. Interestingly, the pigments of euglenoids are identical to those present in higher plants. Example: Euglena. They contain red pigment astaxanthin.
- Nutrition is holophytic (photoautotrophic), saprobic (e.g., Rhabdomonas) or holozoic (e.g., Peranema). Even holophytic forms can pick up organic compounds from the outside medium. Such a mode of nutrition is called mixotrophic.
- Euglena is a connecting link between animals and plants. Nutrition in Euglena is mixotrophic, when light is available it is photosynthetic, in darkness it is saprophytic absorbing food from surrounding water.

Slime Moulds

- Slime moulds are saprophytic protists.
- The body moves along decaying twigs and leaves engulfing organic material.
- Under suitable conditions, they form an aggregation called plasmodium which may grow and spread over several feet.
- During unfavourable conditions, the plasmodium differentiates and forms fruiting bodies bearing spores at their tips. The spores possess true walls. The spores are dispersed by air currents.
- They are extremely resistant and survive for many years, even under adverse conditions.

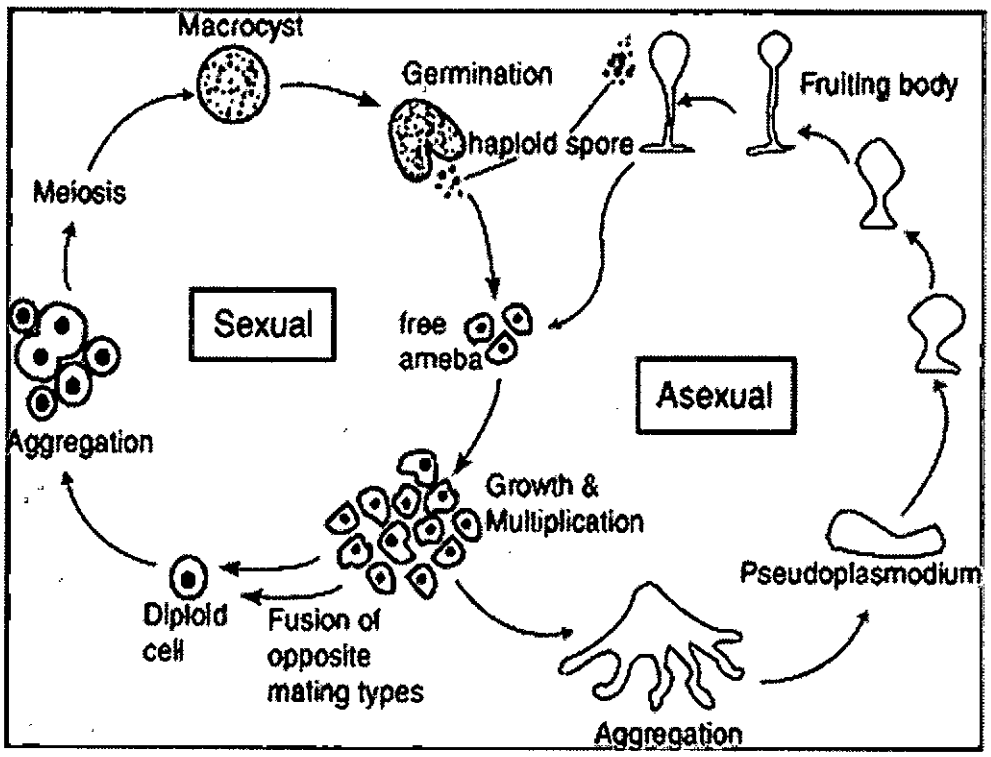
Slime moulds are of two types:

(1) Acellular (Plasmodila) Slime moulds:

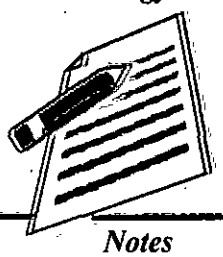
- Acellular slime moulds commonly grow as slimy masses on damp places rich in dead and decaying r organic matter.
- 

- The somatic phase is diploid and consists of a free, living organic matter multinucleated protoplasm called plasmodium.
- The plasmodium slowly streams or glides over decaying organic matter putting out blunt finger -like pseudopodia showing -amoeboid movement.
- They also absorb dissolved organic substances from the substratum showing saprotrophic nutrition.
- Under unfavourable conditions the plasmodium contracts and gets surrounded by thick horny wall. It is called sclerotium.
- Each plasmodium reproduces asexually by the formation of several, small, sessile or stalked, brightly coloured sporangia.
- The multinucleated protoplasm of sporangium is cleaved to produce a large number of small uninucleate spores.

(2) Cellular Slime moulds



- The cellular slime moulds occur in the form of, haploid uni nucleated, naked (without cell wall)cell covered by plasma membrane.
- These cells are called myxamoeba. The myxamoebas move freely with the help of amoeboid movement and phagotrophic or holozoic nutrition.
- They grow and divide to form a large population of individuals.
- Under unfavourable condition a myxamoeba secrete a rigid cellulose wall to form the microcyst. Microcyst formation is a means of perennation.



Did You Know?

- Slime moulds possess animal like as well as fungi like character.
- Euglenoids possess plant like as well as animal like characters.
- De Bary (1887) classified slime moulds as an animal and called them 'Mycetozoa'.
- Macbrid coined the term 'Myxomycetes' (Slime moulds).

Protozoans

All protozoans are heterotrophs and live as predators or parasites. They are believed to be primitive relatives of animals.

There are four major groups of protozoans

Group 1. Flagellated Protozoans

Characters:

(i) They possess flagella for locomotion.

(ii) They may be free living aquatics, parasites, commensals or symbionts.

(iii) Zooflagellates are generally uninucleate, occasionally multinucleate.

(iv) The body is covered by a firm pellicle.

(v) Nutrition is holozoic, saprozoic and parasitic

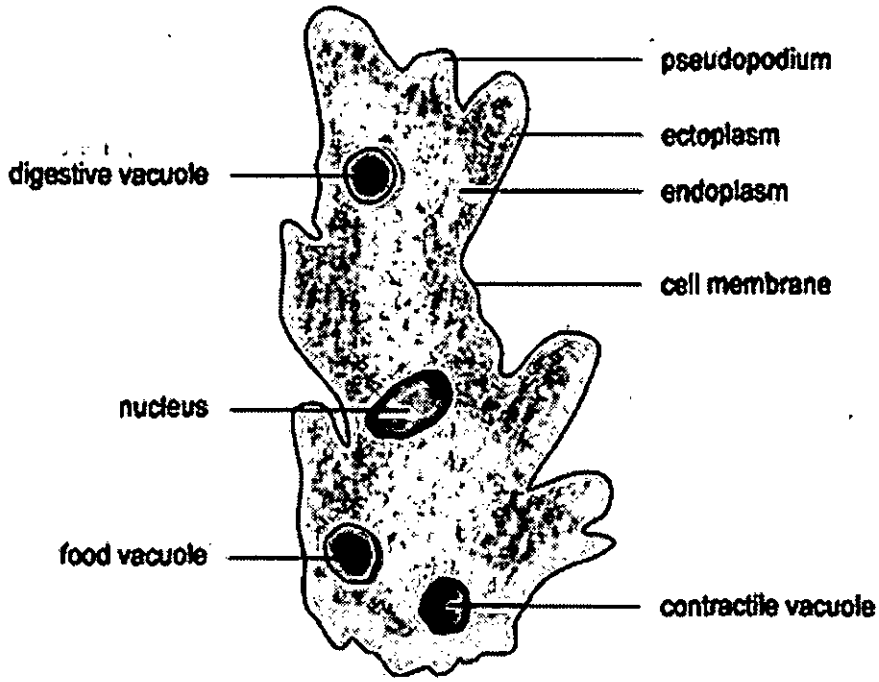
(vi) Asexual reproduction is by binary fission.

Examples:

- **Trypanosome gambiense** –The parasite of sleeping sickness. It was first observed by Forde in 1901. Fruce discovered that the parasite of sleeping sickness is transmitted by **tse-tse fly**. It causes Gambian sleeping sickness. The disease, also called **Gambain trypanosomiasis** is found in western and central parts of Africa.
- **Trypansoma rhodesiense** - It causes Rhodesian sickness. The disease is also called **Rhodesian trypanosomiasis**. The parasite is transmitted by the bites of tse-tse fly (glossina palpalis and glossina morsitans). Initially parasite is present in the blood of man but later on it enters the cerebrospinal fluid.
- **Trypanosome cruzi** - It causes South American trypanosomiasis (also called **Chagas disease**). The symptoms of the disease are fever, diarrhoea, anaemia and enlargement of lymphoid glands.

Group 2. Amoeboid Protozoans

Characters:



(i) They develop pseudopodia which are temporary protoplasmic outgrowths. They are of four types- lobopodia (broad and blunt), filppodia (slender, unsupported, independent), axpodia (slender with axial support) and reticulopodia (slender, reticulate).

(ii) pseudopodia are used for locomotion and engulfing food articles.

(iii) Sarcodines are mostly free living, found in fresh water, sea water and on damp soil. Only a few are parasitic.

(iv) The body may be covered with plasmalemma or a shell.

Examples: Amoeba, Pelomyxa, entamoeba, radiolarians, foraminifera's, heliozoans.

- **Amoeba proteus- The Proteus Animalcule.** Amoeba was discovered by **Russel Von Rosenhoff** in 1755. **H.I. Hirschfied** (1962) has given a detailed account of the biology of amoeba. It is found in fresh water. Types of pseudopodia are lobopodia.
- **Pelomyxa** - It is also known as giant amoeba. The size is about 2.5 mm long. Pelomyxa occurs in fresh water. Nutrition is holozoic. The chief food article is diatoms.
- **Entamoeba histolytica – Lamble** (1859) discovered Entamoeba histolytica. **Losch** (1875) discovered its pathogenic nature. The life cycle of Entamoeba histolytica is monogenetic (single host life cycle). It resides in the upper part of the human large intestine and causes the disease known as amoebic dysentery or amoebiasis.

Group 3. Sporozoans

Characters:

(i) All sporozoans are endoparasites.

(ii) Some sporozoans such as Eimeria cause several diseases like coccidiosis in the birds.

(iii) Locomotory organelles (cilia, flagella, pseudopodia, etc.) are absent.

(iv) Nutrition is parasitic (absorptive). Phagotrophic is rare.

(v) The body is covered with an elastic pellicle or cuticle.

(vi) Contractile vacuoles are absent.

(vii) Asexual reproduction occurs through syngamy.

(ix) Life cycle consists of two distinct asexual and sexual phases. They may be passed in one (monogenetic)or two different hosts (digenetic).

Examples:

Plasmodium, monocystis, eimeria.

- **Monocystis:** Monocystis live as endoparasite in the coelomic epithelial cells and seminal vesicles of earthworm. The fertility of the earthworm is not greatly impaired, since most of the seminal vesicles are not haemorrhage.

Group 4. Ciliated Protozoans

Characters:

(i) Ciliates are protozoan protists which develop a number of cilia during a part or whole of the life cycle.

(ii) Cilia are used for locomotion and driving food.

(iii) There is a high degree of morphological and physiological specialization.

(iv) Most ciliates are free living individuals in fresh and marine waters. A few are parasitic.

(v) The body is covered by a pellicle.

(vi) Nutrition is holozoic except in the parasitic forms.

(vii) there are definite regions for ingestion and egestion. The region of ingestion consists of an oral groove, cytostome (mouth) and gullet.

Examples:

Paramecium, vorticella, opalina, balantidium.

- **Paramecium-** The slipper organism or slipper Animalcule. Paramecium is a free-living ciliate which is found in fresh water. Most widely distributed species are paramecium caudatum and paramecium Aurelia. Nutrition is microphageal. Bacteria are its chief feed. Paramecium is a surface feeder. Pellicle maintains the shape. The cilia of the extreme posterior end longer and form a bunch called caudal tuft.

EXERCISE

Multiple Choice Questions

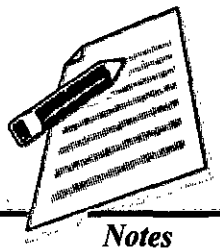
1. In two kingdom system of classification Euglena is included in-
   (a) Animalia
   (b) Plantae
   (c) Both the above
   (d) Protista
2. Whittaker placed prokaryotes and eukaryotes in
   (a) Protista
   (b) Protozoa
   (c) Plantae
   (d) Monera
3. According to four kingdom system of Copeland, the fungi belong to kingdom –
   (a) Protista
   (b) Mychota
   (c) Mycota
   (d) Plantae
4. According to Copeland the «Red algae» belongs to
   (a) Monera
   (b) Protista
   (c) Plantae
   (d) Animalia
5. Which of the following organisms were never included in Protista?
   (a) Bacteria
   (b) Red algae
   (c) Slime moulds
   (d) Mosses
6. Kingdom of unicellular eukaryotes –
   (a) Monera
   (b) Protista
   (c) Fungi
   (d) Plantae

Answer

1.(c) 2.(d) 3.(a) 4.(b) 5.(d) 6.(b)

Review Questions

1. Explain antibiotic resistance observed in bacteria in light of Darwinian selection theory.
2. Find out from newspapers and popular science articles any new fossil discoveries or controversies about evolution.
3. Attempt giving a clear definition of the term species.
4. Try to trace the various components of human evolution (hint: brain size and function, skeletal structure, dietary preference, etc.)



5. Find out through internet and popular science articles whether animals other than man have self-consciousness.
6. List 10 modern-day animals and using the internet resources link it to a corresponding ancient fossil. Name both.
7. Practise drawing various animals and plants.
8. Describe one example of adaptive radiation.
9. Can we call human evolution as adaptive radiation?
10. Using various resources such as your school Library or the internet and discussions with your teacher, trace the evolutionary stages of any one animal say horse.

Space for notes

3 KINGDOMS PLANTAE AND ANIMALIA

Top of Form

Kingdom Plantae

Kingdom plantae includes green, brown and red algae, liver Worts, mosses, ferns and seed plants with or without flowers. They have the following characters.

(1) Multicellular organisms with walled and frequently vacuolate eukaryotic cells.

(2) They contain photosynthetic pigment in plastids.

(3) Principal mode of nutrition is photosynthesis but number of plants have become absorptive.

(4) Primarily non-motile, living anchored to a substrate.

(5) Structural differentiation leading towards organs of photosynthesis, anchorage and support and in higher forms towards specialised photosynthetic, vascular and covering tissues.

(6) Reproduction is primarily asexual or sexual. The reproductive organs are multicellular.

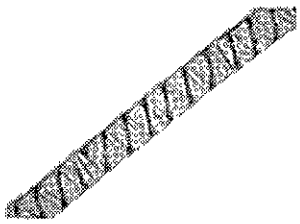
(7) A multicellular embryo is formed during development from the zygote. Algae lack embryo stage. Life cycle consists of alternating haploid gametophyte and diploid sporophyte generation. This phenomenon is called alternation of generation.

Classification of Plantae

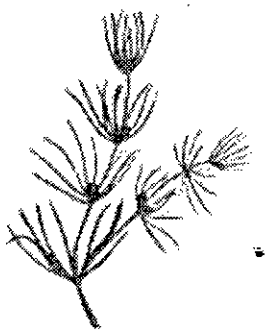
August Wilhelm Eichler (1883)a Vinnese botanist, divided plant kingdom into two sub-kingdoms mainly on the basis of presence or absence of seeds.

(1) Cryptogamae (Gr. Cryptos = hidden; gamos = marriage): Lower plants in which sex organs are hidden and seeds and flowers absent. It includes Thallophytes, Bryophytes, pteridophytes.

(2) Phanerogamae (Gr. Phaneros = visible; gamos = marriage): Higher plants in which sex organs are evident; seeds present. It includes Gymnosperms and Angiosperms.



Spirogyra



Chara

Thallophyta

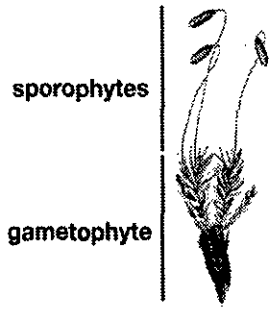
Comprises the simplest plants which possess undifferentiated or thallus like forms.

Reproductive organs single celled no jacketed called gametangia.

Embryo stage, vascular and mechanical tissues are all absent.

Differentiation of true roots, stems and leaves is also absent.

Asexual reproduction by accessory spores is very common. Presently, it includes only Algae.



Bryophytes

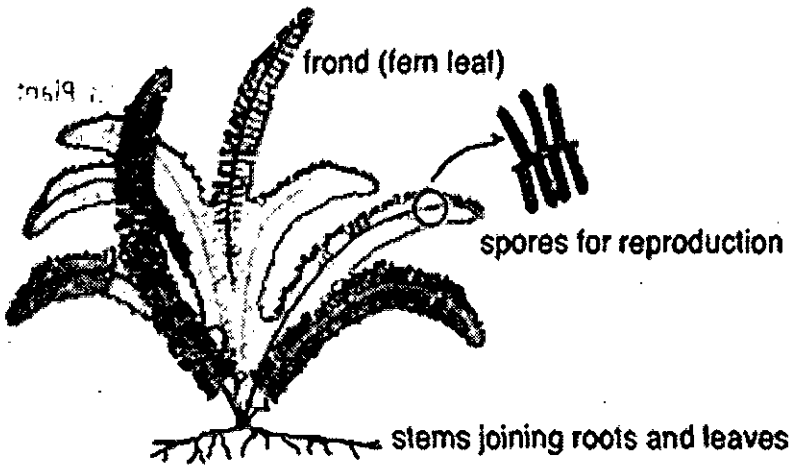
These are nonvascular terrestrial plants of moist habitats in which a multicellular diploid sporophyte lives as a parasite on an independent multicellular haploid gametophyte that develops multicellular jacketed sex organs.

Vascular plants – tracheophyte

- They are those plants which possess conducting or vascular tissues, **xylem** and **phloem.** Xylem transports water and minerals while phloem conducts organic food.
- Vascular plants comprise more than 275,000 living species.
- They are most visible green plants around us, so much so that the term 'plants' generally means vascular plants.

Pteridophytes- pteridophyta

Pteridophytes are seedless vascular or bryptogamic plants that have saprophytic plant body, inconspicuous gametophytes containing small sessile antheridia and partially embedded archegonia with 4- rowed neck.



Seed plants- spermatophyte

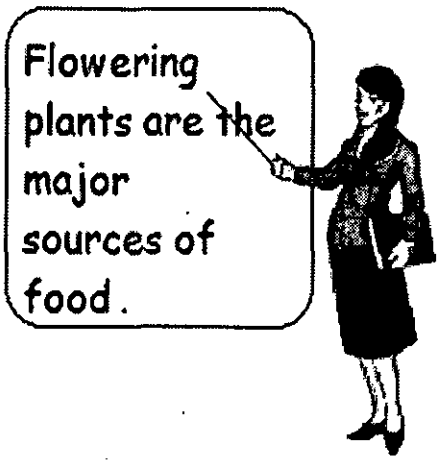
They comprise over 250,000 vascular plants.

After sexual reproduction, the plants produce seeds for dispersal and multiplication. The seeds are dormant and can easily pass-through unfavourable conditions.

The plant body belongs to sporophyte generation.

The sporophyte plant body is differentiated into true stem, leaves and roots.

Plants show **heterospory** or two types of meiospores, microspores and megaspores.



Gymnosperms

Gymnosperms are those seed plants in which the seeds remain exposed over the surface of the megasporophylls because the latter are not folded to form pistils.

Angiosperms

Angiosperms are those seed plants in which seeds are formed inside fruits and the sporophylls are organized into flowers.

Did You Know?

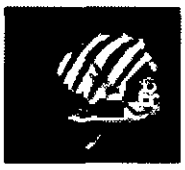
In Linnaeus' time a Two Kingdom system of classification with Plantae and Animalia kingdoms was developed that included all plants and animals respectively. This system did not distinguish between the eukaryotes and prokaryotes, unicellular and multicellular organisms and photosynthetic (green algae) and non-photosynthetic (fungi) organisms.

Kingdom Animalia

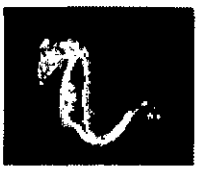
- This kingdom is characterised by heterotrophic eukaryotic organisms that are multicellular and their cells lack cell walls.
- They directly or indirectly depend on plants for food. They digest their food in an internal cavity and store food reserves as glycogen or fat.
- Their mode of nutrition is holozoic - by ingestion of food.
- They follow a definite growth pattern and grow into adults that have a definite shape and size.
- Higher forms show elaborate sensory and neuromotor mechanism.
- The sexual reproduction is by copulation of male and female followed by embryological development.
  - **Anaima:** Animals without red blood e.g., sponges, cnidaria, Mollusca, Arthropoda, Echinodermata, etc.
  - **Enaima:** Animals with red blood e.g., vertebrate
  - 
  - **Vivipara:** Animals which give birth to young ones are included in this subgroup e.g., man, dogs, cows, etc.
  - **Ovipara:** Animals which lay eggs are included in this subgroup e.g., frogs, toads, lizards, snakes, birds, etc.
  - **Anamniotes:** *Vertebrates without embryonic membranes* e.g., fishes, amphibians.
  - **Amniotes:** Vertebrates with embryonic membranes (chorion, amnion, allantois, yolk sac)e.g., reptiles, birds, mammals.
  - **Acraniata or Protochordata:** Chordates without cranium (brain box). It includes urochordata and cephalochordata.

- **Chordates:** Animals with notochord dorsal tubular nerve cord, paired pharyngeal gill slits.
- All urochordates, cephalochordates and vertebrates are called chordates.

Hemiramphus



Bony Fish



Hippocampus

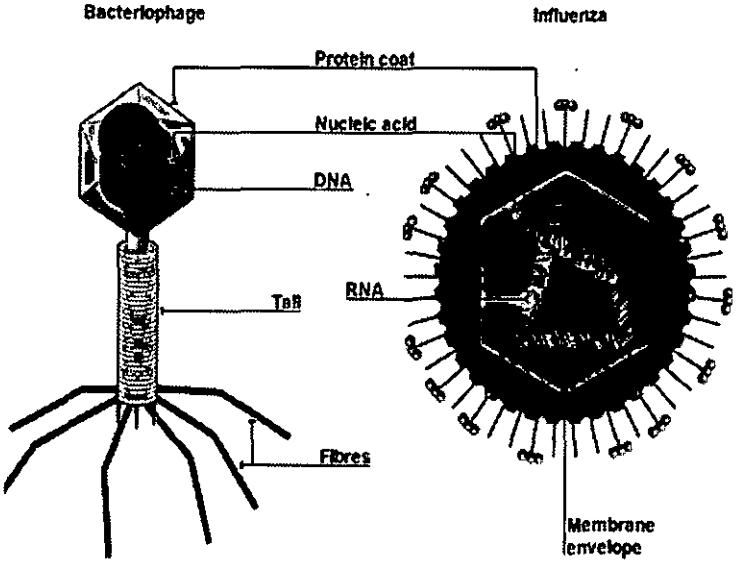
Cowhorse-Ray

- **Craniata or Vertebrate:** Chordates with cranium.
- It Includes cyclostomes, Pisces, amphibians, reptiles, birds and mammals.
- **Nonchordates:** Animals without notochord (a rod like elastic structure which supports the body). Phylum Porifera to phylum Hemichordata are called nonchordates.
- **Invertebrates:** Animals without vertebral column (backbone). All the nonchordates, urochordates and cephalochordates are collectively called invertebrates.

Viruses, Viroids and Lichens

The viruses are non-cellular organisms that are characterised by having an inert crystalline structure outside the living cell. Once they infect a cell, they take over the machinery of the host cell to replicate themselves, killing the host.

The name virus that means venom or poisonous fluid was given by Pasteur. D.J. Ivanowsky (1892) recognised certain microbes as causal organism of the mosaic disease of tobacco. These were found to be smaller than bacteria because they passed through bacteria-proof filters.



M.W. Beijerinek (1898) demonstrated that the extract of the infected plants of tobacco could cause infection in healthy plants and called the fluid as Contagium vivum fluidum (infectious living fluid).

W.M. Stanley (1935) showed that viruses could be crystallised and crystals consist largely of proteins. They are inert outside their specific host cell.

Viruses are obligate parasites.

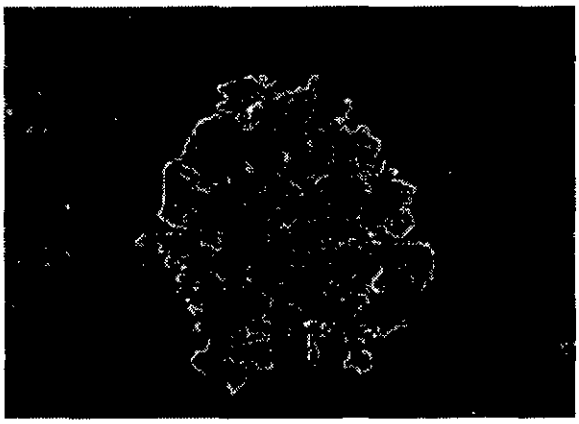
In addition to proteins viruses also contain genetic material, that could be either RNA or DNA.

No virus contains both RNA and DNA.

A virus is a nucleoprotein and the genetic material is infectious. In general, viruses 'that infect plants have single stranded RNA and viruses that infect animals have either single or double stranded RNA or double stranded DNA. Bacterial viruses or bacteriophages (viruses that infect the bacteria) are usually double stranded DNA viruses.

The protein coat called capsid made of small subunits called capsomeres, protects the nucleic acid. These capsomeres are arranged in helical or polyhedral geometric forms.

Viruses cause diseases like mumps, small pox, herpes and influenza. AIDS in humans is also caused by a virus. In plants, the symptoms can be mosaic formation, leaf rolling and curling, yellowing and vein clearing, dwarfing and stunted growth.



Viroids: In 1971 T.O. Diener discovered a new infectious agent that was smaller than viruses and caused potato spindle tuber disease. It was found to be a free RNA; it lacked the protein coat that is found in viruses, hence the name viroid. The RNA of the viroid ‹was of low molecular weight.

Lichens: Lichens are symbiotic associations i.e., mutually useful associations, between algae and fungi. The algal component is known as phycobiont and fungal component as mycobiont, which are autotrophic and heterotrophic, respectively.

Algae prepare food for fungi and fungi provide shelter and absorb mineral nutrients and water for its partner.

EXERCISE

Multiple Choice Questions

1. Which animal is "Non-chordate-protochordata"
   (a) Herdamania
   (b) Balanoglossus
   (c) Branchiostoma
   (d) Botryllus
2. Sometimes parasites themselves are parasitised by other organism; such parasites known as
   (a) Symbionts
   (b) Endoparasites
   (c) Ectoparasites
   (d) Hyperparasites
3. On the basis of body organization, animals are grouped as
   (a) Metazoa and eumetazoa
   (b) Protozoa and parazoa
   (c) Parazoa and metazoa
   (d) Protozoa and metazoan
4. Among the following organisms point out a completely non-parasitic form
   (a) Sea anemone
   (b) Leech
   (c) Tape worm
   (d) Mosquito
5. A common characteristic of all vertebrates without exception is
   (a) The possession of two pairs of functional appendages
   (b) The presence of well-developed skull
   (c) The division of body into head, neck, trunk and tail
   (d) Their body is covered with an exoskeleton

Answer

1. (b) 2. (d) 3. (d) 4. (a) 5. (b)

Space for notes

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4 CELL – STRUCTURE AND FUNCTIONS

A Cell (from Latin cella, meaning "Small Room") is the basic Structural, Functional, and Biological unit of all known Living Organisms. A cell is the Smallest Unit of life that can replicate independently, and cells are often called the "Building Blocks of Life".

Discovery of the Cell

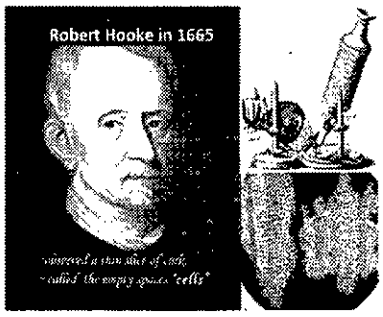


Figure1: Robert Hooke discovered cells in 1665.

Hooke saw honeycomb-like structure when he observed thin slices of cork under a microscope. He noticed that each box was separated from the other by a partition or a wall. He was the one to name each of these boxes as cells.

Cork is a part of the bark of a tree.

Scientists could study cells of living organisms only when improved microscopes with high magnification were invented – 150 years after the Hooke first observed the cells. In 1830s, two German scientists called Matthias Schleiden and Theodor Schwann proposed the Cell Theory which stated:

- All living organisms are made of cells.
- Cells are basic structural or functional units of living organisms.
- All cells are born out of pre-existing cells through cell division.

The Cell

While cells are often referred to as 'bricks' making up a building, cells are complex living structures that can have a variety of shapes, sizes and functions.

Did you know?

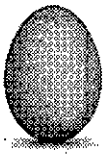
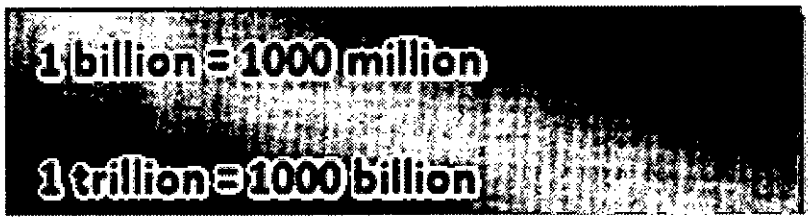


Figure 2: An egg of a hen is a single cell which can be seen by the naked eye.

Organisms Show Variety in Cell Number, Shape and Size

To study cells, scientists use microscopes to magnify them. They often use stains (dyes) to colour parts of the cell and study them in detail.

Number of Cells



There are billions and trillions of cells in a tall tree or a large animal. A human body also has trillions of cells which have different shapes, sizes and functions.

Organisms can be of two types:

- **Multicellular Organisms** are made up of more than one cell. **For Example,** Mango Tree and Frog.
- **Unicellular Organisms** are made up of a single cell. **For Example,** Amoeba and Paramecium.

Did you know?

Multicellular organisms with billions of cells also start their life as a single cell. The fertilised egg (which is a single cell) multiplies to form more cells as the organism develops.

Single-celled organisms also perform all the necessary life functions like multicellular organisms, including:

- ingestion and digestion of food,
- respiration,
- excretion,
- reproduction, and
- growth.

The only difference is that while a single cell performs all the functions in the unicellular organisms, multicellular organisms have a specialised group of cells to perform different functions. The specialised cells form tissues, which in turn form organs.

Shape of Cells

Amoeba, which is a single-celled organism, does not have a definite shape. Its shape keeps changing as it moves or feeds, protruding parts of its body to form 'pseudo' (meaning 'false') 'podia' (meaning 'feet'). These projects are known as pseudopodia.

Humans have millions of cells, such as white blood cells (found in blood), cells that make up muscles, and cells that form nerves. Their shapes vary according to the functions they perform.

Most cells are round, spherical or elongated. Some are spindle-shaped which are long and pointed at both ends. Nerve cells or neurons are quite long and are branched out to receive and transfer messages.

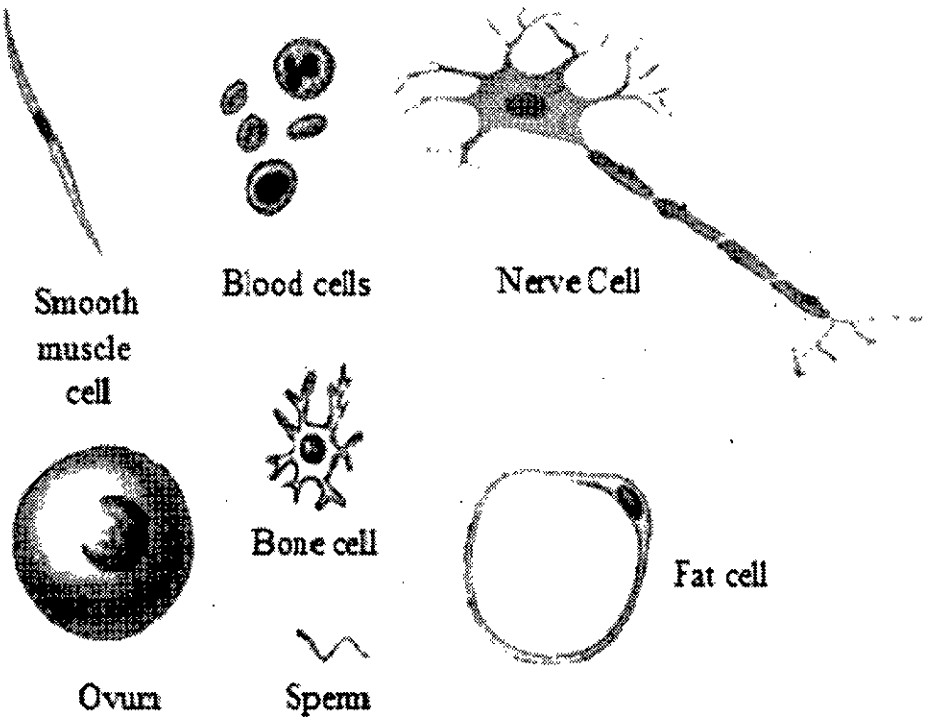


Figure 3: Different shapes of human cells

Shapes of the cells are maintained by a covering called **Cell Membrane or Plasma Membrane**

Bacterial cells and plant cells have an additional rigid covering called a **Cell Wall**

Size of Cells

The size of the cells may vary from a millionth of a metre (known as a micron) to a few centimetres but most of them cannot be seen with the naked eye. We need microscopes to see these microscopic cells.

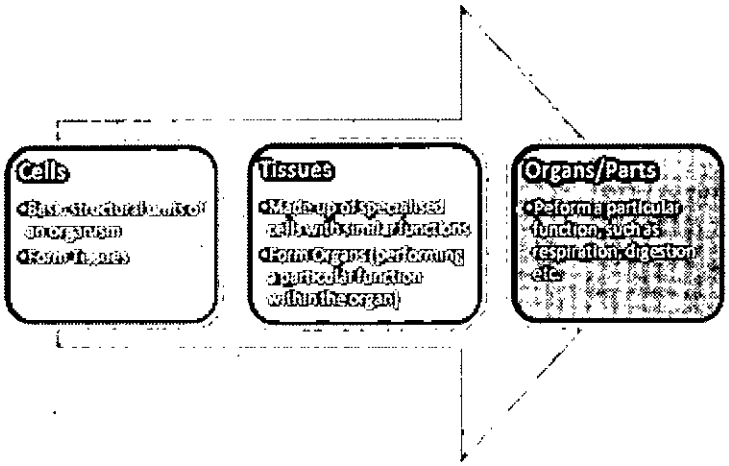
Smallest cell is found in bacteria and is just 0.1 to 0.5 micrometre long.

Largest cell is an ostrich's egg which has an area of about 17 cm X 13 cm (or 170 mm X130 mm).

It is not necessary that the size of cells of a large animal (such as an elephant) will be larger than cells of a small animal (such as a rat). **The size of the cell depends on the function it performs.** For example, nerve cells of a rat and nerve cells of an elephant perform the same functions and hence, are of the same size.

Cell Structure and Function

In a unicellular organism, a single cell performs all the basic functions of life but in multicellular organisms there is division of labour.



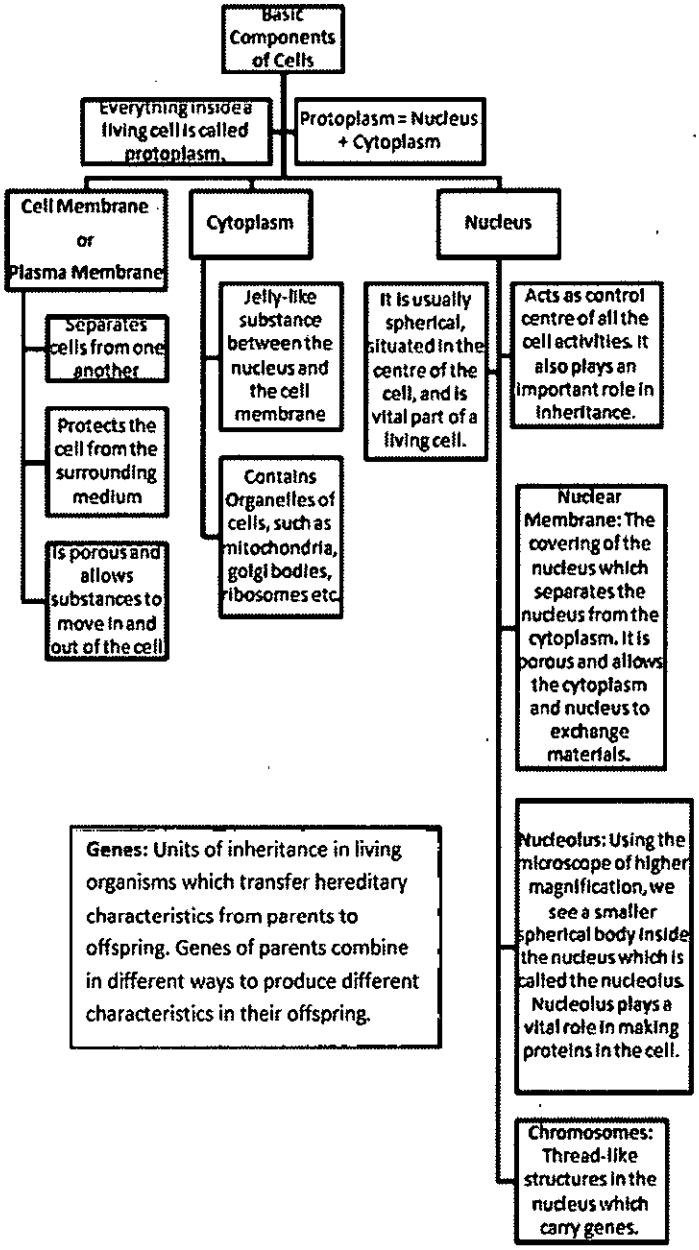


Figure 4: Parts of cells

To observe the basic components of a plant cell:

- Peel an onion.
- Place a small piece of the dry and thin onion peel in a drop of water on a glass slide.
- Put a drop of methylene blue solution on this thin layer and place a coverslip on it (while ensuring that no air bubbles get trapped in the coverslip).
- Place the slide under the microscope.

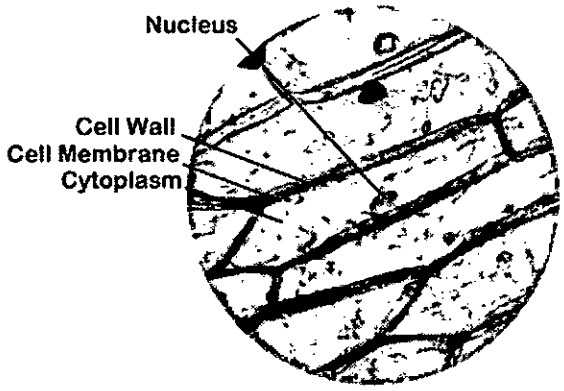


Figure 5: Onion peel cells under microscope

You will see:

- The boundary of the onion cell is a cell membrane, which is covered by another thick covering called the cell wall.
- The dense round body in the centre of the cell is called the nucleus.
- The jelly-like substance between the cell membrane and the nucleus is called the cytoplasm.

To observe the basic components of an animal cell:

- Scrape the inside of your cheek lightly with a clean toothpick.
- Place it in a drop of water on a glass slide.
- Add a drop of iodine solution or methylene blue solution and place a coverslip on it.
- Place the slide under the microscope.

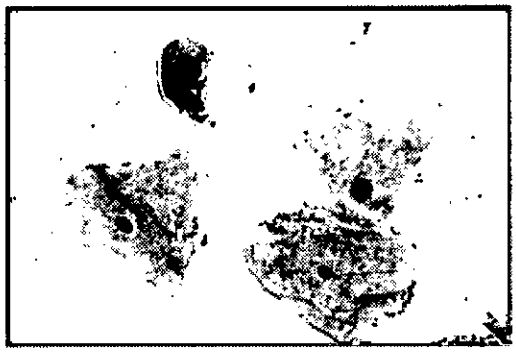


Figure 6: Cheek cells

You will see:

- Cell membrane (Cell wall is absent in animal cells),
- Nucleus, and
- Cytoplasm.

There are some other organelles (or components of cells) too. These include mitochondria, ribosomes, and Golgi bodies.

Organelles found in both Plant and Animal Cells are:

1. **Endoplasmic Reticulum**

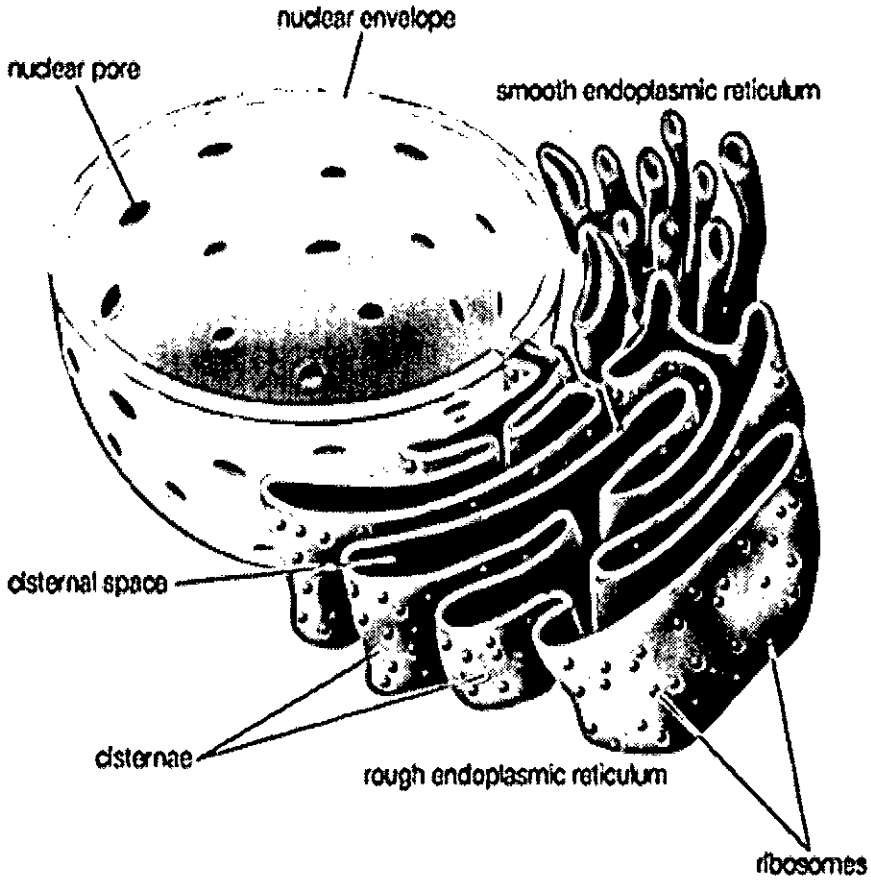


Figure 7: Endoplasmic reticulum- SER and RER

Endoplasmic Reticulum (ER) is a network of canals made up of membranes that encloses a fluid-filled lumen. It is of two types:

- Rough Endoplasmic Reticulum (RER): It is lined with ribosomes and hence, look rough.
  - **Function of RER:** It plays a key role in synthesis of protein as ribosome are attached to it.
- Smooth Endoplasmic Reticulum (SER): It does not have any ribosomes and hence, look smooth.
  - **Function of SER:** It plays a key role in synthesis of lipids.

2. **Ribosomes**

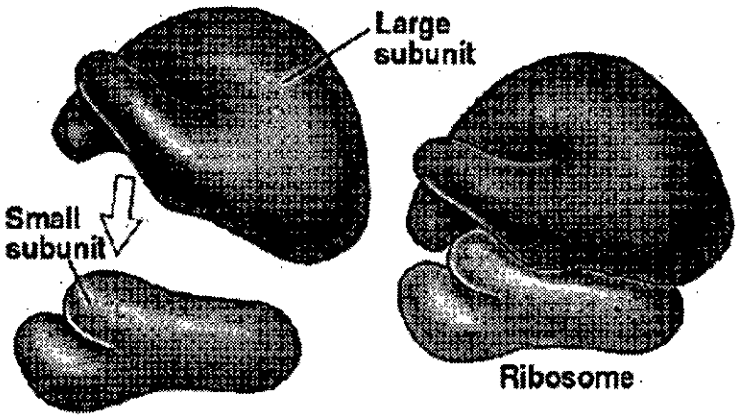


Figure 8: Ribosomes- Protein Factory of cells

Ribosomes are spherical bodies made up of RNA (ribonucleic acid) and protein enzyme. They do not have membranes and are present separately in cytoplasm.

Function of Ribosome: Ribosomes are the sites where the protein synthesis takes place.

3. Golgi Bodies

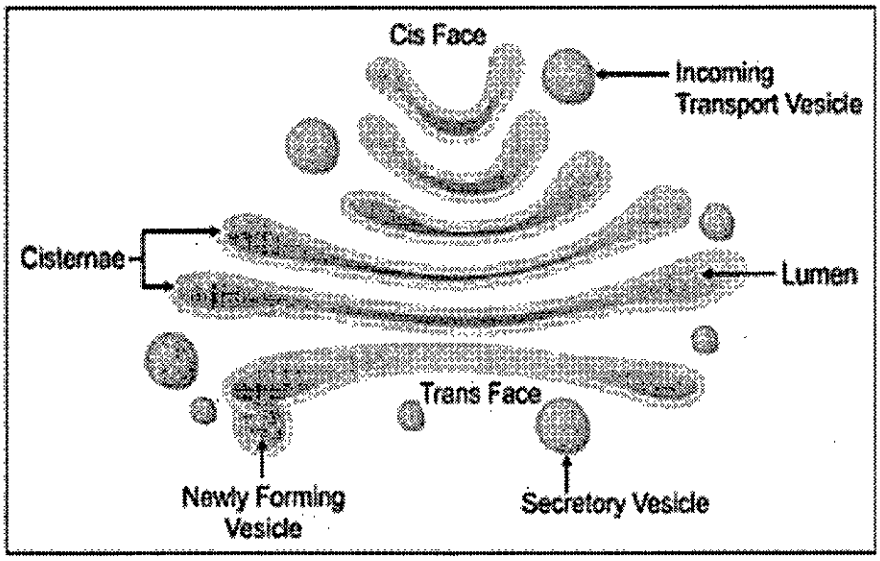


Figure 9: Golgi Apparatus

Smooth, flattened sac-like structures called Cisternae stack together in parallel rows to form Golgi bodies. Golgi Cis face receives protein from Endoplasmic reticulum and modifies, packages and stores it.

It also dispatches proteins in vesicles to various destinations.

Function of Golgi bodies: The Golgi apparatus are responsible for the secretion of enzymes, hormones and proteins.

4. **Mitochondria**

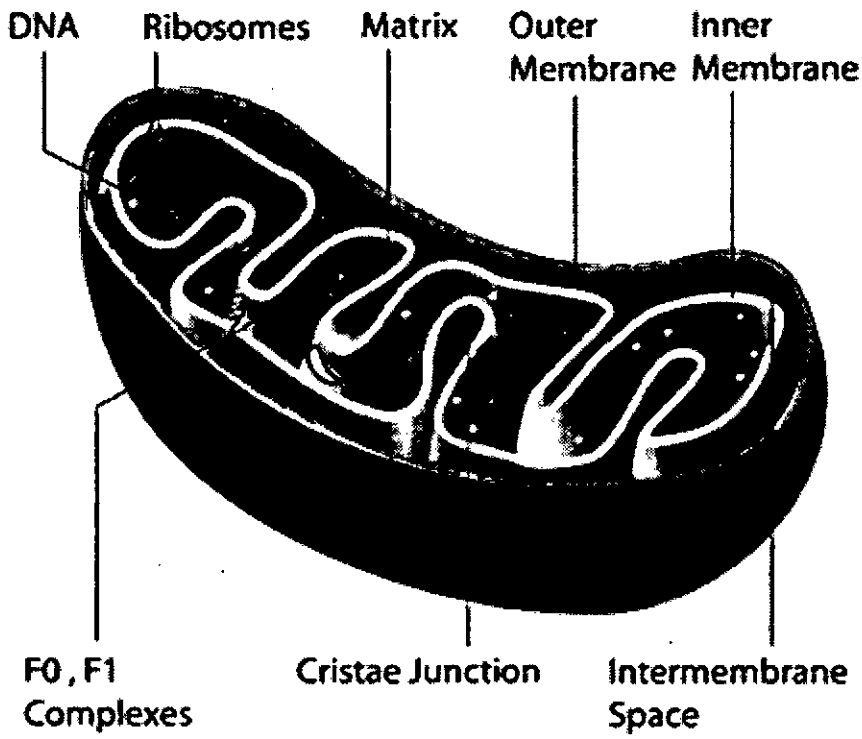


Figure 10: Mitochondria

Mitochondria are rod-shaped organelles with a double membrane. The outer membrane is smooth while the inner membrane folds over many times to form *cristae. Cristae* increase the surface area of the inner membrane by several times. *Matrix* is the fluid inside the mitochondria.

Function of Mitochondria: Mitochondria act as energy production sites and are hence, known as the **Powerhouses of the Cell.**

Glucose + Oxygen → Carbon Dioxide + Water + Energy (ATP)

5. **Lysosome**

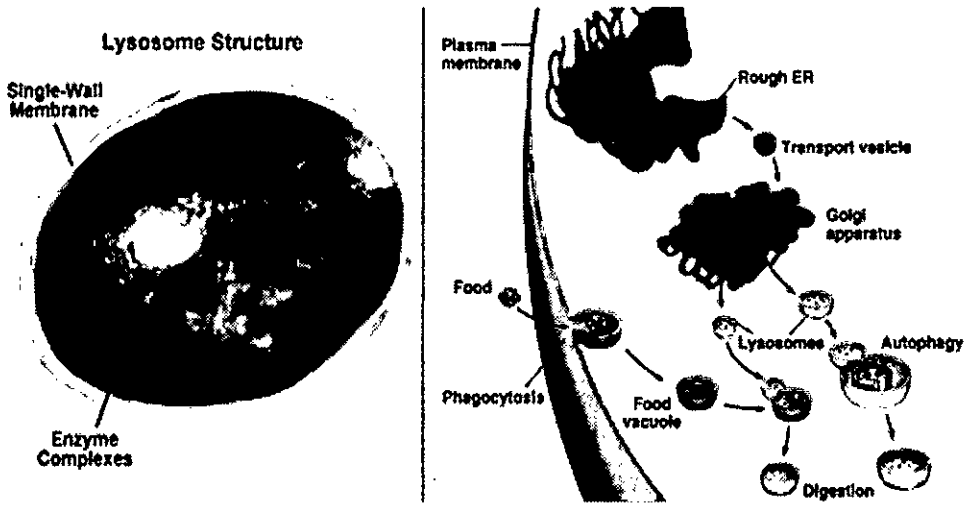


Figure 11: Lysosome - A single membrane organelle

Lysosomes are sac-like structures surrounded by single-layered membranes. They contain powerful digestive enzymes that can break down all organic material. It acts as a mini digestive system within the cell.

Function of Lysosomes: Lysosomes digest damaged cells and a variety of extra- and intra-cellular material. Since they remove cell organelles that are worn out or are not functioning properly and may even digest the entire cells (that are damaged or dead), they are also known as **Suicidal Bags**.

6. **Vacuoles**

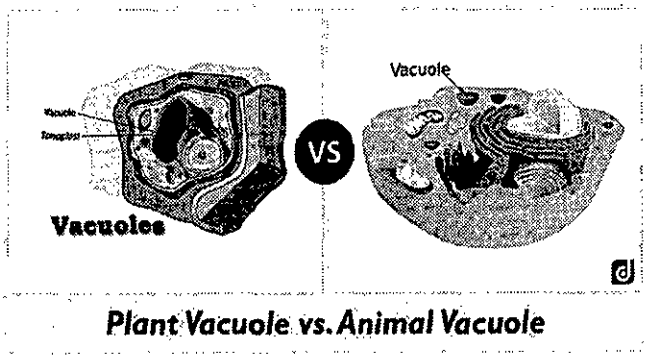


Figure 12: Vacuoles

Vacuoles are organelles enclosed by a membrane and filled with fluid. Plant cells usually have a large vacuole filled with a liquid called 'cell sap'. Cell Sap contains dissolved sugar and salts.

Animal cells may or may not have vacuoles. If they do have vacuoles, they are much smaller than the ones found in plant cells.

Function of Vacuoles in Plant Cells: Vacuoles in plant cells keep the cells firm or turgid. They store various substances (including waste products of the cell).

Function of Vacuoles in Animal Cells: Vacuoles in animal cells store food, water, sugar, minerals and waste products of the cell. In Amoeba, vacuoles that contain food particles are also referred to as food vacuoles.

7. **Plastids**

Plastids are also type of organelles that are found only in Plant Cells.

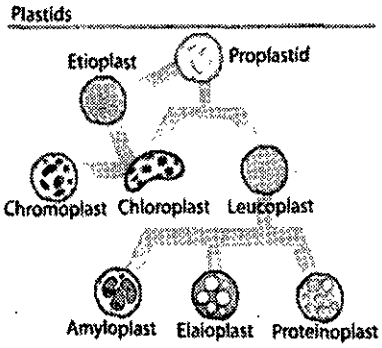


Figure 13: Types of Plastids

With double-layered membrane, these organelles are found in cytoplasm of the cells. They are of two types (depending on the colour of the pigment they contain);

- **Leucoplasts:** These colourless organelles store starch or other plant nutrients. **For Example**, Starch stores in potato cells. Leucoplast are of different types :
  - Amyloplast: stores starch
  - Elaioplast: stores fat
  - Proteinoplast/ Aleuroplast: stores protein
- **Chromoplasts:** These contain different-coloured pigments. Most important type of chromoplasts is **chloroplast** which contain green-coloured pigments called **Chlorophyll.**

Function of Chloroplast: Chloroplasts are the sites where photosynthesis takes place. Here, carbon dioxide and water combine in the presence of energy from the sunlight to produce food. Hence, chloroplasts help in synthesis of food by green plants.

$CO_2 + H_2O \rightarrow$ Glucose + Oxygen

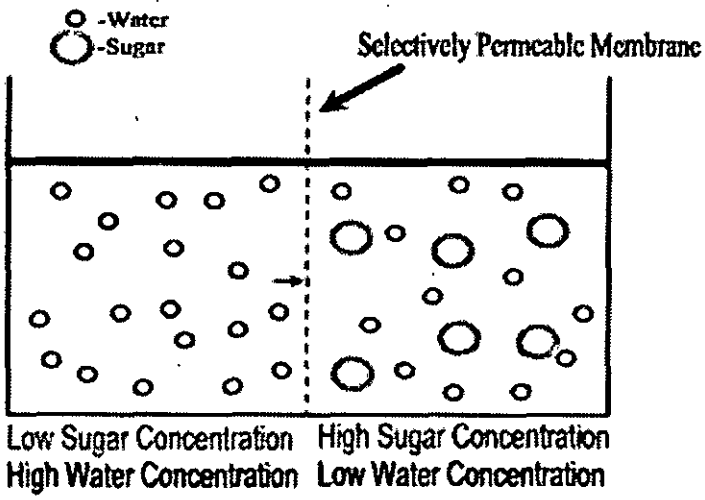
(in the presence of chlorophyll + sunlight)

How do molecules move in and out of the cell?

Molecules use two main methods of passive transport to move in or out of the cell:

- Osmosis, and
- Diffusion.

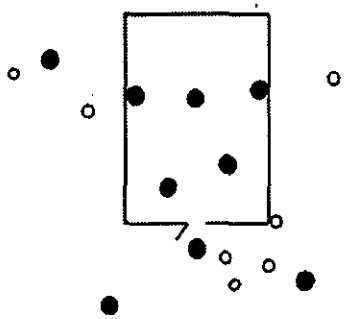
Osmosis



When the solvent moves from the area of dilute solution to the area of concentrated solution through a semipermeable membrane in order to equalize the concentration level of both the solutions, the process is known as **'Osmosis'**.

For Example: Roots absorb water from the soil through osmosis.

Diffusion



When the particles of any material move from a region of higher concentration to that of lower concentration until the equilibrium is reached, the process is known as **'Diffusion'**.

For Example: When you spray perfume, its fragrance spreads in air through diffusion.

Differences between Osmosis and Diffusion

Osmosis	Diffusion
Only solvent molecules move from one place to another	Solvent as well as solute molecules can move from one place to another
Takes place only in liquids	Takes place in all the three mediums – solids, liquids and gases.
Takes place through a semi-permeable membrane	Does not need a membrane

Why do plant cells have cell walls?

A cell wall is the outer thick layer in plant cells that protect the cell membrane. Since plants cannot move from their place, this cell wall serves to protect their cells from the possible damage by temperature variations, high wind speed, atmospheric moisture etc.

Prokaryote

Bacterial cells and cells of blue-green algae do not have well-defined nuclei (plural of nucleus) like those of multi-cellular organisms. The cells of such organisms have nuclear materials without the nuclear membrane. Such cells are called prokaryotic cells where 'pro' stands for 'primitive' and 'karyon' stands for 'nucleus'.

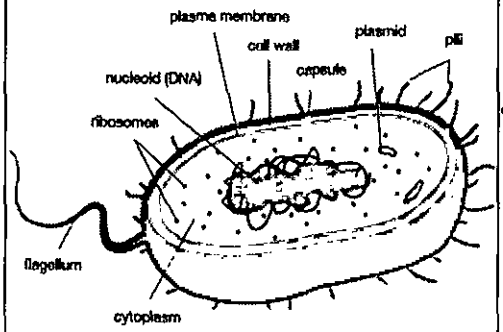
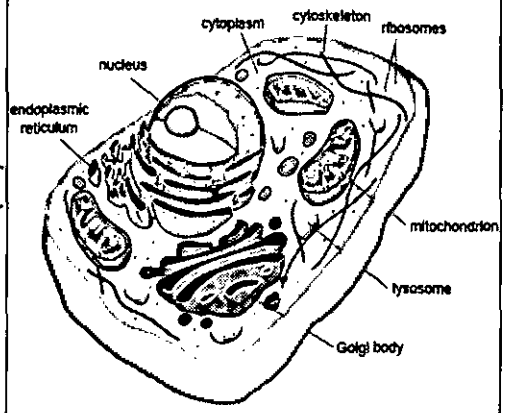
Organisms with prokaryotic cells are known as prokaryotes.

Eukaryotes

Plant and animal cells with well-organised nucleus with nuclear membrane are called eukaryotic cells. 'Eu' stands for 'true' while 'karyon' stands for 'nucleus'.

Organisms with eukaryotic cells are known as **Eukaryotes**.

Differences between Prokaryotic and **Eukaryotic Cells**

Prokaryotic Cells	Eukaryotic Cells
	
DNA is clumped in an area but there is no organised nucleus with a membrane.	True nucleus is present, which is well-organised and has a nuclear membrane.
Do not have any organelles (except ribosomes)	Usually have organelles like Golgi bodies, lysosomes, endoplasmic reticulum etc.
Smaller in size	Larger in size
Examples: Bacteria and Blue-green algae	Examples: Plant and Animal cells

Comparison of Plant and Animal Cells

Now, we know that both plant and animal cells have:

- Cell Membrane,
- Cytoplasm,
- Nucleus, and
- Nuclear Membrane.

We also know that only plant cell, Bacterial and fungal cells have **Cell Walls**.

Plant Cell

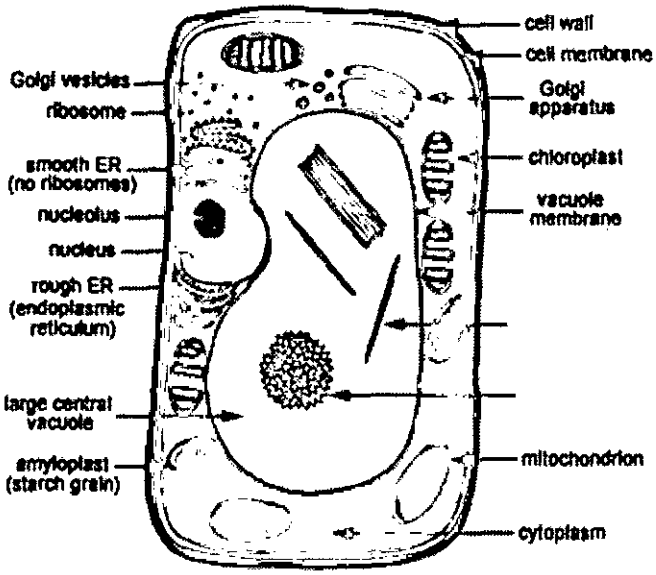


Figure 14: Detailed structure of Plant cell

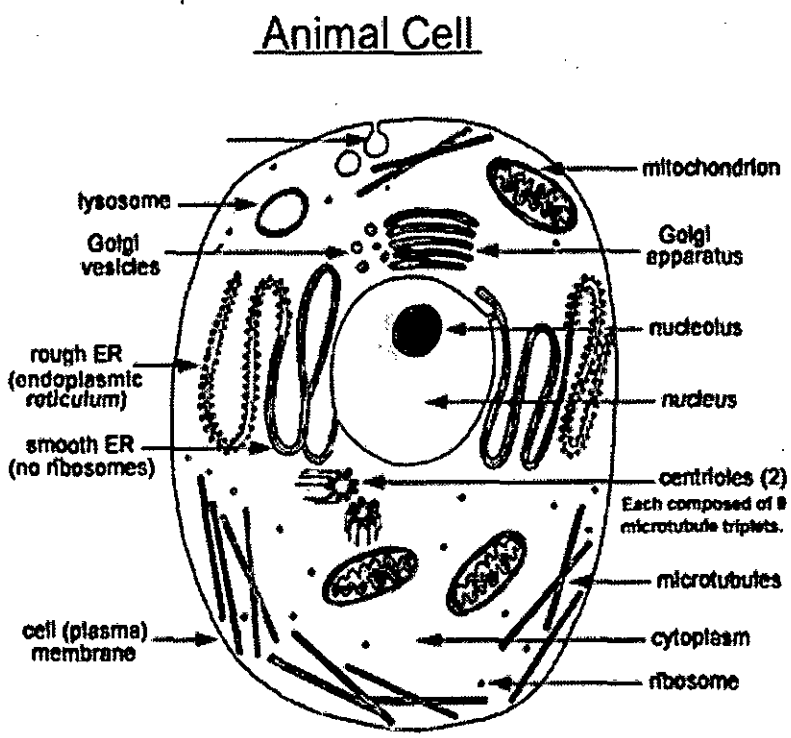


Figure 15: Detailed Structure of Animal Cell

There are some other differences in plant and animal cells that you need to know:

- **Plants have larger vacuoles while animals have smaller vacuoles.** Vacuoles store water or food for plants and even store waste products until they can be discarded. Plants need bigger vacuoles as they cannot move to satisfy their hunger or thirst.
- **Only plant cells have plastids.** They help in manufacturing or storing food.
- **Only animal cells have centrioles.** Centrioles help in the division of cells.

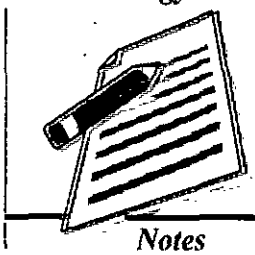
Summary of the chapter

In 1655, Scientist Robert Hooke made an observation while examining a dried section of cork tree with a crude light microscope he observed small chambers and named them cells.

The cell is known as the basic structural and functional unit of life as all organisms are composed of cells.

The single celled organisms are called unicellular e.g.- amoeba while those having more than one cell are called multi-cellular.

All basic chemical and physiological functions of living beings - for example, repair, growth, movement, immunity, communication, and digestion etc are carried out inside the cells.

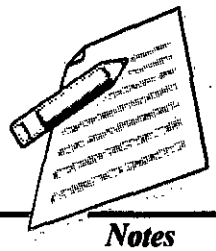


Structure of a cell- Cells are mostly round, spherical or elongated in shape. Cells sometimes are quite long. Some are branched like the nerve cell or a neuron. Components of the cell are enclosed in a membrane which provides shape to the cells. Cell wall is an additional covering over the cell membrane to give shape and rigidity to plant cells.

EXERCISE

Multiple Choice Questions

1. The power house of cell is called
   (a) Cell wall
   (b) Mitochondria
   (c) Ribosomes
   (d) Nucleus
2. The kitchen of the cell is called
   (a) Cell wall
   (b) Nucleus
   (c) Vacuoles
   (d) Plastids
3. The functional unit of life is called
   (a) Cell
   (b) Egg
   (c) Nucleus
   (d) None of these
4. Chloroplast is found in
   (a) Plant cell only
   (b) Animal cell only
   (c) Both of these
   (d) None of these
5. The control unit of cell is
   (a) Nucleus
   (b) Cell wall
   (c) Cytoplasm
   (d) All of these
6. Single celled organisms are called
   (a) Unicellular
   (b) Multi-cellular
   (c) Both of these
   (d) None of these
7. Tissue is a
   (a) Group of organs
   (b) Group of cells
   (c) Group of tissues
   (d) Group of organisms



8. Cell is discovered by
   (a) Robert Brown
   (b) Robert Hooke
   (c) John Mendal
   (d) Charse Darwin
9. The calls capable of changing shapes are
   (a) Amoeba cell
   (b) WBC
   (c) Both of these
   (d) None of these
10. Hen's egg is a
   (a) Tissue
   (b) Organ
   (c) Organ system
   (d) cell

ANSWERS

1. (b)	**2.** (d)	**3.** (a)	**4.** (a)	**5.** (a)
6. (a)	**7.** (b)	**8.** (b)	**9.** (c)	**10.** (d)

High Order Thinking Skills

Cell- Structure and Functions

1. What is the difference between an animal cell and a plant cell?
2. Why are chloroplast found only in plant cells?
3. Cells are the basic structural and functional unit of life. Explain.
4. What is the difference between eukaryotes and prokaryotes?
5. Explain the process of photosynthesis.
6. Explain cytoplasm in brief.
7. Write a note on nucleus of a cell.
8. What is the function of Nerve Cells?
9. What is the function of Nucleus?
10. Draw a neat diagram of a Nerve Cell.

Space for notes

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5 TISSUES AND OTHER LEVELS OF ORGANIZATION

Introduction

Tissue Level of Organisation

In multicellular organisms, cells do not operate independently, instead, they form tight cell communities that live and work together. Individual body cells are specialized, with each type performing specific functions that helps to maintain homeostasis and benefits the body as a whole. Cell specialization is obvious.

How the muscle cell looks and acts differs greatly from skin cells. Cell specialization allows the body to function in co-ordinated ways.

Groups of cells that are similar in structure and perform common or related functions are called '**tissues.**

Tissues are organized in specific proportions and patterns to form **organs** like lungs, heart, stomach, kidneys, ovaries, testes etc; hence the tissues are called the '**living fabrics**. If two or more organs perform common physical and chemical functions they are called '**organ systems**',

E.g.: digestive system, respiratory system, circulatory system, excretory system, etc. Most organs contain different types of tissues and their arrangement determines the organ's structure and functions.

The study of tissues, or **histology**, complements the study of gross anatomy. Together they provide the structural basis for understanding organ physiology.

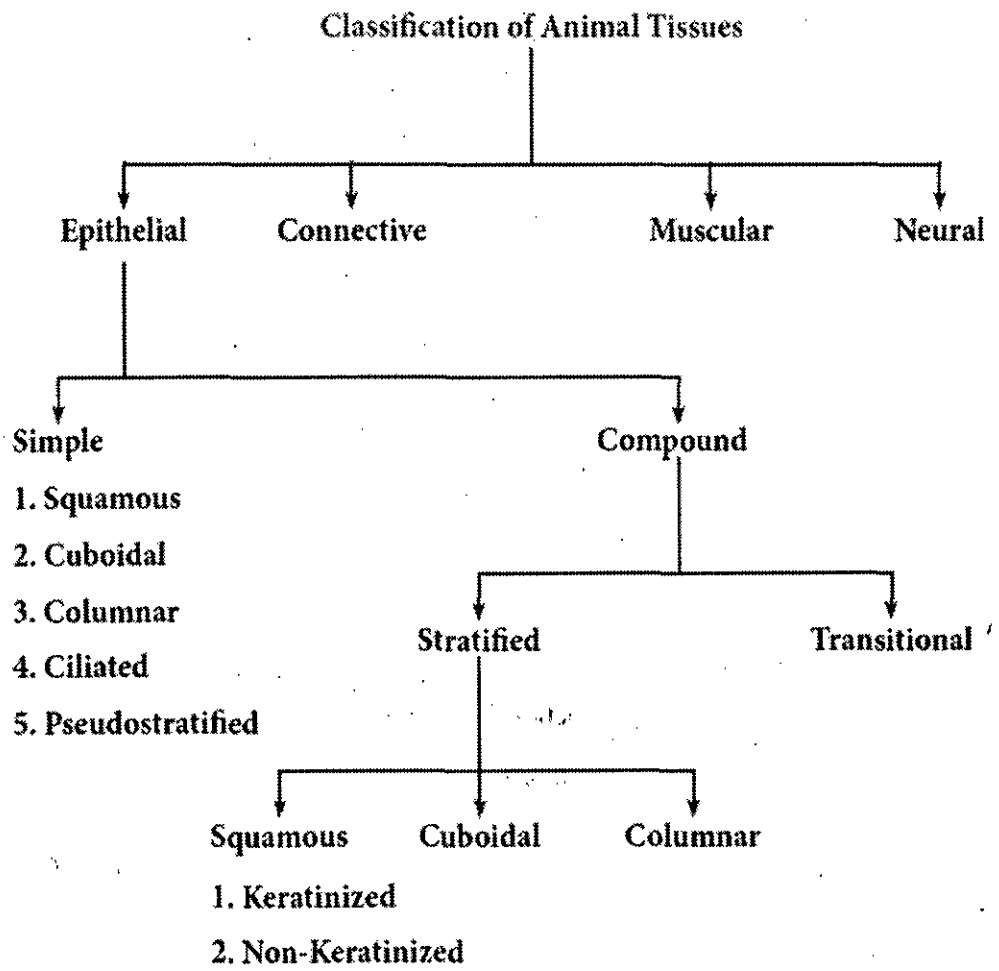
Animal Tissues

Animal tissues are classified according to the size, shape and function of the cells.

Animal Tissues

Animal tissues are classified according to the size, shape and function of the cells. There are four primary (basic) tissue types that interweave to form the 'fabric' of the body.

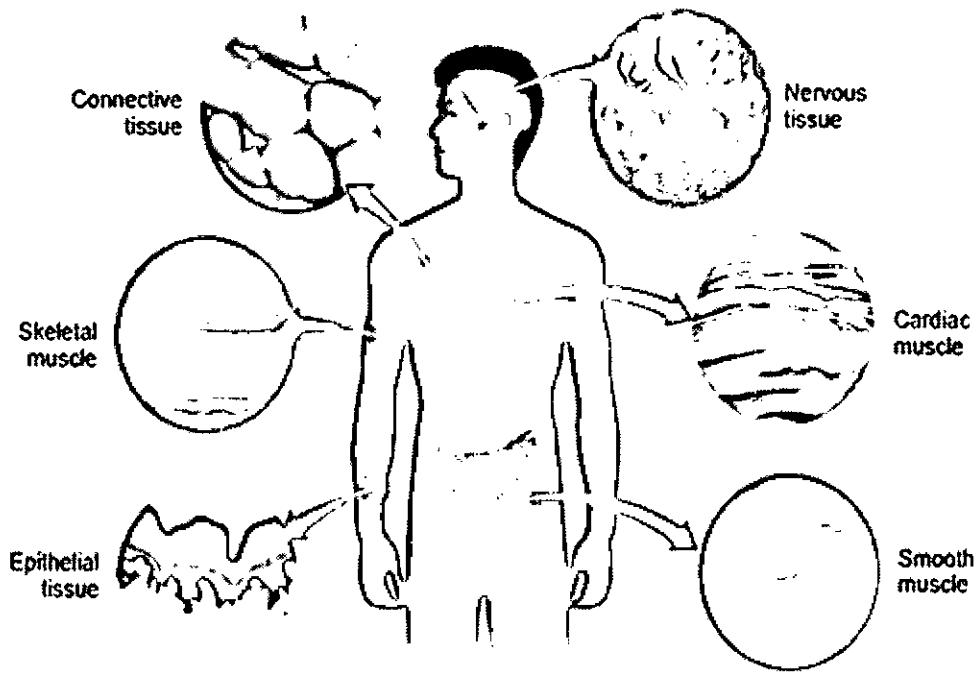
They are, the epithelial tissue (covering), the connective tissue (support), the muscle tissue (movement) and the nervous tissue (control).



Epithelial Tissue

Epithelial tissue is a sheet of cells that covers the body surface or lines the body cavity. It occurs in the body as a covering, as a lining epithelium and as glandular, epithelium. The functions of epithelium includes **protection, absorption, filtration, excretion, secretion** and sensory reception. Based on the structural modification of the cells, the epithelial tissues are classified into simple epithelium and compound epithelium or stratified epithelium.

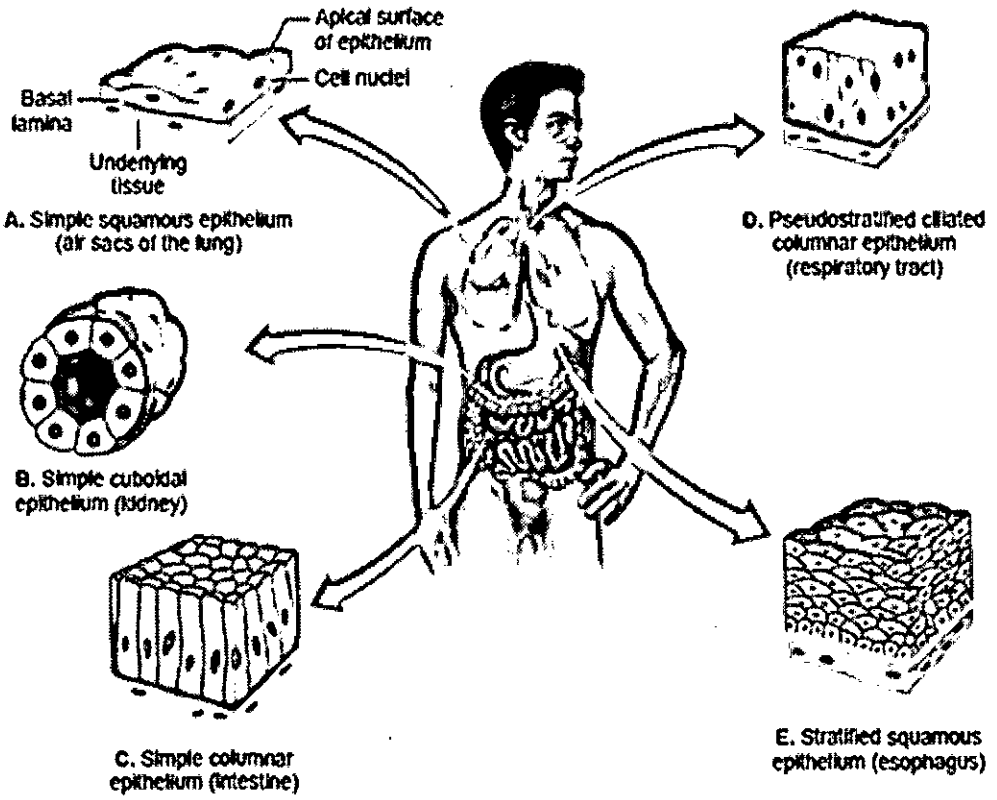
Simple epithelium is composed of a single layer of cells. They are found in the organs of absorption, secretion and filtration. Simple epithelial tissue is further classified into squamous epithelium, cuboidal epithelium, columnar epithelium, ciliated epithelium and pseudostratified epithelium (Figure 3.2). The squamous epithelium is made of a single thin layer of flattened cells with irregular boundaries. They are found in the kidney glomeruli, air sacs of lungs, lining of heart, blood vessels and lymphatic vessels and are involved in functions like forming a diffusion boundary and filtration in sites where protection is not important. The cuboidal epithelium is made of a single layer of cube like cells. This tissue is commonly found in the kidney tubules, ducts and secretory portions of small glands and surface of the ovary.



Its main functions are secretion and absorption. The columnar epithelium is composed of single layer of tall cells with round to oval nuclei at the base. It lines the digestive tract from the stomach to the rectum. The two modifications of this lining are the presence of **microvilli** on the apical surface of the absorptive cells and Goblet cell which secretes the protective lubricating mucus. The functions of this epithelium include absorption, secretion of mucus, enzymes and other substances. If the columnar cells bear cilia on their free surfaces, they are called ciliated epithelium. This ciliated type propels mucus by ciliary actions and it lines the small bronchioles, fallopian tubes and uterus. **Non-ciliated type** lines most of the digestive tract, gall bladder and secretory ducts of glands.

Pseudo-stratified epithelial cells are columnar, but unequal in size. Although the epithelium is single layered yet it appears to be multi-layered because the nuclei lie at different levels in different cells. Hence, it is also called pseudostratified epithelium and its functions are protection, secretion and absorption. Ciliated forms line the trachea and the upper respiratory tract. The non-ciliated forms, line the epididymis, large ducts of a glands and tracts of male urethra.

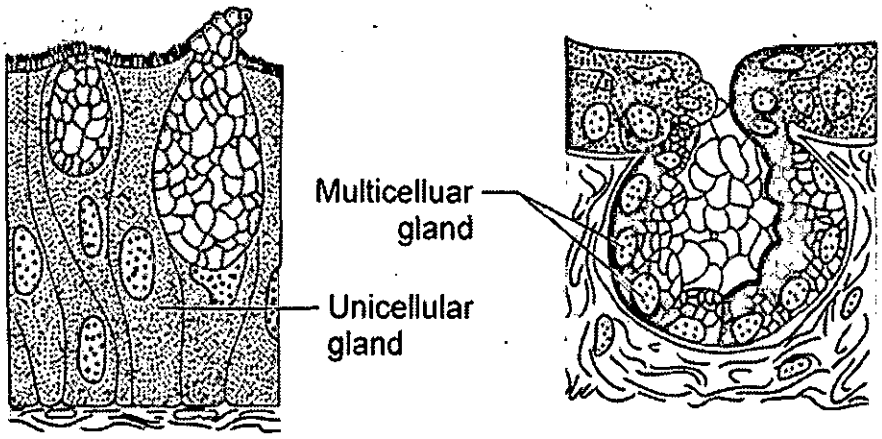
Some of the cuboidal or columnar cells get specialized for secretion and are called glandular epithelium (Figure 3.3). They are mainly of two types: unicellular, consisting of isolated glandular cells (goblet cells of the alimentary canal), and multicellular, consisting of cluster of cells (salivary gland). On the basis of the mode of pouring of their secretions, glands are divided into two categories namely exocrine and endocrine glands. Exocrine glands secrete mucus, saliva, earwax, oil, milk, digestive enzymes and other cell products. These products are released through ducts or tubes. In contrast endocrine glands do not have ducts.



Glandular Epithelium

- **Endocrine glands**
- **Exocrine glands**
  - **Unicellular**
  - **Multicellular**
    - **Based on structure**
      1. Simple glands
      2. Compound glands
    - **Based on their secretory units**
      1. Tubular
      2. Alveolar(Acinus)
      3. Tubulo alveolar
    - **Based on their mode of secretion**
      1. Merocrine
      2. Holocrine
      3. Apocrine

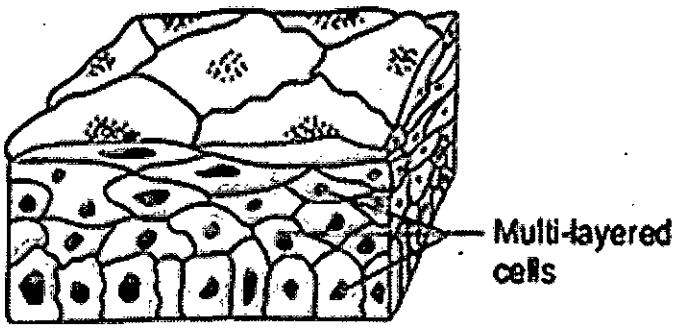
Their secretions called hormones are secreted directly into the fluid bathing the gland. The exocrine glands are classified as unicellular and multicellular glands. The multicellular glands are further classified based on the structure as simple and compound glands, based on their secretory units as tubular, alveolar (Acinus) and tubulo alveolar. Based on the mode of secretion exocrine glands are classified as merocrine, holocrine and apocrine.



(a) (b)

c. Simple columnar epithelium (intestine) epithelium (esophagus)

Compound epithelium is made of more than one layer (multi-layered) of cells and thus has a limited role in secretion and absorption(Figure). The compound epithelia may be stratified and transitional.



Their main function is to provide protection against chemical and mechanical stresses. They cover the dry surface of the skin, the moist surface of buccal cavity, pharynx, inner lining of ducts of salivary glands and of pancreatic ducts. There are four types of compound epithelium namely, stratified squamous epithelium, cuboidal epithelium, columnar epithelium and transitional epithelium. Stratified squamous epithelium is of two types called keratinized type which forms the dry epidermis of the skin and the non-keratinized type forms the moist lining of the oesophagus, mouth, conjunctiva of the eyes and vagina. Stratified cuboidal epithelium mostly found in the ducts of sweat glands and mammary glands. Stratified columnar epithelium has limited distribution in the body, found around the lumen of the pharynx, male urethra and lining of some glandular ducts.

Transitional Epithelium is found lining the ureters, urinary bladder and part of the urethra. This epithelium allows stretching and is protective in function.

All cells of the epithelium are held together with little intercellular material. In most of the animal tissues, specialized junctions provide both structural and functional links between its individual cells. Three types of cell junctions are found in the epithelium and other tissues. These are called as tight, adhering

and gap junctions. Tight junctions help to stop substances from leaking across a tissue. Adhering junctions perform cementing to keep neighbouring cells together. Gap junctions facilitate the cells to communicate with each other by connecting the cytoplasm of adjoining cells, for rapid transfer of ions, small molecules and sometimes big molecules.

Connective Tissue

Connective tissue develops from the mesoderm and is widely distributed in the body. There are four main classes of connective tissues. They are connective tissue (which includes fat and the fibrous tissue of ligaments), cartilage, bones and blood. Major functions of connective tissues are binding and support, protection, insulation and transportation of substances.

Connective Tissues

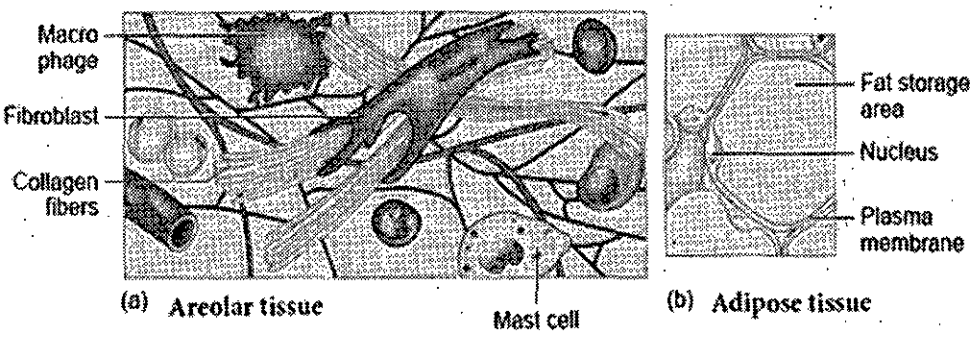
Loose Connective Tissues	Dense Connective Tissues	Specialised Connective Tissues
1. Areolar Tissue	1. Dense Regular	1. Cartilage
2. Adipose Tissue	2. Dense Irregular	2. Bone
3. Reticular Tissue	3. Elastic	3. Blood

Components of connective tissue

All connective tissues consist of three main components namely fibres, ground substance and cells. The 'Fibres' of connective tissue provide support. Three types of fibres are found in the connective tissue matrix. They are collagen, elastic and reticular fibres. Connective tissue is of two types namely, Loose connective tissues (Areolar, Adipose and Reticular) and Dense connective tissues (dense regular, dense irregular and elastic). Specialized connective tissues include cartilage, bone and blood.

Loose connective tissues

In this tissue the cells and fibres are loosely arranged in a semi fluid ground substance. For example, the Areolar connective tissue beneath the skin acts as a support framework for epithelium and acts as a reservoir of water and salts for the surrounding body tissues, hence aptly called tissue fluid. It contains fibroblasts, macrophages, and mast cells (Figure).



(a) Areolar tissue (b) Adipose tissue

Adipose tissue is similar to areolar tissue in structure and function and located beneath the skin. Adipocytes commonly called adipose or fat cells predominate and account for 90% of this tissue mass. The cells of this tissue store fats and the excess nutrients which are not utilised immediately are converted to fats and are stored in tissues. Adipose tissue is richly vascularised indicating its high metabolic activity. While fasting, these cells maintain life by producing and supplying energy as fuel. Adipose tissues are also found in subcutaneous tissue, surrounding the kidneys, eyeball, heart, etc. Adipose tissue is called 'white fat' or white adipose tissue. The adipose tissue which contains abundant mitochondria is called 'Brown fat' or Brown adipose tissue. White fat stores nutrients whereas brown fat is used to heat the blood stream to warm the body. Brown fat produces heat by non-shivering thermogenesis in neonates.

Reticular connective tissue resembles areolar connective tissue, but the matrix is filled with fibroblasts called reticular cells. It forms an internal framework (stroma) that supports the blood cells (largely lymphocytes) in the lymph nodes, spleen and bone marrow.

Dense connective tissues (connective tissue proper)

Fibres and fibroblasts are compactly packed in the dense connective tissues. Orientation of fibres show a regular or irregular pattern and is called dense regular and dense irregular tissues. **Dense regular connective tissues** primarily contain collagen fibres in rows between many parallel bundles of tissues and a few elastic fibres.

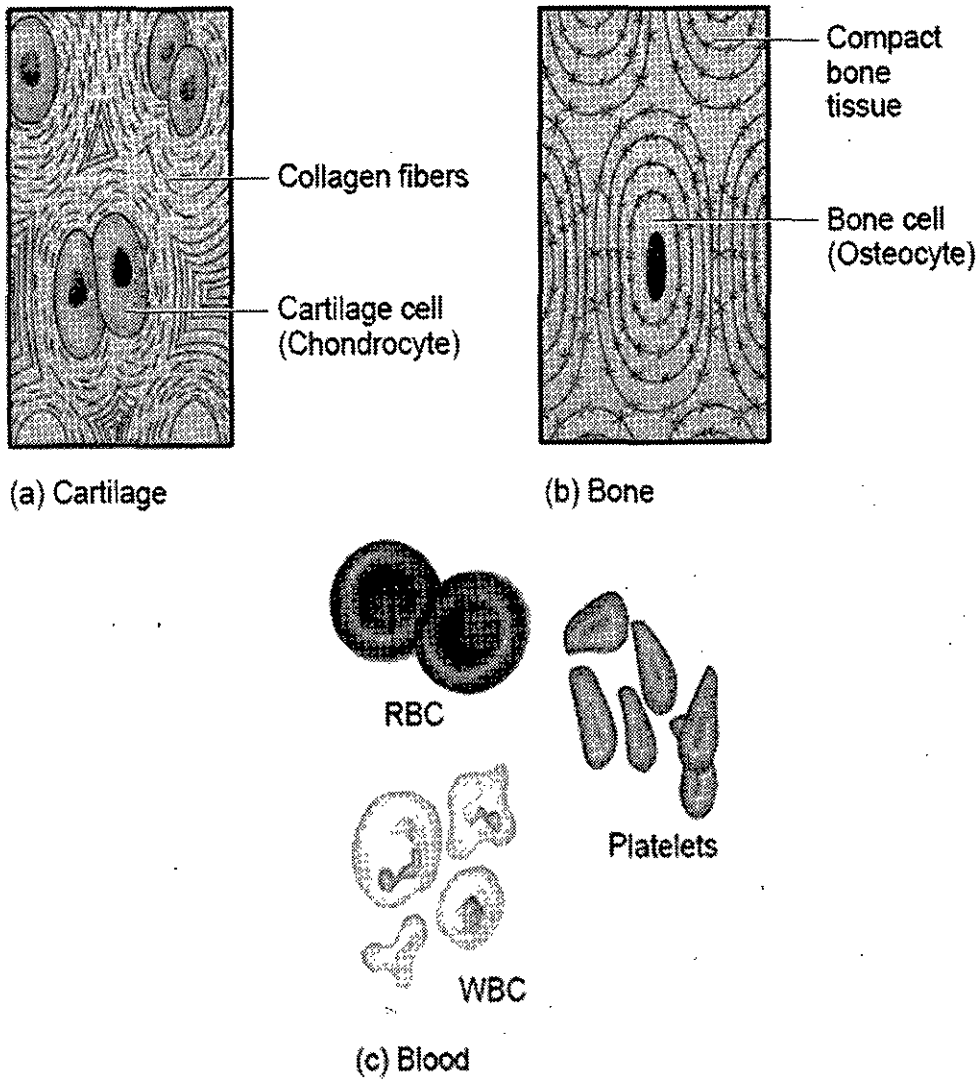
The major cell type is **fibroblast.** It attaches muscles and bones and withstands great tensile stress when pulling force is applied in one direction. This connective tissue is present in **tendons,** that attach skeletal muscles to bones and ligaments attach one bone to another.

Dense irregular connective tissues have bundles of thick collagen fibres and fibroblasts which are arranged irregularly. The major cell type is the **fibroblast**. It is able to withstand tension exerted in many directions and provides structural strength. Some elastic fibres are also present. It is found in the skin as the leathery dermis and forms fibrous capsules of organs such as kidneys, bones, cartilages, muscles, nerves and joints.

Elastic connective tissue contains high proportion of elastic fibres. It allows recoil of tissues following stretching. It maintains the pulsatile flow of blood through the arteries and the passive recoil of lungs following inspiration. It is found in the walls of large arteries; ligaments associated with vertebral column and within the walls of the bronchial tubes.

Specialised connective tissues are classified as cartilage, bones and blood. The intercellular material of **cartilage** is solid and pliable and resists compression. Cells of this tissue (chondrocytes) are enclosed in small cavities within the matrix secreted by them (Figure 3.6).

Most of the cartilages in vertebrate embryos are replaced by bones in adults. Cartilage is present in the tip of nose, outer ear joints, ear pinna, between adjacent bones of the vertebral column, limbs and hands in adults.



Specialized connective tissues

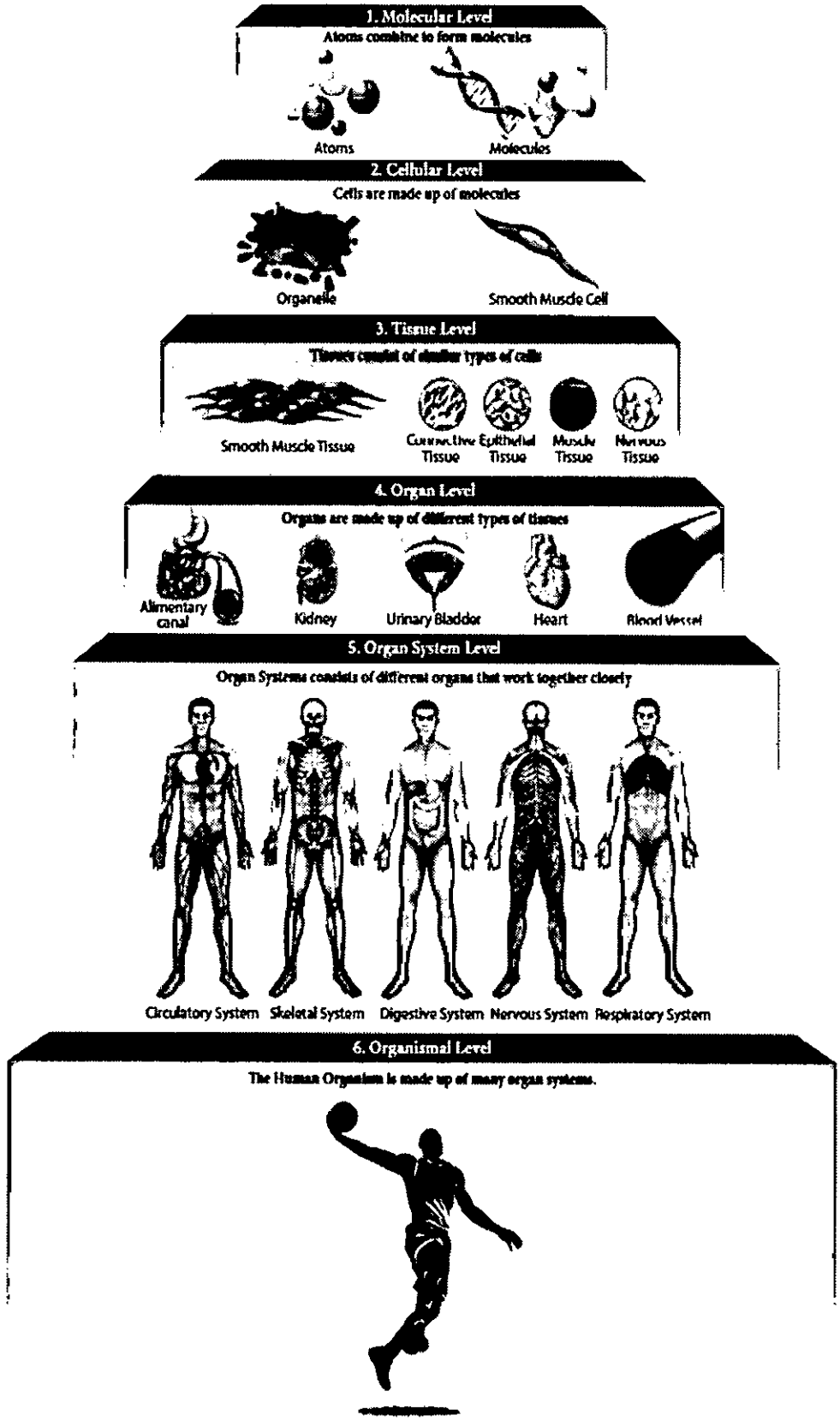
Bones have hard and non-pliable ground substance rich in calcium salts and collagen fibres which gives strength to the bones.

It is the main tissue that provides structural frame to the body. Bones support and protect softer tissues and organs. The bone cells (osteocytes) are present in the spaces called lacunae. Limb bones, such as the long bones of the legs, serve weight-bearing functions. They also interact with skeletal muscles attached to them to bring about movements. The bone marrow in some bones is the site of production of blood cells.

Blood is the fluid connective tissue containing plasma, red blood cells (RBC), white blood cells (WBC) and platelets. It functions as the transport medium for the cardiovascular system, carrying nutrients, wastes, respiratory gases throughout

the body.

Levels of Structural Organisation

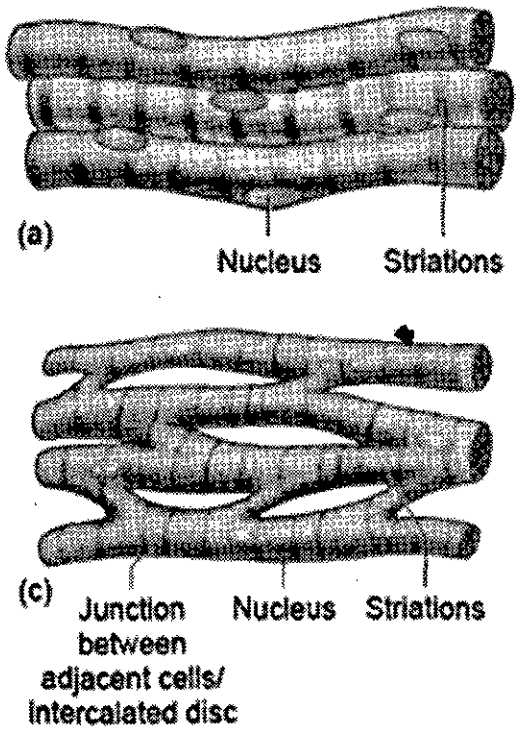


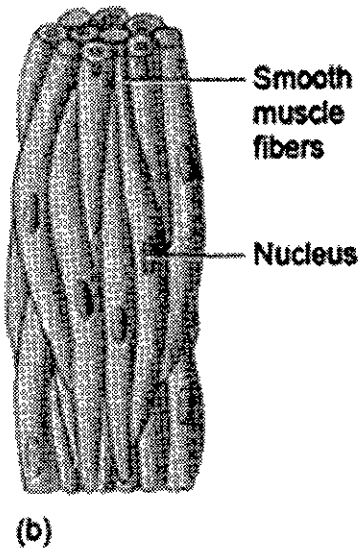
Muscle Tissue

Each muscle is made of many long, cylindrical fibres arranged in parallel arrays. These fibres are composed of numerous fine fibrils, called myofibrils. Muscle fibres contract(shorten) inures poststimulation, then relax (lengthen) and return to their uncontracted state in a coordinated fashion. In general muscles play an active role in all the movements of the body.

Muscles are of three types, skeletal, smooth and cardiac. **Skeletal muscle tissue** is closely attached to skeletal bones. In a typical muscle such as the biceps, the striated (striped) skeletal muscle fibres are bundled together in a parallel fashion. A sheath of tough connective tissue encloses several bundles of muscle fibres.

The smooth muscle fibres taper at both ends (fusiform) and do not show striations. Cell junctions hold them together and they are bundled together in a connective issues' heath. The wall so internal organs such as the blood vessels, stomach and intestine contain this type of muscle tissue.





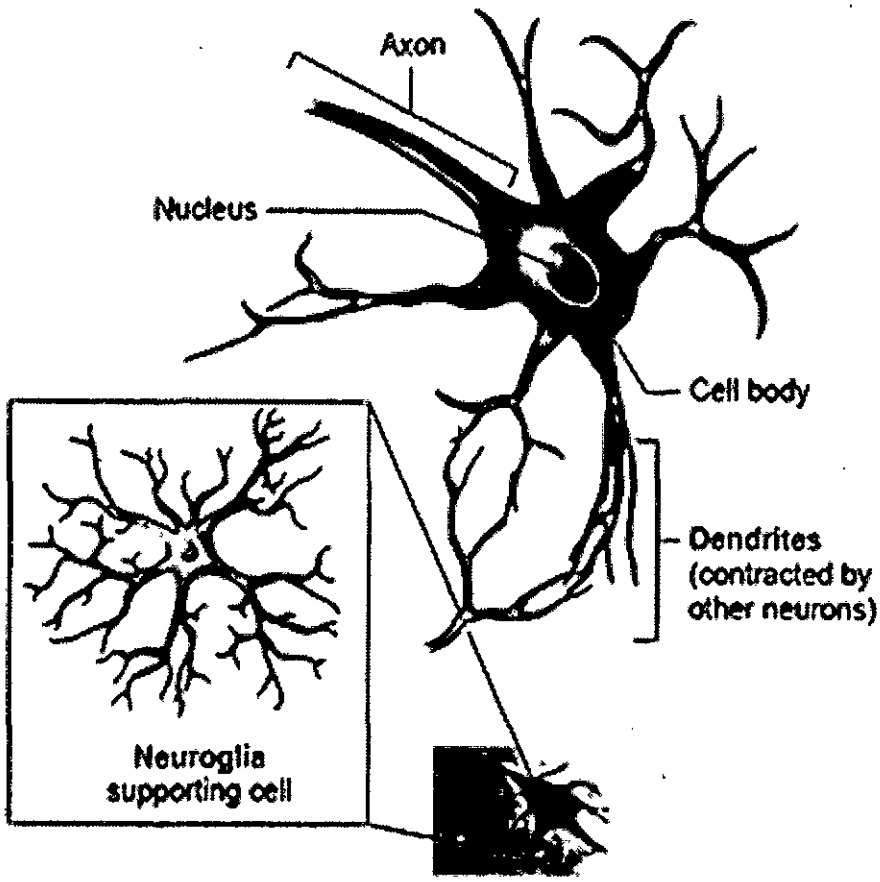
Smooth muscles are 'involuntary' as their functions cannot be directly controlled. Unlike the smooth muscles, skeletal muscles cannot be controlled by merely thinking.

Cardiac muscle tissue is a contractile tissue present only in the heart. Cell junctions fuse the plasma membranes of cardiac muscle cells and make them stick together. Communication junctions (intercalated discs) at some fusion points allow the cells to contract as a unit, i.e., when one cell receives a signal to contract, its neighbours are also stimulated to contact.

Neural Tissue

Nervous tissue exerts the greatest control over the body's responsiveness to changing conditions. Neurons, the unit of neural system are excitable cells. The neuroglial cells which constitute the rest of the neural system protect and support the neurons. Neuroglia makes up more than one-half of the volume of neural tissue in our body.

When a neuron is suitably stimulated, an electrical disturbance is generated which swiftly travels along its plasma membrane. Arrival of the disturbance at the neuron's endings, or output zone, triggers events that may cause stimulation or inhibition of adjacent neurons and other cells



Summary of the chapter

- 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.

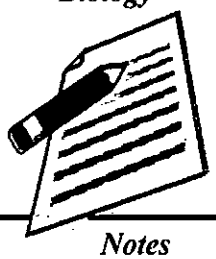
EXERCISE

Multiple Choice Questions

1. The main function of the cuboidal epithelium is
   (a) Protection
   (b) Secretion
   (c) Absorption
   (d) Both (b) and (c)
2. The ciliated epithelium lines the
   (a) Skin
   (b) Digestive tract
   (c) Gall bladder
   (d) Trachea
3. What type of fibres are found in connective tissue matrix?
   (a) Collagen
   (b) Areolar
   (c) Cartilage
   (d) Tubular
4. Prevention of substances from leaking across the tissue is provided by
   (a) Tight junction
   (b) Adhering junction
   (c) Gap junction
   (d) Elastic junction
5. Non-shivering thermogenesis in neonates produces heat through
   (a) White fat
   (b) Brown fat
   (c) Yellow fat
   (d) Colourless fat

Review Questions

6. Some epithelia are pseudostratified. What does this mean?
7. Differentiate white adipose tissue from brown adipose tissue.
8. Why blood is considered as a typical connective tissue?



9. Differentiate between elastic fibres and elastic connective tissue.
10. Name any four important functions of epithelial tissue and provide at least one example of a tissue that exemplifies each function.
11. Write the classification of connective tissue and their functions
12. What is an epithelium? Enumerate the characteristic features of different epithelia.

Space for notes

Module 2 FORMS AND FUNCTIONS OF PLANTS AND ANIMALS

Module Content

6. Root System 7. Shoot system 8. Absorption, Transport and water Loss in Plants 9. Nutrition in plants- Mineral Nutrition 10. Nitrogen Metabolism 11. Photosynthesis 12. Respiration in Plants 13. Nutrition and Digestion 14. Respiration and Elimination of Nitrogenous Waste 15. Circulation of Body Fluids 16. Locomotion and movement 17. Coordination and Control 18. Homeostasis

Objective of the module

This module highlights the complex nature of the structure and function of the different organ systems in plants and animals with special emphasis on the life processes.

6 ROOT SYSTEM

Introduction

The root is usually an underground part of the plant which helps in fixation and absorption of water.

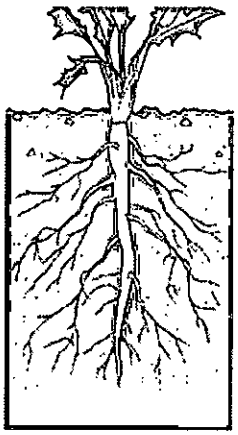
The root with its branches is known as the root system.

Characteristics of the Root

(i) The root is the descending portion of the plant axis and is positively geotropic.

(ii) It is non-green or brown in colour.

(iii) The root is not differentiated into nodes and internodes.



(iv) As a rule, the root does not bear leaves and true buds.

(v) Usually, the root tip is protected by a root cap.

(vi) The root bears unicellular root hairs.

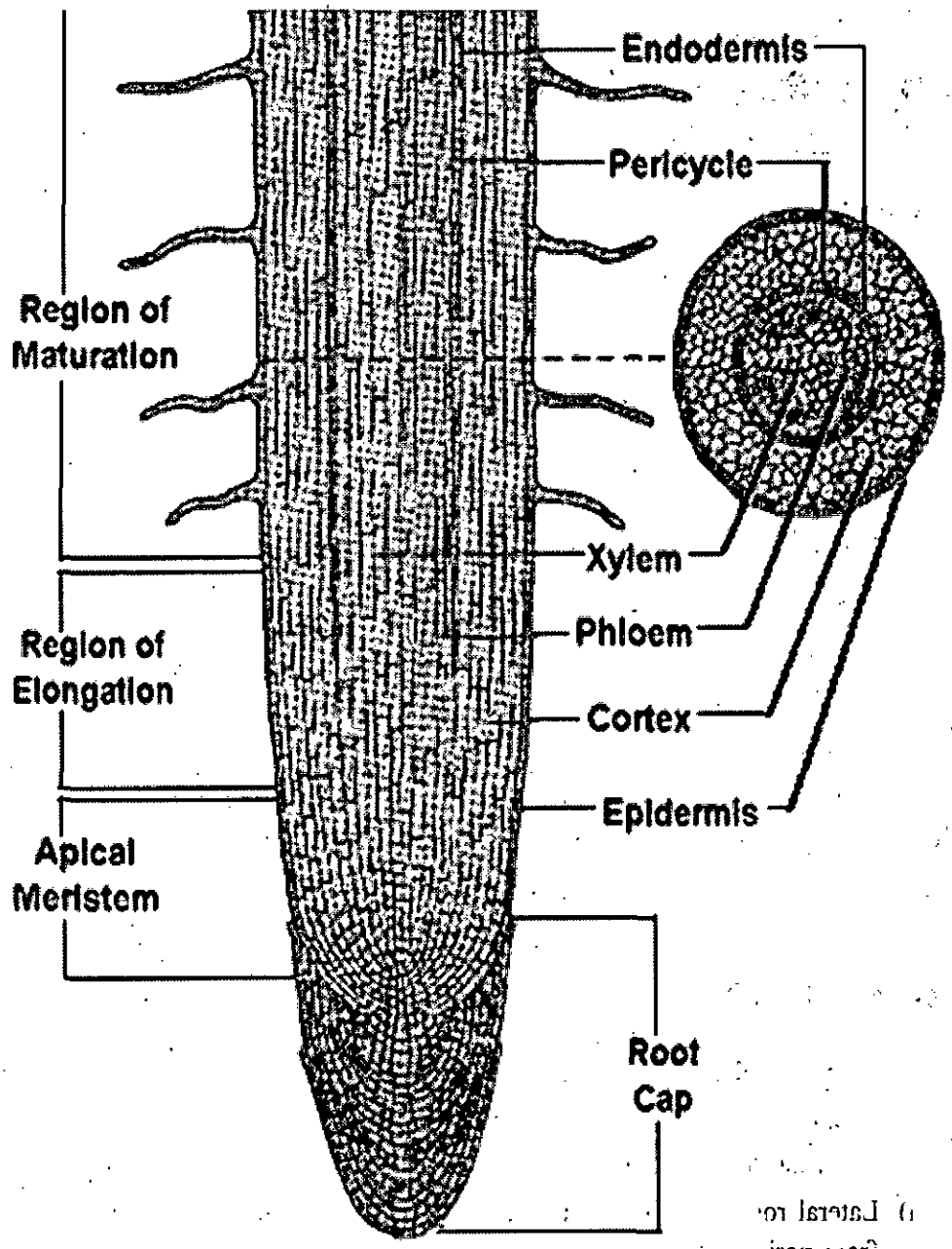
(vii) Lateral roots arise from the root which are endogenous in origin (arises from pericycle).

Parts of the Root

From the tip of the root upwards, the following parts can be traced in root.

(i) **Region of root cap:** The tip of the root is called calyptra or root cap. It is for protection of root tip against any injury. It is formed from meristem called calyptrogen. Pandanus is the only plant with multiple root caps. In the aquatic plants like Pistia, Lemma and Eicchornia instead of root caps, they have root pockets for buoyancy. The root caps are absent in parasites and mycorrhizal roots.

(ii) **Region of cell elongation:** The region of cell division lies partly within and partly beyond the root cap. This is the meristematic region of the root which produces new cells by cell division.



(iii) **Region of Root Hairs:** This region is present above the region of elongation. In this region the epidermal cells produce many tubular, unicellular outgrowths called root hairs. This is also called Piliferous region. Water absorption mostly takes place through this region. The root hairs are absent in many aquatic plants.

(iv) **Region of Maturation**: Above the root hair zone, mature region is present. This region consists of permanent cells. Lateral roots are produced endogenously from the mature region. Conduction of water and mineral salts takes place through this region.

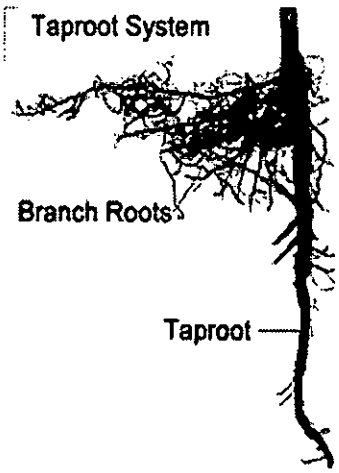
Types of Root System

The root system is generally of two types:

(i) Tap root system

(ii) Adventitious root system

Tap Root System



The tap root system develops from radicle of the germinating seed.

It is also called the normal root system.

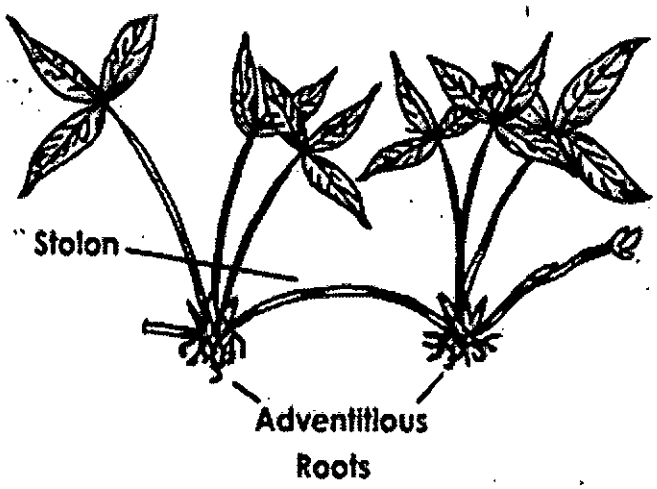
The radicle develops into a primary root which grows vertically downwards and become the tap root.

The tap root is the true root that produces many lateral roots endogenously which grow obliquely.

The tap root system is present in **dicotyledonous plants**.

Adventitious Root System

The root system that develops from any part of the plant body other than the radicle is called the adventitious root system.



- **Anaerobic Respiration:** In this type of respiration, partial oxidation of food takes place and energy is released in the absence of oxygen. This type of respiration occurs in prokaryotic organisms like bacteria and yeast. Ethyl alcohol and carbon dioxide are formed in this process.

Glycolysis

The term glycolysis is derived from two Greek words, i.e. *Glycos* which means sugar and *lysis* means splitting. The scheme of glycolysis was given by Otto Meyerhof, J. Parnas and Gustav. In case of anaerobic respiration, respiration is carried out via glycolysis which occurs in cytoplasm of the cells. In it, partial oxidation of glucose is carried out resulting in two molecules of pyruvic acid. Glucose and fructose are phosphorylated to give rise to glucose-6-phosphate via enzyme hexokinase. This phosphorylated glucose is isomerized to produce fructose-6-phosphate.

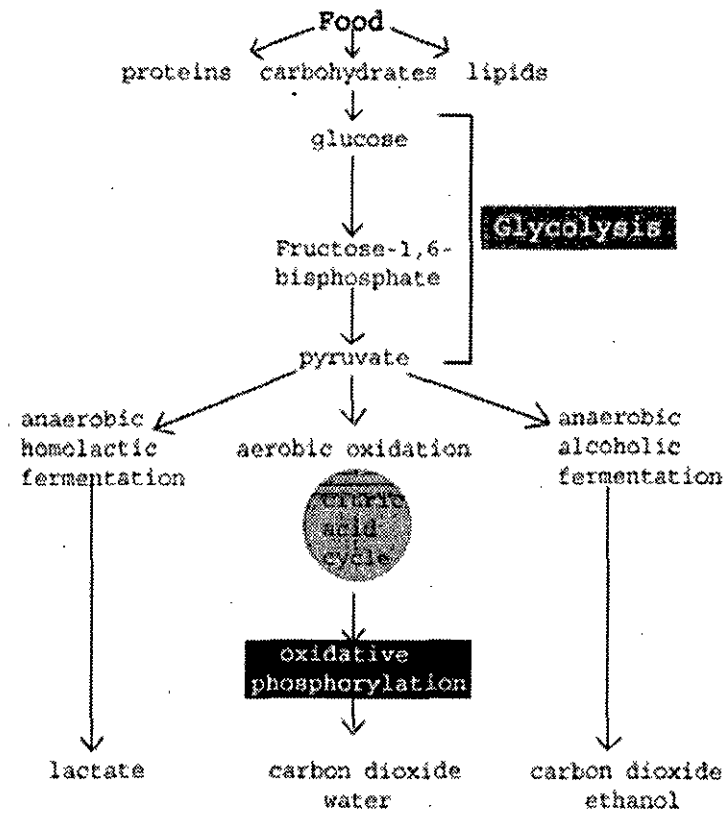
The several steps of Glycolysis are depicted in the figure below. In this process, chain of ten reactions takes place under the control of various enzymes and the outcome is pyruvate. ATP is utilized at two steps:

- During the conversion of glucose into glucose-6-phosphate.
- During the conversion of fructose-6-phosphate in fructose 1 and 6-diphosphate.

The fructose 1, 6 diphosphates is broken into

(i) **Dihydroxyacetone Phosphate** and

(ii) **3-Phosphoglyceraldehyde** (PGAL).



of oxygen. This process is also called as **Glycolysis** which includes breaking down of glucose to **Pyruvic Acid**.

Respiration in Roots

The process of respiration in roots is carried out in the following manner:

- Air occurs in several interspaces of soil. The hairs of the roots are in direct contact with them.
- *Oxygen of the soil gets diffused via root hairs and reaches all internal* cells of the root for respiration.
- Carbon dioxide produced during the diffusion is released in the opposite direction.
- In the condition of water logging, air gets deficient in soil and in this case, metabolic activity of the root's declines.

Respiration in Stems

- The stems of herbaceous plants possess stomata and the air gets diffused via it and reaches the cells for respiration.
- The carbon dioxide produced during the process gets diffused in the air via stomata.
- When the stems are woody, this gaseous exchange is carried out by lenticels.

Respiration in Leaves

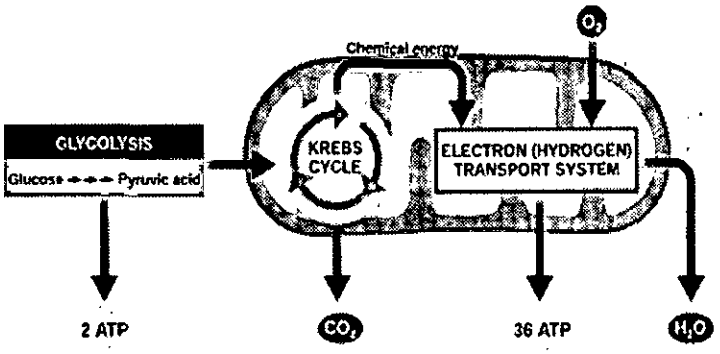
- Leaves of the plants have tiny pores which are referred as stomata. The exchange of gases takes place by the process of diffusion via stomata. The stomata are present in large number on lower surface of leaves of plant. Each stoma is surrounded and controlled by **Guard Cells** (two kidney shaped cells). Then the stoma, open gaseous exchange takes place between **Atmosphere** and **Interior of Leaves**.

Types of Respiration

Respiration is of two types:

- **Aerobic Respiration:** In this type of respiration, the food substances are completely oxidized into H_2O and CO_2 with the release of energy. It requires atmospheric oxygen and all higher organisms respire aerobically. Following figure shows the steps included in **Aerobic Respiration**.

AEROBIC RESPIRATION -- SUMMARY



11 RESPIRATION IN PLANTS

What is Plant Respiration?

"Plant respiration is the chemical reaction by which plants cells stay alive." The process of respiration is expressed as:

Glucose + Oxygen → Carbon Dioxide + Water (+ Energy)

Do Plants Breathe?

The answer to this question is not direct. Yes, plants need oxygen for respiration but at the same time they also give out carbon dioxide. Thus, plants have proper system to ensure the availability of oxygen. Unlike animals, plants do not possess any specialized organs for exchange of gases but they have lenticels and stomata (present in stems and leaves respectively) that carry out the function of gaseous exchange.

Plants do not have any specialized organ to respire and exchange gases because each part of the plant takes care of the need of gases themselves. The parts of the plant do not display any great demand for exchange of gases. Added to this, stems, leaves and roots respire at very lower rate as compared to animals. But during the process of photosynthesis, large exchange of gases takes place and each part of the plant is well adapted to fulfil its need of gases. Availability of oxygen is not a problem during photosynthesis because the cells release oxygen within cells. It is important to note that each living cell in a plant is located quite close to the surface of the plant and in case of stems, the living cells are arranged in the form of thin layers beneath and inside the bark and have openings which are referred as lenticels. Thereby, the respiration and translocation take place at every part of the plant.

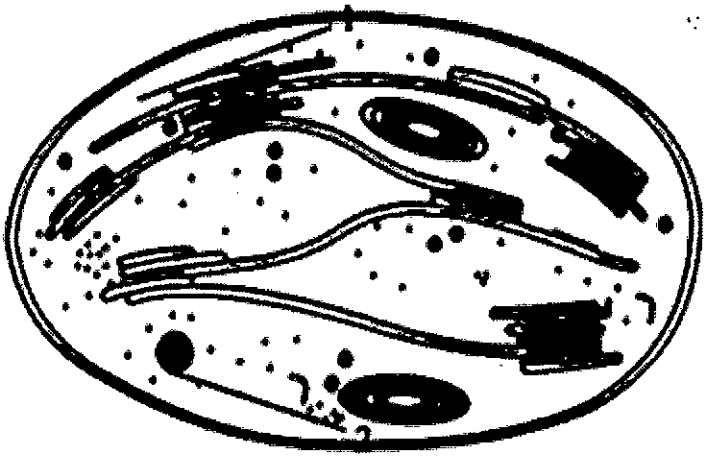
The complete combustion of glucose produces H_2O and CO_2 as end products and release energy in the form of heat. In case, this energy is required by the cell, it will utilize accordingly. Following reaction explains the entire process:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

During the process of respiration, O_2 is utilized and carbon dioxide, energy and water are released as products. There is also a situation when then the oxygen is not available. For instance, the first cell on this planet must have carried out reaction in the absence of oxygen and even in the current living world we are aware of several living organisms adapted to anaerobic conditions. Some of these organisms are facultative and some are obligate. In any of these cases, all living organisms retain enzymatic machinery to partially oxidize glucose in the absence

Review Questions

1. Observe the given figure:



   (a) Is this composition present in a plant cell or animal cell?
   (b) Can it be inherited by the offspring? How?

2. Answer the following questions based on the equation given below:
   $2H_2O\ 2H^+ + O_2 + 4e^-$
   a) Where in plants does this reaction occur?
   b) What is the importance of this reaction?

3. How do photosynthetic bacteria such as Cyanobacteria conduct photosynthesis in the absence of chloroplasts?

4. (a) Where is the enzyme NADP reductase located?
   (b) What does the breakdown of proton gradient cause the release of?

5. Can we perform girdling experiments on monocots? State why if yes or no.

Space for notes

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14. Maximum photosynthesis occurs in
(a) Blue light
(b) Red light
(c) White light
(d) Green light

15. The first acceptor of CO_2 in C_4 plants is
(a) Aspartic acid
(b) Malic acid
(c) Oxaloacetic acid
(d) Phosphoenolpyruvate

16. The first product of C_4 pathway is
(a) PGA
(b) DHAP
(c) Oxaloacetate
(d) Phosphoenolpyruvate

17. The two-pigment system theory of photosynthesis was proposed by
(a) Aron
(b) Blackman
(c) Hill
(d) Emerson

18. H_2 donor during photosynthesis is
(a) ATP
(b) NADP
(c) NADPH
(d) NADH

19. The minerals involved in splitting reaction during photosynthesis is
(a) Potassium and manganese
(b) Magnesium and chlorine
(c) Potassium and chlorine
(d) Manganese and chlorine

20. The water-soluble photosynthetic pigment is
(a) Chlorophyll a
(b) Xanthophyll
(c) Anthocyanin
(d) Chlorophyll b

Answer Key

1. (a)	**2.** (d)	**3.** (d)	**4.** (c)	**5.** (d)
6. (c)	**7.** (b)	**8.** (d)	**9.** (c)	**10.** (a)
11. (a)	**12.** (d)	**13.** (b)	**14.** (b)	**15.** (d)
16. (c)	**17.** (d)	**18.** (c)	**19.** (d)	**20.** (c)

6. Peroxisomes are involved in which type of reactions
   (a) Calvin cycle
   (b) Glyoxylate cycle
   (c) Glycolate cycle
   (d) Bacterial photosynthesis
7. Photorespiration involves oxidation of
   (a) PGA
   (b) RuBP
   (c) Chlorophyll a
   (d) Both a and b
8. C_3 and C_4 plants differ with respect to
   (a) Number of ATP molecules consumed
   (b) First product
   (c) The substrate which accepts carbon dioxide
   (d) All
9. In Calvin cycle, 1 molecule of glucose is formed from
   (a) $6CO_2$ + 30ATP + 12NADPH
   (b) $6CO_2$ + 12ATP
   (c) $6CO_2$ + 18ATP + 12NADPH
   (d) $6CO_2$ + 18ATP + 30NADPH
10. Where does the light reaction takes place?
   (a) Grana
   (b) Stroma
   (c) Cytoplasm
   (d) Endoplasmic reticulum
11. Electrons from the excited chlorophyll molecules of PS-II are first accepted by
   (a) Pheophytin
   (b) Ferredoxin
   (c) Cytochrome f
   (d) Cytochrome b
12. Non-cyclic photophosphorylation results in the production of
   (a) NADH
   (b) NADPH
   (c) ATP
   (d) ATP and NADPH
13. DCMU inhibits
   (a) PS-I
   (b) PS-II
   (c) Oxidative phosphorylation
   (d) It destroys chloroplast

Also Read: Glycolysis

- Each chloroplast contains a green-coloured pigment called chlorophyll. Light energy is absorbed by chlorophyll molecules whereas carbon dioxide and oxygen enter through the tiny pores of stomata located in the epidermis of leaves.
- Another by-product of photosynthesis is sugars such as glucose and fructose.
- These sugars are then sent to the roots, stems, leaves, fruits, flowers and seeds. In other words, these sugars are used by the plants as an energy source, which helps them to grow. These sugar molecules then combine with each other to form more complex carbohydrates like cellulose and starch. The cellulose is considered as the structural material that is used in plant cell walls.

EXERCISE

Multiple Choice Questions

1. Photosynthesis occurs in
   (a) Chloroplast
   (b) Golgi body
   (c) Endoplasmic reticulum
   (d) Nucleus
2. The optimum temperature for photosynthesis is
   (a) 25-35°C
   (b) 10-15°C
   (c) 35-40°C
   (d) 20-25°C
3. Photorespiration occurs in
   (a) Four cell organelles
   (b) Two cell organelles
   (c) One cell organelle
   (d) Three cell organelles
4. Reduction of NADP occurs in
   (a) Oxidative photophosphorylation
   (b) Cyclic photophosphorylation
   (c) Non-cyclic photophosphorylation
   (d) None
5. Kranz anatomy is found in the leaves of
   (a) Wheat
   (b) Mustard
   (c) Potato
   (d) Sugarcane

4. **Oxygen** – Oxygen inhibits photosynthesis in C_3 plants but C_4 plants show little effect. This is so because C_4 plants carry out photorespiration and high oxygen stimulates it. The rate of photosynthesis increases with the reduction of concentration of oxygen.
5. **Water** – It is an essential raw material for the assimilation of carbon. Less than one percent of absorbed water is utilized in photosynthesis. The decrease of water content in soil decreases the rate of photosynthesis as well. This is so because it results in dehydration of protoplasm and also results in stomatal closure. Added to this, it impairs enzymatic efficiency, affects its colloidal state, inhibits respiration, etc.
6. **Mineral elements** – These are also essential for the growth of plants and it includes **Cu, Cl, Mg, Fe, P** and these are closely related with the process of photosynthesis.
7. **Air pollutants** – Metallic and gaseous pollutants reduce photosynthesis. The pollutants include SO_2, oxidants, ozone and hydrogen fluorides.
8. **Chemical compounds** – Although, chemical compounds are present in very less quantity but even the small quantity depresses the rate of photosynthesis. On contrary, increase in the presence of chemical compound results in dying of cells.

Thus, there are several factors that affect the rate of photosynthesis. Other factors include content of chlorophyll, protoplasmic factor, accumulation of carbohydrates, etc.

Summary of the unit

Photosynthesis also applies to other organisms besides green plants. These include several prokaryotes such as cyanobacteria, purple bacteria and green sulphur bacteria. These organisms exhibit photosynthesis just like green plants.

The glucose produced during photosynthesis is then used to fuel various cellular activities. The by-product of this physio-chemical process is oxygen.

$$\text{Carbon dioxide + Water} \xrightarrow{\text{Sunlight}} \text{Glucose + oxygen}$$

A visual representation of the photosynthesis reaction

- Photosynthesis is also used by algae to convert solar energy into chemical energy. Oxygen is liberated as a by-product and light is considered as a major factor to complete the process of photosynthesis.
- Photosynthesis occurs when plants use light energy to convert carbon dioxide and water into glucose and oxygen. Leaves contain microscopic cellular organelles known as chloroplasts.

Photorespiration results in light dependent uptake of O_2 and release of CO_2 and is associated with metabolism and synthesis of small molecule named glycolate. This process simultaneously takes place in green plants along with photosynthesis. Its end result decreases the net amount of CO_2 and both photosynthesis and photorespiration work opposite to each other.

Factors affecting Photorespiration

The rate of photorespiration increases at any time when the level of carbon dioxide is low and oxygen is high. Such condition occurs when stomata remain partially closed or completely closed and photosynthesis is underway.

Majority of time, the stomata of plants are open, resulting in lowering down the rate of photorespiration. But when plants become water stressed, they close stomata to prevent loss of water via transpiration. Thus, on the other hand, restricts the normal exchange of gases. The level of CO_2 gradually rises as water splits during light reaction.

In desert and dry tropical areas, photorespiration is reduced due to water stress and this on the other hand, results in lowering down the potential of plant growth. Some plants have adapted to this problem by modifying the way they carry out photosynthesis. One of the common adaptations is called **C_2 Metabolism** in which plants develop different leaf anatomy called **Kranz Anatomy**.

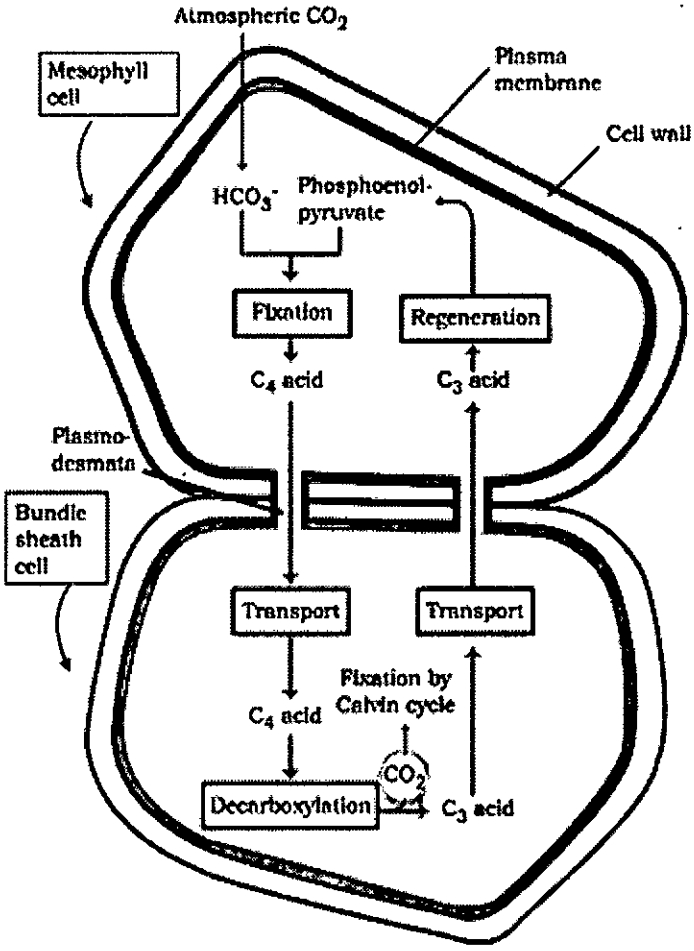
Factors affecting Photosynthesis

There are several factors that affect the rate of photosynthesis. These factors are both internal and external factors:

1. **Temperature** – When carbon dioxide, light and other factors are not limiting, photosynthesis rate increases with the rise in temperature. The most preferred range of temperature is **6° C – 37° C**. High temperature results in inactivation of enzymes and thereby affects enzymatically controlled dark reactions.
2. **Carbon Dioxide Concentration** – It is the major limiting factor and its concentration is very low in atmosphere, i.e. 0.03 – 0.04%. Increase in concentration to 0.05% causes increase in fixation rate of CO_2. Added to this, the C_3 and C_4 plants differently respond to the concentration of carbon dioxide. "The fact that C_3 plants respond to higher CO_2 concentration by showing increased rate of photosynthesis leading to higher productivity has been used for some greenhouse crops like bell pepper and tomatoes." Such plants are allowed to grow in CO_2 enriched environment that leads to higher yields.
3. **Light** – The light varies as per quality, duration and intensity and has significant impact on the rate of photosynthesis. For instance, there is a linear relationship between incident light and CO_2 fixation at low light intensities. Added to this, increase in the incident light beyond point causes breakdown of chlorophyll and decrease in photosynthesis.

This pathway is cyclic in nature. The primary CO_2 acceptor is 3-Carbon Molecule **PEP** (phosphoenol pyruvate) and is present in mesophyll cells. PEPcase or PEP carboxylase is the enzyme that is responsible for this fixation. It is important to note that the mesophyll cells do not have **RuBisCO** enzyme and C_4 acid **OAA** is formed within cells.

After this, 4 - carbon compounds like aspartic acid or malic acid are formed in mesophyll cells which are then transported to bundle sheath cells, where C4 acids are broken down to release **Carbon Dioxide** (CO_2) and three carbon molecules. These 3 Carbon molecules are transported back to mesophyll cells where it gets converted in PEP, thereby completing the cycle. The CO_2 released enters in bundle sheath cells and thereby the Calvin pathway. These bundle sheath cells have surplus of an enzyme called RuBisCO **(Ribulose Biphosphate Carboxylasé – Oxygenase)** and is deficient in PEPcase. Following diagram explains the entire C_4 pathway as discussed above:

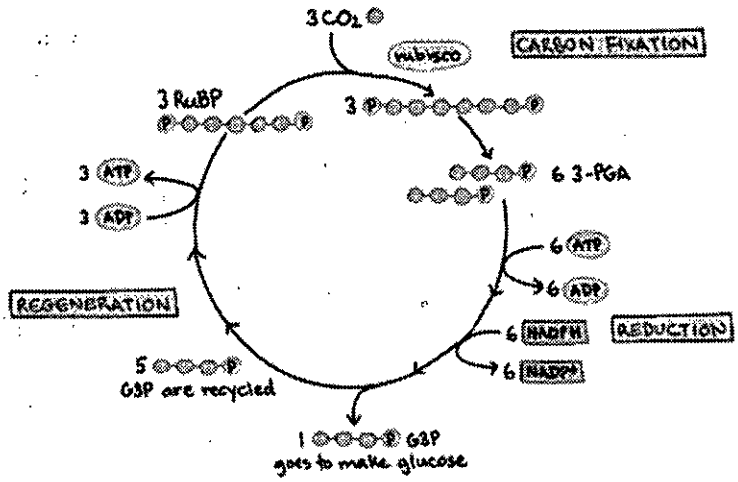


Photorespiration

Definition of Photorespiration

Photorespiration is a biochemical process in plants in which, especially under conditions of water stress, oxygen inhibits the Calvin cycle, the carbon fixation portion of photosynthesis.

Following diagram represents the entire Calvin cycle, as discussed above in detail. The cycle starts with carboxylation, followed by reduction and then, finally regeneration. The last stage includes regeneration of CO_2 acceptor molecule and requires 1 **ATP** for phosphorylation to form RuBP:



Reactions in Calvin Cycle

With reference to the above diagram, the reactions are divided in three different stages:

- **Carbon Fixation** – A CO_2 molecule combines with **5 C** acceptor molecule and **RuBP**. This step makes 6 Carbon compound that splits into 2 molecules of 3 Carbon compound and **3PGA**. The reaction is catalyzed by **RuBP** carboxylase or oxygenase.
- **Reduction** – At the second stage, **ATP** and **NADPH** are converted to **3 PGA** molecules into molecules of a three-carbon sugar and G3P **(glyceraldehyde–3–phosphate)**.
- **Regeneration** – At the final stage, **3GP** molecules go to make glucose while other may be recycled to regenerate **RuBP** acceptor. The process of regeneration requires **ATP** along with complex network of reactions.

For exiting cycle, three CO_2 molecules enter the cycle for exiting **3GP** molecule. This provides three new atoms of fixed carbon. Entering of **3**CO_2 molecules, results in regeneration of 3 molecules of **RuBP** acceptor.

The C4 Pathway

Plants that carry out C_4 pathways comprise of specific enzyme that are located in two different cell types, i.e. **Mesophyll Cells** and **Bundle – Sheath Cells**. This pathway is the method that is used by plants to convert atmospheric carbon dioxide in chemical compound containing four carbons. This pathway is used by the plants in subtropical areas such as Sugar Cane, Maize, Millet, Papyrus and Sorghum. These plants are special and have several type of leaf anatomy, i.e. they can tolerate higher temperature and also show response to high light intensity.

Definition of Biosynthetic Phase

*"**Biosynthetic Phase** is the process by which carbon dioxide is reduced to carbohydrates and the process is termed as carbon fixation; it makes use of the **ATP** and **NADPH** produced in the light phase. This process occurs in the stroma of chloroplasts with the help of series of enzyme-catalysed reactions."*

How ATP and NADPH are used in Biosynthetic Phase?

We are aware of the fact that CO_2 is combined with H_2O to produce sugar. Scientist were very eager to find out how this reaction proceeded and just after **Second World War**, the use of radioisotope **14C** led to the discovery that the first CO_2 fixation product was **3 – Carbon Organic Acid**. **Melvin Calvin** contributed in answering this and therefore, the complete biosynthetic pathway is named as **Calvin Cycle**. The first identified product was **PGA**, i.e. **3 – Phosphoglyeric Acid**.

Scientist also worked hard to understand if all plants have **PGA** as a first product of CO_2 fixation, or some other product is found in plants. In this direction, several experiments were carried out and it resulted in the discovery of another group of plants, where the first stable product was organic acid. This acid was identified as **Oxaloacetic Acid** (OAA). Thus, assimilation of CO_2 during photosynthesis is carried out in two main ways:

- The **C3** pathway
- The **C4** pathway

The Calvin Cycle

In **Calvin Cycle**, Carbon atoms from CO_2 are fixed and are used to form three – **Carbon Sugar**. This process is dependent on **ATP** and **NADPH** formed from light reactions. The light reaction is carried out in thylakoid membrane while the Calvin Cycle takes place in stroma. The Calvin cycle can be described in three stages:

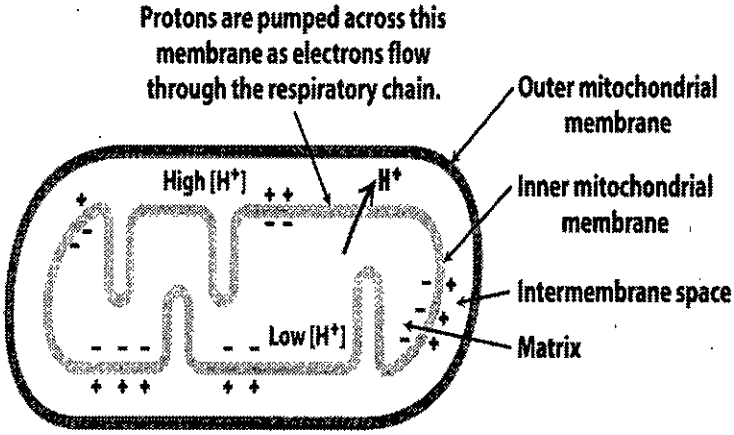
- **Carboxylation** – It is the fixation of CO_2 in stable organic intermediate. It is an important stage in Calvin Cycle where CO_2 is utilized for carboxylation of **RuBP** in the presence of enzyme **RuBP** carboxylase. It results in the formation of 2 molecules of **3-PGA**. **RuBP** carboxylase also helps in oxygenation activity and is therefore also referred as RuBP carboxylase – oxygenase (RuBisCO).
- **Reduction** – This stage includes series of reactions that result in the formation of glucose. This step utilizes 2 molecules of ATP (for phosphorylation)and two molecules of **NADPH** (for reduction per CO_2 molecule). The fixation of 6 molecules of CO_2 and 6 turns of cycle result in the removal of 1 molecule of glucose from pathway.
- **Regeneration** – This stage includes regeneration of CO_2 acceptor molecule and requires 1 **ATP** for phosphorylation to form RuBP.

Chemiosmotic Hypothesis

*"The chemiosmotic hypothesis suggests that the action of **ATP** synthase is coupled with that of a proton gradient. It is the action of the proton gradient that causes a proton motive force that allows **ATP** synthase to phosphorylate **ADP** and inorganic phosphate to **ATP**."*

Peter Mitchell in the year **1961** postulated this hypothesis which explains the mechanism of synthesis of ATP during photosynthesis, in chloroplast. During light reaction or photochemical phase, **ATP** and **NADP** are generated and these are the key components used in dark reaction for production of sugar molecule. According to chemiosmotic hypothesis, **ATP** production is the outcome of photon gradient across the membrane of thylakoids. The essential components required in this process are proton gradient, proton pump and ATP synthase (enzyme that helps ATP synthesis).

Following diagram explains the entire process included in chemiosmotic hypothesis. In this process, protons are pumped across the membrane as electron flows through the respiratory chain:



Importance of Proton Gradient

The **Proton Gradient** is important in this process because it is the breakdown of this gradient result in release of energy. This gradient is broken down due to the movement of proton across membrane via transmembrane channel of $\mathbf{F_0}$ of **ATPase**. This [illegible] comprise of $\mathbf{F_0}$ and $\mathbf{F_1}$, whereby $\mathbf{F_0}$ is embedded in membrane and forms transmembrane channel and protrudes $\mathbf{F_1}$ on outer membrane of thylakoid membrane.

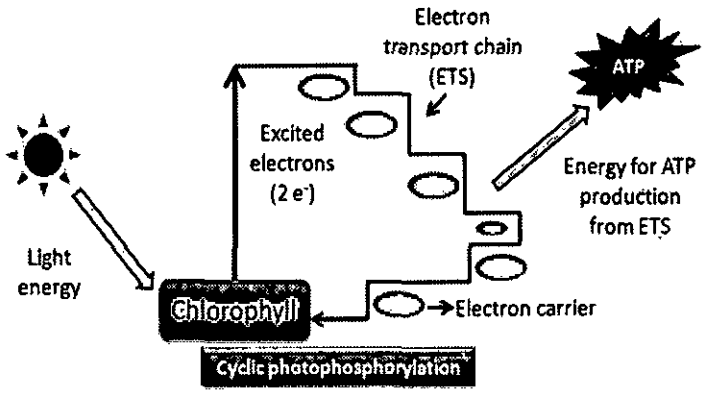
Where are the ATP and NADPH used?

We are aware of the products of light reaction, i.e. **ATP**, **NADPH** and $\mathbf{O_2}$. Amongst these $\mathbf{O_2}$ diffuses out of chloroplast and **ATP** and **NADPH** helps in driving the process leading to food synthesis and forming sugars. It is also referred as biosynthetic phase of photosynthesis and this process does not depend on the presence of light, rather it depends on the product of light reaction. It is carried out in stroma of chloroplast.

Cyclic and Non – Cyclic Photo – Phosphorylation

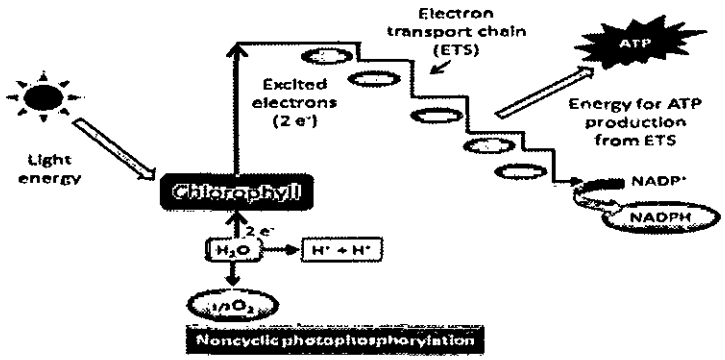
In bacterial photosynthesis, a single PS **(Photo System)** is involved. When an electron is energized by absorption of light, it is ejected from the **PS** reaction center. This electron then passes through an electron transport system and finally back to reaction center. "The energy released during the electron transport is used to produce ATP. Since the excited electron returns to the reaction center, this mechanism of making b is called Cyclic Photophosphorylation."

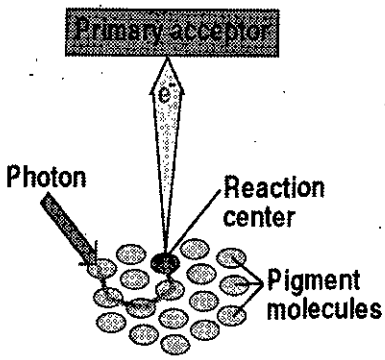
Following diagram shows the above explained process of cyclic photophosphorylation. No reducing power, required for biosynthesis is generated in this process. In this process, the energy released during the electron transport is used to produce **ATP** and the excited electron returns to the reaction center:



Cyanobacteria and **Plants** use two **PS** which simultaneously work to produce energy and reduce power. Primarily, a photon of light ejects a high energy light from **PS II**. This electron travels from excited reaction center of **PS II** down the chain and enters in **PS I**. "*This electron transport system generates a proton motive force that is used to produce **ATP**. Since the excited electron does not return to **PS II**, this mechanism for making ATP is called **Non – Cyclic Photophosphorylation**.*" When **PS I** absorb a photon of light, it releases high energy electron that is used to drive the formation of reducing power in the form of **NADPH**. This ejected electron is replaced by an electron of **PS II**.

The following diagram shows the entire process of noncyclic photophosphorylation as discussed above. In this process the excited electron does not return to **PS II** and therefore, this entire mechanism for making **ATP** is referred as **Non – Cyclic Photophosphorylation**:



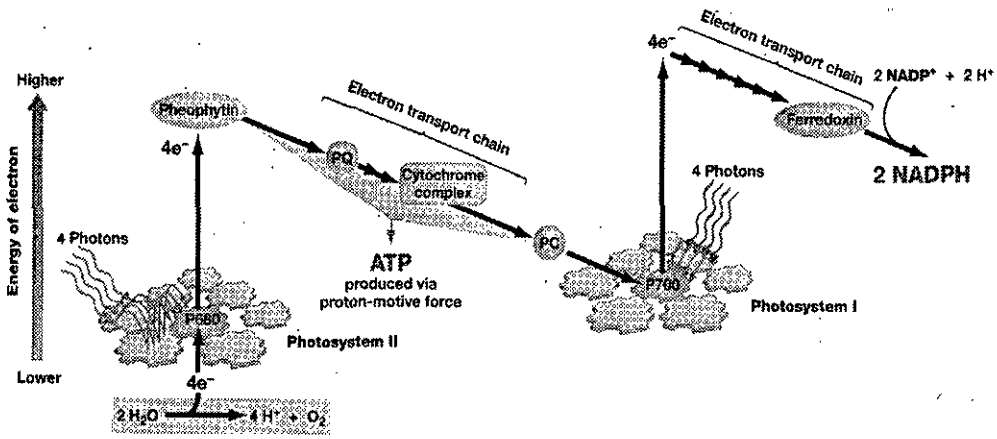


The Electron Transport

In **PS II**, the reaction center chlorophyll *a* absorbs **680 nm** wavelengths of light (Refer the figure below for each step). This result the electrons to be excited and jump in an orbit. These electrons are captured by electron acceptor which passed to electron transport system of cytochromes.

These electrons are not used as they pass through the entire electron transport chain but are passed onto the pigment of **PS I**. At the same time, electrons at **PS I** reaction center are also excited when they receive red light of wavelength **700 nm**. These electrons are transferred to another acceptor molecule with greater redox potential. In this electron transport chain, electrons are not used rather they are passed to the pigments of b. At the same time, electrons present in reaction center of **PS I** also gets excited after receiving red light of wavelength **700 nm**. Then, these electrons are transferred to another acceptor molecule with greater redox potential. These electrons, then move downhill and this time to energy rich molecule i.e. **$NADP^+$**, whose addition reduces **$NADP^+$** to **NADPH + H^+**.

This entire scheme of transfer of electrons starting from **PS II** to uphill then down the electron chain to **PS I**, excitation of electrons, transferring to another acceptor and ultimately downhill to **$NADP^+$** resulting in formation of **NADPH + H^+** is referred as **Z** Scheme. Following diagram shows the entire process of Electron Transport in detail, as discussed above:



- **Cytoplasm** – It is the platform of different chemical processes and is controlled by enzymes.
- **Cell Membrane** – It acts as a barrier and helps in controlling the movement of substances in and out of cell.
- **Chloroplasts** – It contains chlorophyll and green substance that absorb light energy.
- **Vacuole** – It holds moisture and keeps the plant turgid.
- **Nucleus** – It contains **DNA** and controls the activities of cell.

How many pigments are involved in Photosynthesis?

"Pigments are the substances that possess the ability to absorb light at specific wavelength." Leaves of plants have four types of pigments, i.e. **Chlorophyll *a*** (bright or blue green in chromatogram), **Chlorophyll *b*** (yellow green), **Carotenoids** (yellow to yellow – orange) and **Xanthophylls** (yellow). **Photosynthesis** takes place in red and blue regions of spectrum and some photosynthesis also takes place at other wavelengths. Chlorophyll is the major pigment that traps the light energy and other pigments are referred as accessory pigment which traps light and transfer the energy to chlorophyll *a*.

Types of Photosynthetic Reactions

Photosynthetic Reactions are of two types, i.e.

- **Light Dependent Reaction** – In these reactions, the energy from sunlight is absorbed by chlorophyll and transformed into chemical energy in the form of **ATP** and **NADPH** (electron carrier molecule).
- **Light Independent Reaction** – This reaction is also referred as **Calvin Cycle**. In this reaction, the energized electron from light dependent reactions provides energy to form carbohydrates from CO_2 molecules.

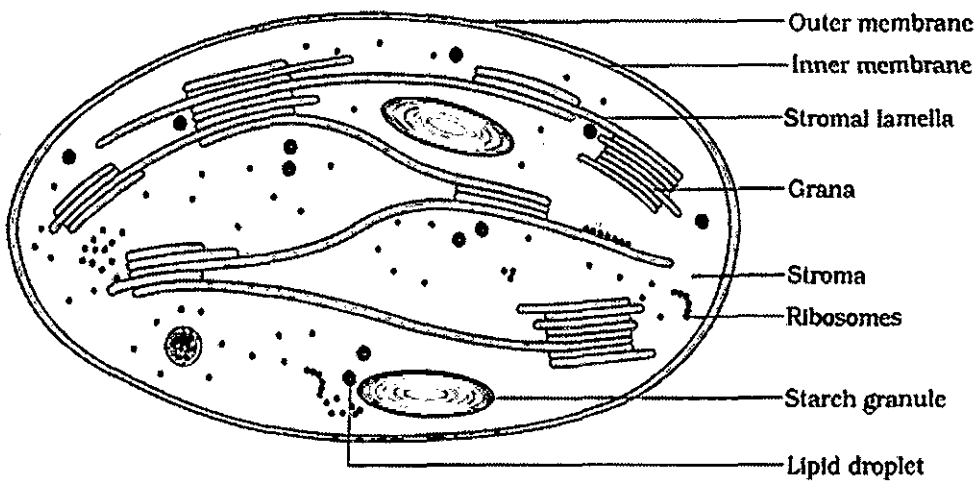
What is Light Reaction?

Light Reaction is also called **Photochemical Phase**. It includes absorption of light, splitting of water, oxygen release followed by release of high energy chemical intermediates, **NADPH** and **ATP**. The pigments in light reaction are organized in light harvesting complexes **(LHC)** within **PSI** and **PSII** (Photosystem 1 and Photosystem 2). Both these photo chemicals are named in the sequence of discovery. **LHC** is formed from hundreds of pigment molecules bound to proteins (except chlorophyll a) forming a light harvest system called **Antennae**. These pigments make the process of photosynthesis more efficient. The single molecule of chlorophyll a form the **Reaction Center** and this center are different in both photosystems first and second. The following diagram shows the light harvesting complex:

the entire process requires input of energy. Photosynthesis is also classified as oxidation – reduction reaction as it includes loss of electrons by water and gain of electrons by carbon dioxide.

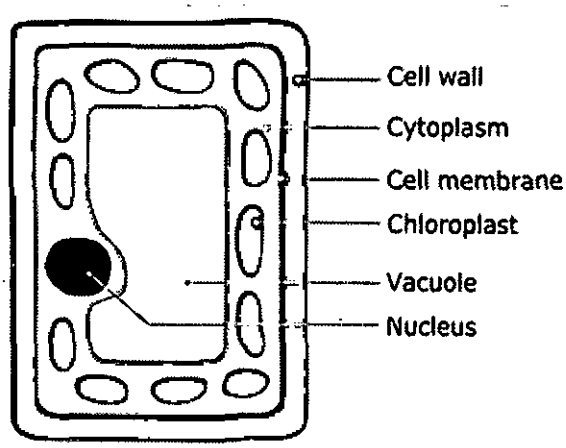
The process of photosynthesis takes place in **Mesophyll Cells** and the carbon dioxide required by the process enters the process via stomata, i.e. the small holes present on the outer layer of leaves. The water required for the process is transported via roots through the vascular tissues.

The chloroplast contains membranous system (shown in image below) consisting of the stroma lamellae, grana and the fluid stroma. The membrane system traps the light energy and helps in synthesizing **ATP** and **NADPH**. Following diagram shows the electron micrograph of a section of chloroplast:



Structure of Mesophyll Cells

Following figure shows the structure of **Mesophyll Cells**. It includes outer cell wall, cell membrane, cytoplasm, chloroplast, vacuole and nucleus.



Role of different Part of Mesophyll Cells:

- **Cell Wall** – It provides mechanical and structural support, determine and maintain the shape of cell, protect cells against pathogens and control the direction of growth.

Using the similar set up used by **Priestly, Jan Ingenhousz** (1730 – 1799) carried out an experiment to show the importance of sunlight to plants, which somehow purifies the air fouled by breathing animals or burning candles. He took aquatic plants into observation and showed that in the presence of bright sunlight, small bubbles were formed around the green parts, while there were not bubbles during night. Later, he concluded that the bubbles were of oxygen and only the green parts are able to release oxygen.

In the year 1854, **Julius Von Sachs** provided evidence of the production of glucose during the growth of plants. This glucose is stored as starch and later, he concluded that the green substances are located in special bodies within plant cells. He also concluded that glucose is made in the green part of the plant and is stored as **Starch**.

T.W. Engelmann (1843 – 1909) also carried out an interesting experiment. He used prism and split the light in several components and illuminated green algae, called **Cladophora**, placed in the suspension of aerobic bacteria. These bacteria helped in detecting the site of evolution of oxygen. During the experiment, he observed that the bacteria accumulated mainly in the region of red and blue light of the split spectrum. This was the first time when photosynthesis was described and it resembled the absorption of spectra of chlorophyll.

By the middle **19th century**, the were features about the photosynthesis were known and following empirical equation was introduced that represented the entire process of photosynthesis:

$$CO_2 + H_2O \xrightarrow{\text{Light}} [CH_2O] + O_2$$

Then, **Cornelius van Niel** (1897 – 1985) added that photosynthesis is a light dependent reaction in which hydrogen form an oxidisable compound and reduces carbon dioxide to carbohydrates. The entire reaction is represented as follows:

$$2H_2A + CO_2 \xrightarrow{\text{Light}} 2A + CH_2O + H_2O$$

He also concluded that O_2 evolved from green plants comes from H_2O and not from CO_2. This was later proved via radio isotopic techniques. The correct equation that represented the entire photosynthesis process is:

$$6CO_2 + 12H_2O \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

Where, $C_6H_{12}O_6$ is glucose and O_2 is released from water.

Where Photosynthesis does takes place?

Photosynthesis includes series of chemical reactions which are carried out in chloroplast, i.e. The specialized structures found on cells of plants. In these series of reaction, water and carbon dioxide are converted into glucose and in this reaction energy from sunlight is used. Because, it is an endothermic reaction,

10 PHOTOSYNTHESIS

Definition of Photosynthesis

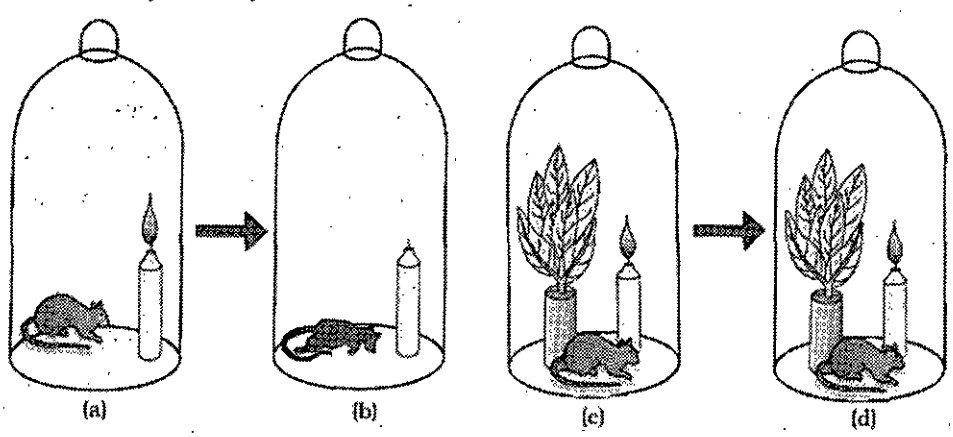
"**Photosynthesis** is a process used by plants in which energy from sunlight is used to convert carbon dioxide and water into molecules needed for growth. These molecules include sugars, enzymes and chlorophyll. Light energy is absorbed by the green chemical chlorophyll."

All animals and human beings are dependent on plants for food and these plants synthesize the food via physio – chemical process called **Photosynthesis**. This process is important because:

- It is the primary source of food.
- It results in the release of oxygen in atmosphere.

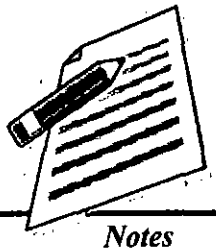
Early experiment for Photosynthesis

In the year 1770, **Joseph Priestly** performed several experiments that revealed the role of air in growth of green plants. Following figure shows the experiment carried out by Priestly:



Priestly observed that the candle burning in closed space, i.e., a bell jar, extinguishes after some time. As shown in **figure (a)** and **(b)** mouse is also fainted after some time. This concluded that both candle and mouse require air, but somehow damaged it. But when the mint plant was placed in the jar, **(c)** and **(d)** the candle was burning after some time and mouse also stayed alive. After this experiment, Priestly hypothesized that:

"Plants restore to the air whatever breathing animals and burning candles remove."



(c) Magnesium
(d) Sodium

8. Deficiency of _____ causes the leaves to develop a dark green colouration.
   (a) Phosphorous
   (b) Potassium
   (c) Sodium
   (d) None of the above
9. Deficiency of _____ causes chlorosis in older leaves
   (a) Calcium
   (b) Magnesium
   (c) Sodium
   (d) Nitrogen
10. A "wild type" organism that does not need any additional growth supplement is known as
   (a) Phenotype
   (b) Auxotroph
   (c) Autotroph
   (d) Prototroph

Answer

1. (d)	**2.** (a)	**3.** (c)	**4.** (d)	**5.** (b)
6. (c)	**7.** (d)	**8.** (a)	**9.** (b)	**10.** (d)

Review Questions

1. Give the name of a plant that accumulates silicon.
2. How do entities in a mutualistic association benefit from each other as seen in mycorrhiza?
3. Why is nitrogen fixation observed in prokaryotes and not eukaryotes?
4. Name the nutrients obtained by carnivores such as venus flytrap and Nepenthes. Where do they obtain them from?
5. Name a plant that lacks chlorophyll. How does it fulfil its nutritional requirements? Give an example.
6. Write the name of an insectivorous angiosperm.
7. Name the mineral element that is restored with the addition of Azotobacter culture to the soil.
8. In the root nodule of a legume, what are the conditions posed by a leghaemoglobin?
9. In the context of the mode of nutrition, what do the following share in common? Nepenthes, Drosera, Utricularia

Space for Notes

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the form of ATP. N_2 -fixation is accomplished with the help of nitrogen fixing microbes, mainly Rhizobium. The enzyme nitrogenase which plays an important role in biological N_2 fixation is very sensitive to oxygen. Most of the processes take place in anaerobic environment. The energy, ATP, required is provided by the respiration of the host cells. Ammonia produced following N_2 fixation is incorporated into amino acids as the amino group.

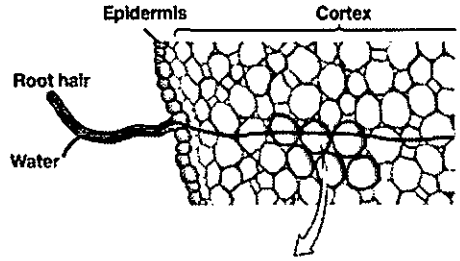
EXERCISE

Multiple Choice Questions

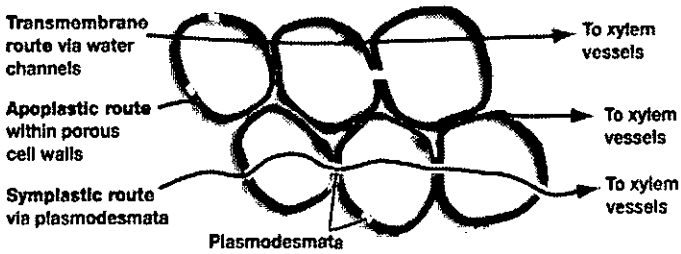
1. _____ are the elements, without which, the plants will not be able to complete its life cycle.
   (a) Fertilizers
   (b) Microelements
   (c) Microelements
   (d) Essential elements
2. One of the following is not a criterion for an element to be termed as "essential"
   (a) The element is not required for growth and development
   (b) The function of a particular element cannot be replaced with another
   (c) The element should be used in plant metabolism
   (d) None of the above
3. The idea that plants need essential minerals was first proposed by
   (a) Aristotle
   (b) Bernand Simpson
   (c) Arnon and Stout
   (d) Von Haier
4. _____ is a technique where the plants are grown with their roots suspended in the air.
   (a) Osmosis
   (b) Aerophytes
   (c) Aerosolization
   (d) Aeroponics
5. _____ is an important mineral nutrient
   (a) Hydrogen
   (b) Nitrogen
   (c) Oxygen
   (d) Carbon
6. _____ is not a trace element
   (a) Sodium
   (b) Boron
   (c) Carbon
   (d) Zinc
7. _____ is a trace element
   (a) Phosphorous
   (b) Carbon

initial phase, the passive uptake of ions takes place in outer space or free space of cells - **Apoplast**. In the latter phase of uptake, ions are slowly absorbed in inner space referred as the symplast of the cells. The passive movement of ions into the apoplast is carried out via ion – channels, the trans-membrane proteins that act as selective pores. Added to this, the entry and exit of ions to and from symplast need metabolic energy and thus, it is an active process. This movement of ions is referred as **Flux**, whereby inward movement into the cells is influx and vice versa, i.e., outward movement is **Efflux**.

Following diagram shows the mechanism of absorption in plants. For instance, water travels with the help of root hairs to xylem via three routes, i.e. transmembrane route, apoplastic route and symplastic route.

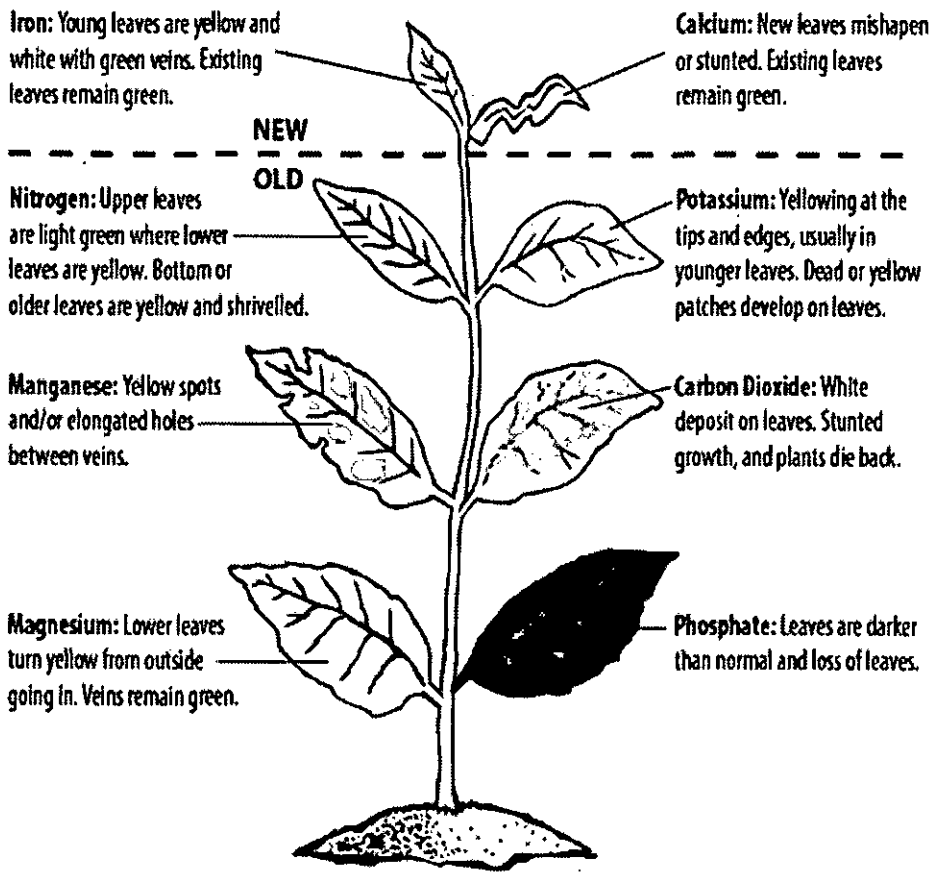


(a) Water travels from root hairs to xylem via three routes.



Summary of the chapter

Plants obtain their inorganic nutrients from air, water and soil. Plants absorb a wide variety of mineral elements. Not all the mineral elements that they absorb are required by plants. Out of the more than 105 elements discovered so far, less than 21 are essential and beneficial for normal plant growth and development. The elements required in large quantities are called macronutrients while those required in less quantities or in trace are termed as micronutrients. These elements are either essential constituents of proteins, carbohydrates, fats, nucleic acid etc., and/or take part in various metabolic processes. Deficiency of each of these essential elements may lead to symptoms called deficiency symptoms. Chlorosis, necrosis, stunted growth, impaired cell division, etc., are some prominent deficiency symptoms. Plants absorb minerals through roots by either passive or active processes. They are carried to all parts of the organism through xylem along with water transport. Nitrogen is very essential for the sustenance of life. Plants cannot use atmospheric nitrogen directly. But some of the plants in association with N_2 -fixing bacteria, especially roots of legumes, can fix this atmospheric nitrogen into biologically usable forms. Nitrogen fixation requires a strong reducing agent and energy in



Example of Deficiency – The **Deficiency Symptom** of Magnesium, Potassium and Nitrogen are visible in senescent leaves.

Toxicity of Micronutrients

The micronutrients are the nutrients that are required in very less amounts and therefore, even their little deficiency results in deficiency symptoms. On the other hand, even the moderate increase of nutrient causes toxicity. Thus, it can be said that plants have the optimum requirement of nutrition. The symptoms of toxicity are difficult to identify because level of toxicity varies from plants to plants. There are several cases where an excess of an element may prevent the uptake of another element. For instance, in case of toxicity of manganese, the plants show prominent symptom, i.e. appearance of brown spots all over chlorotic vein. It, on the other hand, inhibits translocation of calcium in the apex of shoots. Moreover, Manganese competes with magnesium and iron for uptake and with magnesium for binding with enzymes. Thus, the toxicity of manganese results in Deficiency Symptoms of Magnesium, Calcium and Iron.

Mechanism of Absorption of Elements

The studies for understanding the Mechanism of Absorption of Elements in plants are carried on isolated organs of it like tissues and cells. According to these studies, two main phases are included in the absorption of elements. In the

- **Copper** – Copper is absorbed in the form of cupric ions (Cu^{2+}) and is important for the overall metabolism of plant. Copper is associated with the enzymes involved in redox reactions as iron and is irreversibly oxidized from Cu^{+} to Cu^{2+}. More than half of the copper is present in chloroplast and plays an integral role in photosynthesis. Absence of copper results in dieback of shoots.
- **Boron** – Boron is absorbed as BO_3^{3-} or $B_4O_7^{2-}$ and is required for uptake and utilization of Ca^{2+}, pollen germination, functioning of membrane, cell differentiation, cell elongation and translocation of carbohydrate. In case of deficiency of Boron, terminal buds are damaged, resulting in rosette effect on leaves. Fruits, roots and tubers are discoloured, cracked and flecked with brown spots.
- **Molybdenum** – Molybdenum is obtained as molybdate ions (MoO_2^{2+}). It is a component of various enzymes like nitrogenase and nitrogen reductase, enzymes which participate in the metabolism of nitrogen. Absence of molybdenum results in pale green leaves with cupped or rolled margins.
- **Chlorine** – Chlorine is absorbed in the form of chloride ions (Cl^{-}) and adding with Na^{+} and K^{+} it helps in determining solute concentration and anion – cation balance in cells. Chlorine is important in water splitting reaction in photosynthesis and as a result of this; it leads the evolution of oxygen. Absence of chlorine results in reduced growth, interveinal chlorosis, reduced growth and no succulent tissue.

Deficiency Symptoms of Essential Elements

Each nutrient has an important role to play and perform specific functional or structural function. In the absence of those nutrients, plants show several morphological changes. These changes are indicative of certain deficiencies of an element is called **Deficiency Symptom**.

These Symptoms vary from plant to plant and disappear as soon as the deficiency is recovered. It is important to note that if the deficiencies occur continuously, it may result in death of the plant.

The symptom of deficiency also depends on mobility of the element in plant. For instance, if the elements that are actively mobilized and exported to younger developed tissues, the deficiency symptom tends to appear first in older tissues. On the other hand, in case the element is immobile, the deficiency symptoms are visible in younger leaves at the initial stage.

Following image shows the deficiency symptoms of different nutritional elements. For instance, deficiency of iron results in yellowing of leaves and white with green veins and deficiency of calcium results in stunted growth of new leaves, etc.

- **Calcium** – The calcium ions (Ca^{2+}) are also absorbed from soil and are required by differentiating and meristematic tissues. Calcium improves the penetration of water and root via soil and helps in maintaining the stability of soil particles. During the cell division, calcium is used in the formation of wall of cells in the form of calcium pectate in middle lamella. Calcium is used and is involved in normal functioning of cell membranes during the formation of mitotic spindle. It regulates several metabolic activities and activates certain enzymes as well. In case of deficiency of calcium ions, the growth of the bud is inhibited, followed by cupping of mature leaves and weak growth.
- **Magnesium** – Magnesium is absorbed in the form of divalent Mg^{2+}. It is responsible for activating the enzymes of photosynthesis, respiration and is involved in synthesis of nucleic acid (RNA and DNA). Magnesium is important constituent of ring structure of chlorophyll and helps in regulating metabolic activities. It also helps in the formation of fruits and nuts and in germination of seeds as well. Deficiency of magnesium results in extensive interveinal chlorosis that initiates with basal leaves and progresses to younger leaves.
- **Sulphur** – Sulphur is obtained by plants in the form of sulphate ion SO_4^{2-}. It is present in two amino acids and is the main constituent of several coenzymes like methionine and cysteine. Sulphur is also taken by leaves in gaseous form SO_2. Deficiency of sulphur results in general chlorosis of leaves, including vascular bundles.
- **Iron** – Iron is obtained in the form of ferric ions (Fe^{3+}) and plenty of ferric ions are required by plants as compared to other micronutrients. It is an important constituent of protein which is involved in transference of electrons such as cytochromes and ferredoxin. It is reversibly oxidized from Fe^{2+} to Fe^{3+} during the transfer of electron, activates catalase enzyme and is important for the formation of chlorophyll. Deficiency symptoms are larger amount of interveinal chlorosis, starting with younger leaves.
- **Manganese** – Manganese is absorbed in the form of manganous ions Mn^{2+} and helps in activating enzymes required in respiration, nitrogen metabolism and photosynthesis. Its main role is in splitting of water to release oxygen during the process of photosynthesis. The deficiency of this nutrient results in disorganization of chloroplast thylakoid membrane.
- **Zinc** – Zinc is obtained as Zn^{2+} ions and activates enzymes like carboxylase. Zinc is important in the synthesis of auxin and absence or deficiency of zinc results in interveinal chlorosis of upper leaves. Absence of zinc results in slowing down of shoot, resulting in rosette like appearance of plants.

- Essential elements are the components of biomolecules and structural elements of cell. It includes Hydrogen, Carbon, Oxygen and Nitrogen.
- Essential elements that are related with the component of energy, such as **Magnesium** in **Chlorophyll** and **Phosphorus** in ATP.
- Essential elements that activate or inhibit enzymes such as **Carboxylase:** Oxygenase and Phosphoenol Pyruvate Carboxylase. These enzymes are important in the fixation of photosynthetic carbon.
- Essential element with the capability to change the osmotic potential of cells. **For Example:** Potassium plays an integral role in opening and closing of stomata.

Role of Macro and Micro Nutrients

Every element participates in one or the other metabolic processes in the cells of plants and therefore, carries out several functions. The role of different **Macro** and **Micro Nutrients** are explained below:

- **Nitrogen** – It is one of the very important nutrients required in greatest amount by the plants. It exists in soil in an organic form and is absorbed as No_3^- and some are taken as No_2^- or NH_4^+. Nitrogen is important for all parts of plants such as metabolically active cells and meristematic tissues. It is the major constituent of hormones, vitamins, nucleic acids and proteins. It increases the size of the leaves, promotes rapid growth along with fruit and seed development and hastens the maturity of the crop. In case of deficiency of nitrogen, plants show reduced growth, chlorosis, purples and red may intensify and reduced lateral breaks.
- **Phosphorus** – Phosphorus is absorbed by plants in the form of phosphate ions, i.e., HPO_4^{2-} or $H_2PO_4^-$. Phosphorus is one of the constituents of certain proteins, all nucleic acid, cell membranes and nucleotides. Phosphorous is required in phosphorylation reactions and is easily redistributed in several organs of plants. It activates coenzymes for the production of amino acid used in the synthesis of protein; and is important in metabolic processes as well. In case of deficiency of phosphorus, the plant shows stunted growth, reddish purple tips and margins of leaves, dark green leaves with leathery texture and maturity is delayed.
- **Potassium** – Plenty of potassium is required in meristematic tissues, root tips, leaves and buds. It is absorbed as (K^+) potassium ion and helps in maintaining anion – cation balance in leaves. Potassium is involved in opening and closing of stomata, protein synthesis, maintenance of turgidity of cells, facilitates cell division and growth and activation of enzymes. In case of deficiency of potassium, the plants remain smaller and shows brown margin on its leaves.

Criteria of Essentiality

Following is the Criteria for Element Essentiality for plants:

- An element must be absolutely important for the normal growth of plant and reproduction. In absence of those elements, plant will not be able to set seeds or complete their life cycle.
- The requirement of an element must be specific in nature. It implies that an element cannot be replaced by another. Thus, in case of deficiency of one element, supplying another element does not fulfil the requirement.
- The element must directly participate in metabolism.

Based on this Criteria Elements are Categorized in two heads:

- **Macronutrients** – These nutrients are present in large amount in the tissues of the plant. It includes Oxygen, Hydrogen, Nitrogen, Carbon, Phosphorus, Sulphur, Potassium, Magnesium and Calcium.
- **Micronutrients** – These are also called **Trace Elements** as these are required in very small amount. It includes Manganese, Iron, Zinc, Copper, Chloride, Nickel and Molybdenum.

Following chart shows the detailed list of **Macro** and **Micro Nutrients**:

Essential Elements for Plant Growth	
Macronutrients	**Micronutrients**
Carbon(C)	Iron (Fe)
Hydrogen(H)	Manganese (Mn)
Oxygen(O)	Boron(B)
Nitrogen(N)	Molybdenum (Mo)
Phosphorus(P)	Copper (Cu)
Potassium(K)	Zinc (Zn)
Calcium (Ca)	Chlorine (Cl)
Magnesium (Mg)	Nickel (Ni)
Sulphur(S)	Cobalt (Co)
	Sodium (S)
	Silicon (Si)

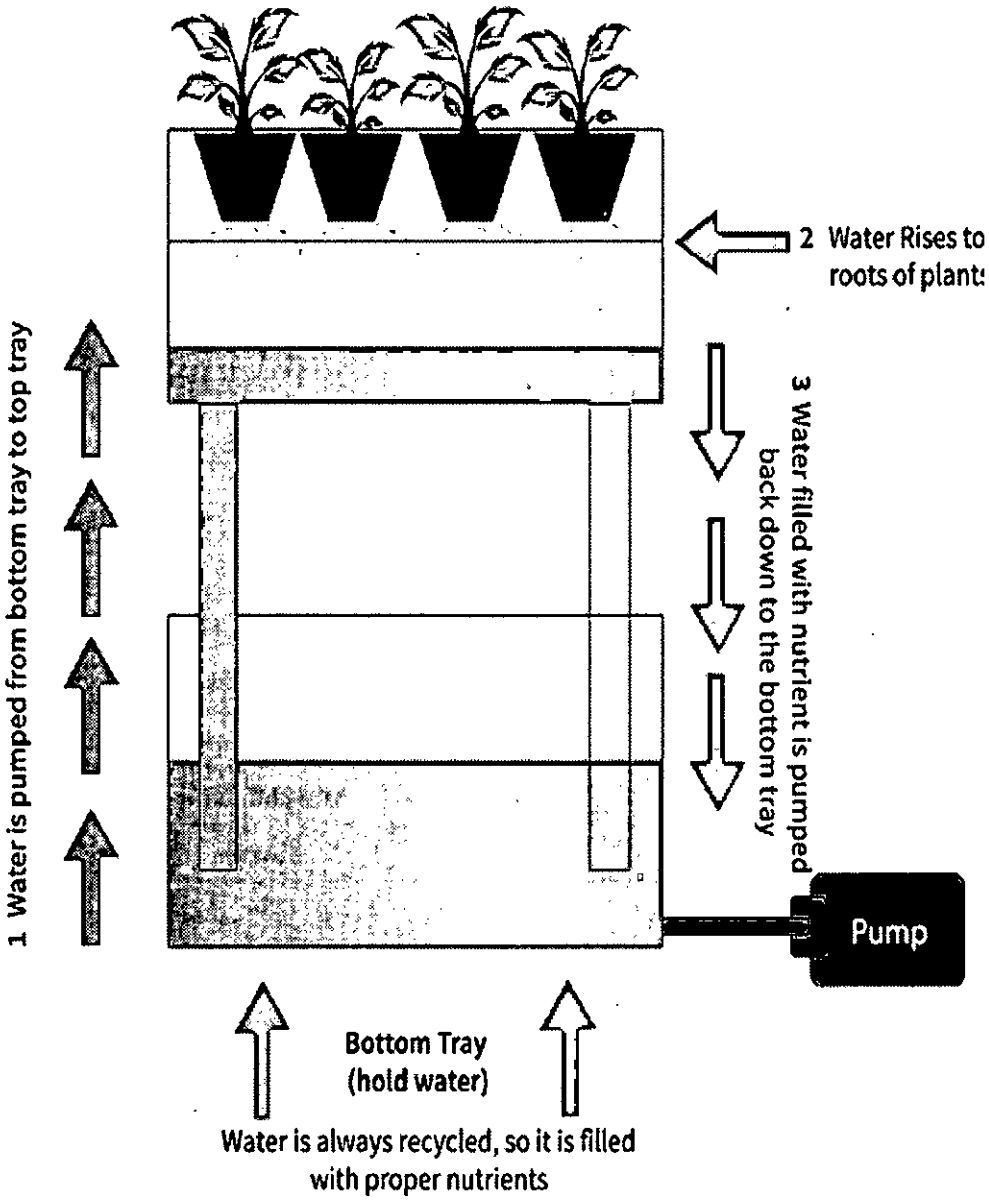
Categorization of Mineral Nutrients on the basis of their Diverse Functions

The Mineral Nutrients are categorized under four heads, on the basis of their diverse functions, which are as follows:

Some of the advantages of this technique are:

- It enables the plants to be grown anywhere.
- It helps in controlling the growth of plants.
- Nutrients and water are conserved in this process.

Following diagram demonstrates that entire process of hydroponics. In this process, water is recycled in order to fill the required nutrients. This process is a repetitive process and allows good growth to plants.



The nutritional elements are present in the soil in ionic form and are absorbed via roots. Soil consists of more than 60 elements out of 105 elements discovered in different plants. These elements may occur in the soil in the form of some aqueous solution, or are adsorbed on inorganic and organic soil colloids, or in the form of insoluble inorganic compound or as a constituent of organic compound.

9 NUTRITION IN PLANTS- MINERAL NUTRITION

Absorption, utilization and assimilation of inorganic compound or minerals by plants for synthesis of essential material for their growth, development, structure and physiology is called **Mineral Nutrition**. The inorganic materials obtained from soil which are used as raw material by plants is called **Mineral Nutrients**.

In other words, all living organisms have common basic needs as all of them need macromolecules i.e., Fats, Proteins, Carbohydrates, Water and Minerals for proper growth and development.

What is Nutrition?

The supply and absorption of specific chemical compounds needed for normal growth and metabolism of plants is defined as **Nutrition**.

What are Nutrients?

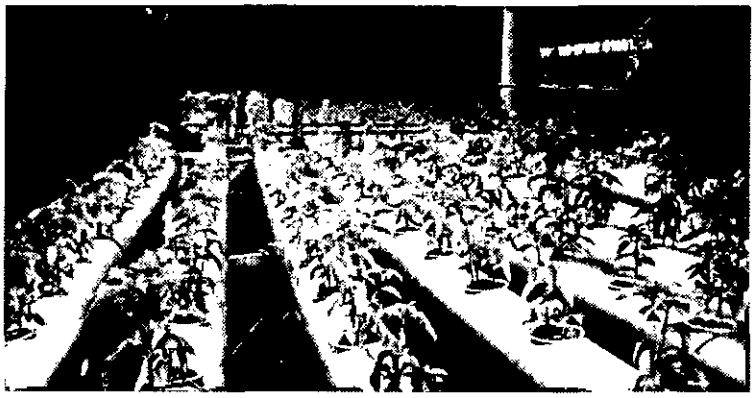
The chemical compounds that function as raw material for synthesis of different structural and functional substance of plants are termed nutrients.

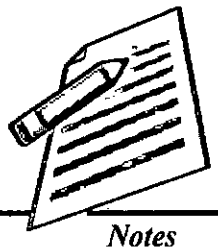
Methods to study the Mineral Requirement of Plants

With the rapid growth of population, it is important to adopt the reliable ways in order to meet the increasing need of food. One such technique is referred as **Hydroponics**.

Hydroponics

In the year 1860, a prominent German Botanist, Julius Von Sachs, explained that fact that "plants can be grown to maturity in a defined nutrient solution in complete absence of soil. Hydroponics is a technique of growing plants without soil in water containing dissolved nutrients." By this method, the scientists were able to identify essential elements and nutrients required by plants along with their symptoms. Following image shows the **Organic Hydroponics** in real life:





8. Nearly 90% of the flowering plants have _____
   (a) Spores
   (b) Mycorrhizae
   (c) Naked seeds
   (d) None of the above
9. The movement of materials from the leaves to other tissues of the plant is called _____
   (a) Tropic movement
   (b) Guttation
   (c) Transpiration
   (d) Translocation
10. The exudation of xylem sap drops on the edges of leaves is called
   (a) Transpiration
   (b) Guttation
   (c) Condensation
   (d) None of the above

Answer

1. (a)	**2.** (a)	**3.** (b)	**4.** (d)	**5.** (c)
6. (c)	**7.** (d)	**8.** (b)	**9.** (d)	**10.** (b)

Review Questions

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?

Space for notes

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EXERCISE

Multiple Choice Questions

1. The rate of transpiration will _____ if the atmospheric pressure is low
   (a) Increase
   (b) Decrease
   (c) Stay unchanged
   (d) Can't be determined
2. The main function of guard cells is to help with _____
   (a) Transpiration
   (b) Guttation
   (c) Transcription
   (d) None of the above
3. Transpiration is regulated by the movements of _____
   (a) Parenchyma cells
   (b) Guard cells
   (c) Epithelial cells
   (d) None of the above
4. The steroid hormones easily pass through the plasma membrane through simple diffusion because they are _____
   (a) Gaseous
   (b) Carbon-based
   (c) Water Soluble
   (d) Lipid Soluble
5. Living cells placed in an isotonic solution tend to retain their shape and size. This is based on the principle of
   (a) Diffusion
   (b) Transpiration
   (c) Osmosis
   (d) None of the above
6. Girdling around the trunk of a tree can cause it to _____ if it cannot regrow to bridge the wound
   (a) Stop absorbing water
   (b) Stop growing
   (c) Die
   (d) None of the above
7. Transport of food materials in higher plants occurs through
   (a) Flowers
   (b) Companion cells
   (c) Tracheids
   (d) Sieve elements

Summary of the unit

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.

of leaf. This gradient is transmitted in photosynthetic cell and also on water – filled xylem in the leaf vein.

Uptake and Transport of Mineral Nutrients

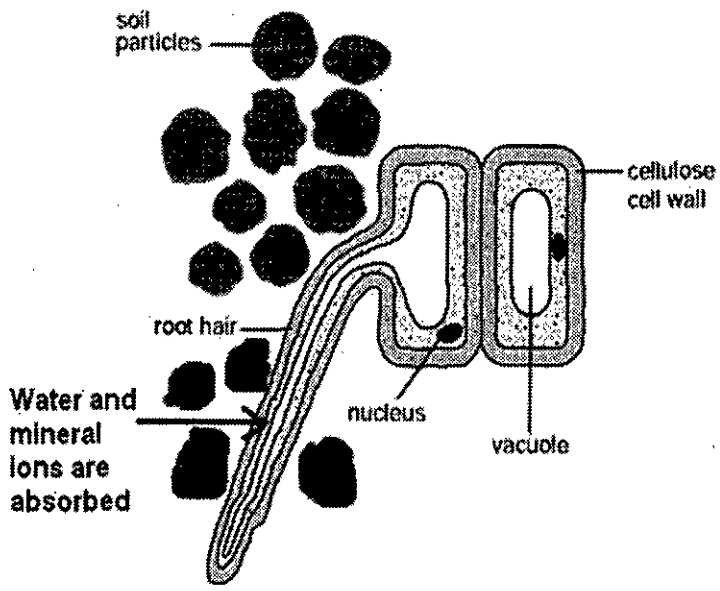
In plants, carbon and oxygen is obtained primarily from carbon dioxide and rest nutritional requirements are fulfilled from absorbing nutrients from soil.

Uptake of Mineral Ions – Like water, all the minerals cannot be absorbed by roots. The uptake of mineral ions depends on two conditions:

- The minerals are present in soil in the form of charged ion. These ions cannot transport or move across the cell membranes.
- The level of concentration of mineral ions in the soil. It must be lower as compared to concentration of that mineral in roots.

Majority of the minerals are absorbed via active absorption via roots into cytoplasm of epidermal cells. This active uptake of ions is partly responsible for the water potential gradient in roots and results in osmosis. Added to this, some ions also move passively in the epidermal cells. Thus, it can be said that absorption of ions is carried out via both active and passive transport.

Following diagram shows the uptake of mineral ions via root hairs from soil.



Translocation of Mineral Ions – When the ions reach xylem via active or passive uptake or combination of two, the further transport of minerals to all parts of the plants is carried out through transpiration stream. These ions are frequently remobilized and older leaves export much of their nutritional content to younger leaves. The most readily mobilized elements are Nitrogen, Potassium, Sulphur and Phosphorus.

Phloem Transport: Flow from Source to Sink – Food (sucrose) is transported from source to sink by **Vascular Tissue Phloem**.

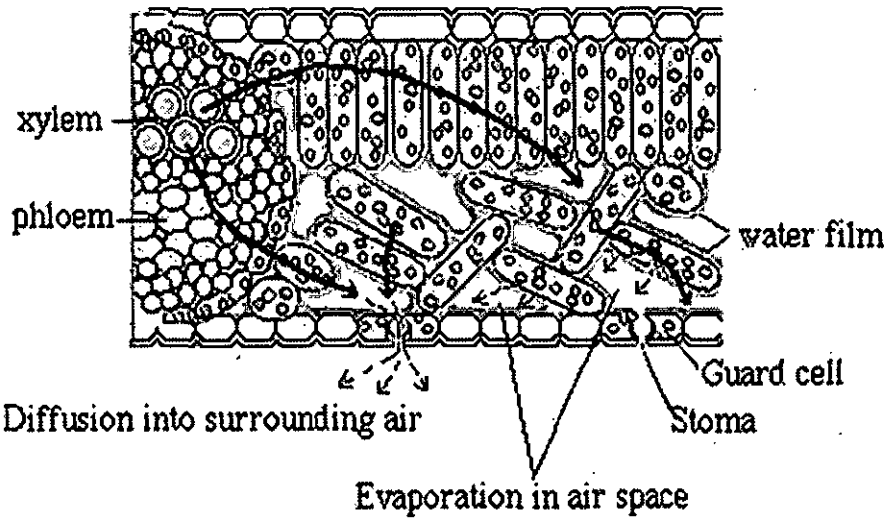
process in plants whereby water is absorbed by roots. The water molecules travels through plant and water is evaporated from the surface of leaves. .

Along with the loss of water vapor in transpiration, exchange of carbon dioxide and oxygen also occurs in the pores of stomata. These stomata are open during day and closed in the night. The opening and closing of stomata is because of turgidity of guard cells. The inner wall of guard cell is elastic and thick and called as **Stomatal Aperture**.

Transpiration is affected by light, temperature, wind speed and humidity. Several plant factors also affect transpiration such as distribution and number of stomata, percent of open stomata, canopy structure and water status of plant. The transpiration driven ascent of xylem sap depends on physical properties of water, which are as follows:

- **Cohesion** – It is the mutual attraction between water molecules.
- **Adhesion** – *It includes the attraction of water molecules to polar surface.*
- **Surface tension** – In this, water molecules are attracted in liquid phase which is more than the water in gaseous phase.

The above listed properties result in high **tensile strength of water**, i.e. *an ability to resist a pulling force*, and **high capillarity**, i.e. *the ability to rise in thin tubes*. Added to this, tracheid and vessel elements are the two elements via which the capillarity of plants is aided.



The process of photosynthesis requires water and the system of xylem helps in the supply of water from roots to leaf veins. During this process, the evaporation of water takes place via stomata, thin film of water result in pulling effect in leaves from xylem. Because of lower concentration of water vapor in atmosphere in comparison to substomatal cavity and intercellular spaces, water gets diffused in the surroundings and creates a "*pull*". This process is explained in the figure right hand.

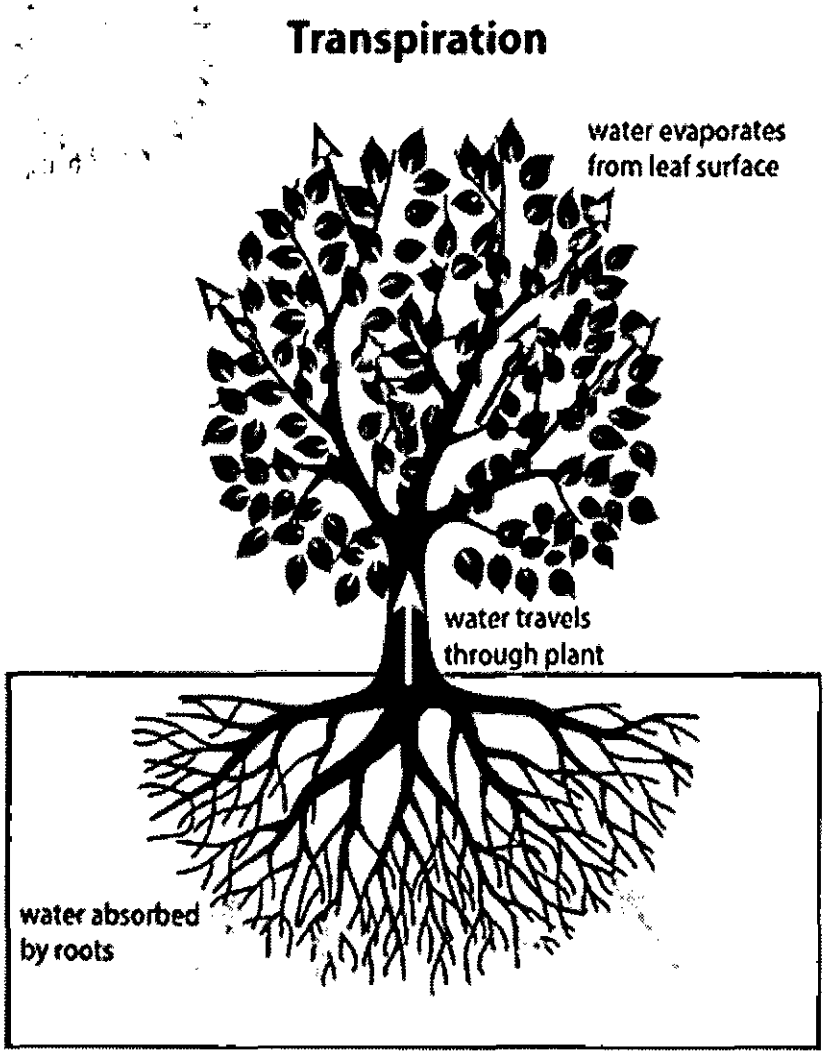
The above figure shows the movement of water in leaf, where evaporation from the leaf set up the pressure gradient between outside air and the air spaces

results in transpiration and thus, transpiration pull is the root cause of water movement in the tall trees.

Transpiration Pull:

Plants do not have any circulatory system, but the flow of water upward via xylem is achieved by fairly high rates and that is up to **15 mts/ hr**. According to researchers, water is "**Pulled**" through the plant and this driving force is transpiration from the leaves. It is termed as cohesion – tension – transpiration pull model of water transport.

Transpiration / Definition of Transpiration



"Transpiration is the process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapor and is released to the atmosphere. Transpiration is essentially evaporation of water from plant leaves."

In other words, transpiration is the evaporative loss of water that occurs primarily through stomata in leaves. Following diagram shows the transpiration

How do Plants Absorb Water?

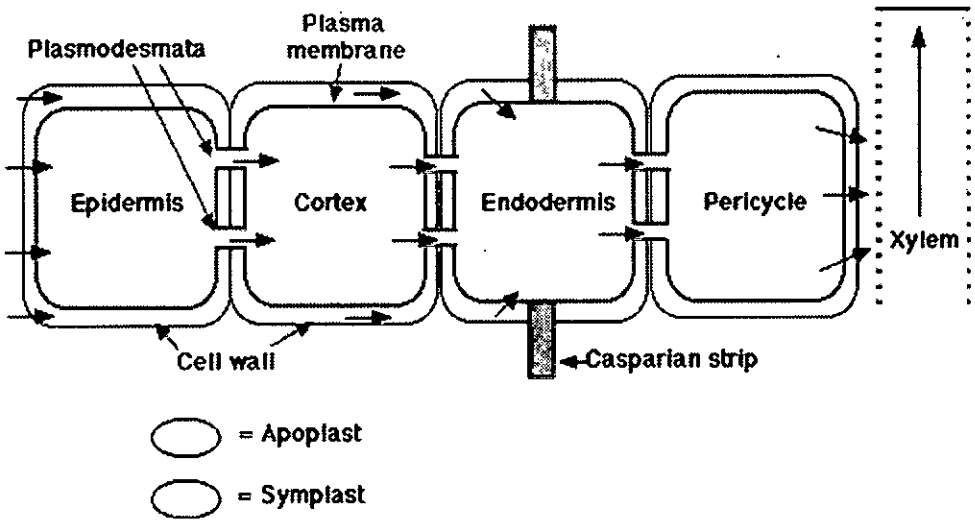
Plants absorb water with the help of roots. The absorption of minerals and water is more specifically the function of root hairs that are present in millions at the tip of roots. These hairs are thin – walled slender extensions that increase the surface of absorption. Once the water is absorbed by root hairs, it moves deeper in the root layers via two different pathways:

- Apoplast pathway
- Symplast pathway

The **Apoplast Pathway** is the condition when water takes the route from cell wall to cell wall and not entering cytoplasm at any point of time.

On the other hand, **Symplast Pathway** is the pathway where water moves between cytoplasm of adjacent cells.

Following image explains the movement of both the above discussed pathways, whereby in apoplast pathway, water takes the route from cell wall and in symplast water moves between cytoplasm and adjacent cells:



Water Movement up a Plant

The water is moved/ transported in various parts of the plants, via different processes. It is important to understand if the transport is active or passive. Moreover, it is also the matter of concern that the water moves against gravity in the stem and from where this energy is achieved. This question can be answered via Root Pressure.

Root Pressure:

As different ions are transported in vascular tissues via active process, the pressure inside the xylem increases. This positive pressure is regarded as root pressure and this pressure is responsible for pushing up water to the small heights in the stem. The root pressure provides only modest push but does not play an integral role in water movement in case of tall trees. The greatest contribution of root pressure is to re-establish to chain of water molecules in the xylem that

equilibrium is reached. At the equilibrium state, equilibrium of both the chambers is achieved. Following figure shows the process of Osmosis via Semi Permeable Membrane.

Plasmolysis / Definition of Plasmolysis

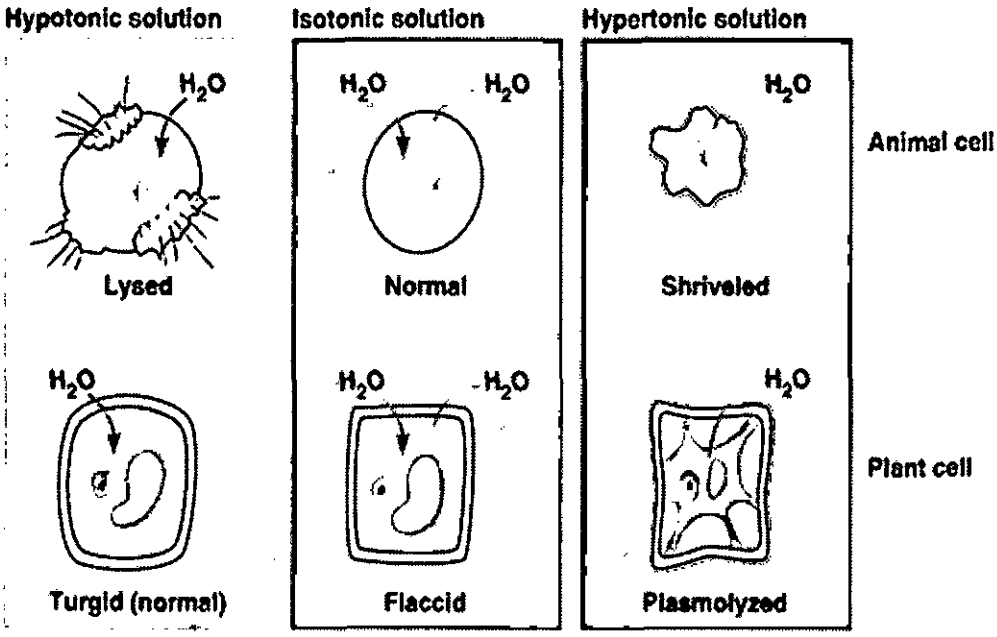
The term Plasmolysis is defined as *"the contraction of the protoplasm of cells within plants due to loss of water through osmosis."*

In other words, the behaviour of plant tissues or cells regarding movement of water depends on surrounding solution and this process occurs when water is drawn out of the cell through the process of osmosis. Osmosis occurs when the cell has higher concentration as compared to its surroundings.

Plasmolysis depends on the three type of solution:

- **Isotonic** – It is the condition when the external solution balances the osmotic pressure of cytoplasm.
- **Hypotonic** – In this case, external solution is dilute as compared to cytoplasm.
- **Hypertonic** – In hypertonic, external solution is more concentrated.

Cell swells in case of hypotonic while it shrinks in hypertonic ones. Following figure shows the three type of solution:



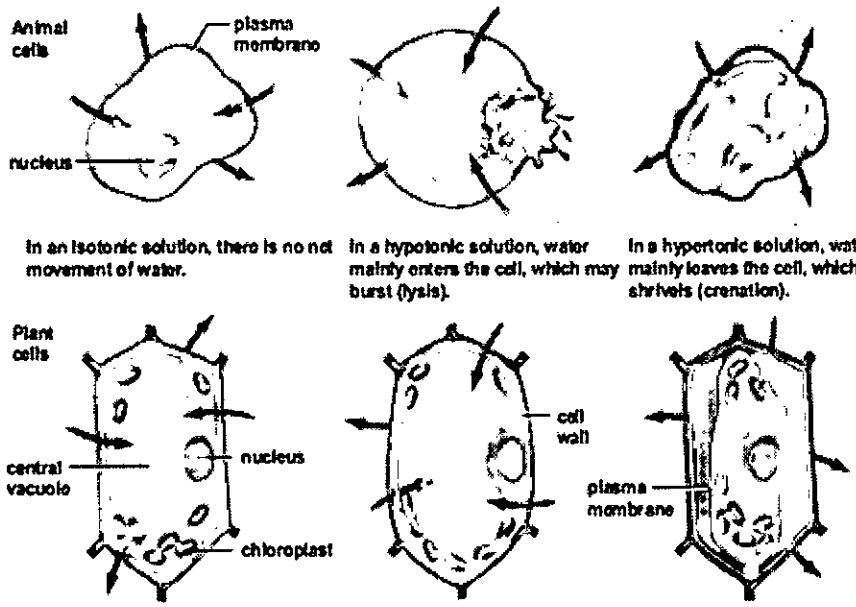
Imbibition

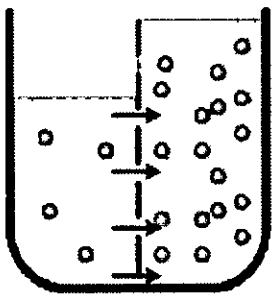
It is a special type of diffusion which includes the absorption of water by solids, called colloids, resulting in enormous increase in volume.

Example of Imbibition: Absorption of water by dry wood and seeds are the examples of imbibition.

Following figure shows osmosis in plant and animal cell in different type of solution. We can clearly observe that in case of isotonic solution, there is not net movement of water. In hypotonic solution, water mainly enters the cell and may bursts in case of animal cells and in case of plants vacuoles are filled with water, turgor pressure develops and chloroplasts are seen next to the cell wall. In the last condition, i.e. hypertonic solution, in animal cells water mainly leaves the cell and in plant cells vacuoles lose water, the cytoplasm shrinks and chloroplast are seen in the center of the cell.

Osmosis in Animal and Plant Cells





Osmosis
(Water moves by concentration gradient)

Osmosis occurs spontaneously in a reaction to the spontaneous force. The rate of osmosis and net direction depends on concentration gradient and pressure gradient. Water moves from higher concentration to lower concentration until

Water Potential

Plants use water potential to transport water to leaves and this helps in carrying out photosynthesis. The term water potential is defined as "the measure of potential energy in water and drives the movement of water through plants." Following equation represents the water potential in plants:

$$\Psi_{system} = \Psi_{total} = \Psi_s + \Psi_p + \Psi_g + \Psi_m$$

Where,

Ψ_s is solute potential,

Ψ_p is pressure potential,

Ψ_g is gravitational potential and

Ψ_m is capillary potential

Water always moves from higher water potential to lower water potential. The two main components of water potential are Solute Potential and Pressure Potential.

Solute potential is also referred as osmotic potential. It is negative in plant cell and zero in case of distilled water. Typical values of solute potential of cytoplasm are -0.5 MPa to -1.0MPa. Solutes can reduce water potential by consuming potential energy available in water. Solute molecules can dissolve in water because water molecules can bind to them by hydrogen bonds.

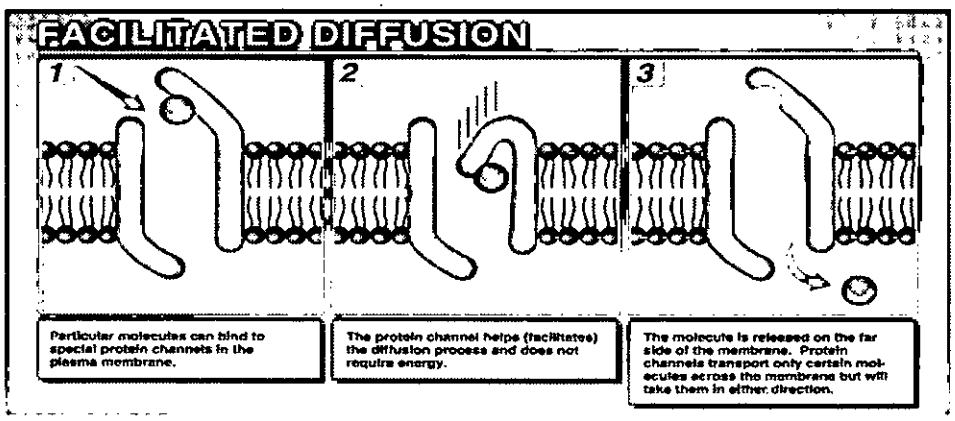
Pressure potential in plants is positive. In plant cell, pressure potential is the pressure exerted by the rigid cell wall that can limit or stop further uptake of water.

Water molecules have kinetic energy. Higher the concentration of water in the system, greater will be the kinetic energy or water potential. Thus, we can conclude that pure water has highest water potential. Consider the two systems containing water. When both these systems come in contact with each other, random movement of molecules takes place such that the water from higher energy will move to lower energy system. This process of movement of molecules down the gradient of free energy is referred as diffusion.

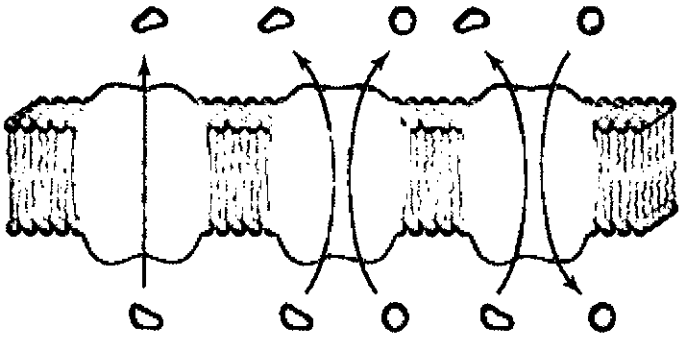
Osmosis / Definition of Osmosis

"Osmosis is the spontaneous movement of a solvent (water) through **a Cellular Membrane**. This is a special kind of diffusion that moves water molecules from a place of higher concentration to a place of lower concentration to create a stable and equal cellular environment."

The cell of the plant is surrounded by cell wall and cell membrane. The wall of the cell is freely permeable to substances in solution and water and therefore, is not a barrier for the movement. The plant cell contains large vacuole, with the vascular sap, and contributes to the solute potential of the cell. In plant cell, the membrane of vacuole, cell membrane and tonoplast are the important determinants of the movement of molecules.



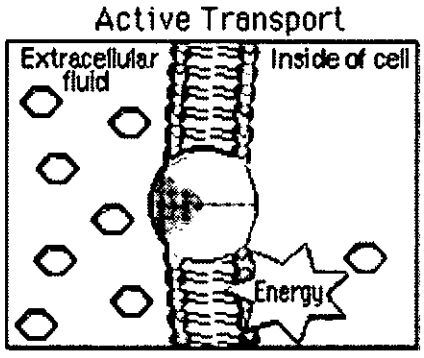
Facilitated diffusion is the passive process and include three type of transport protein namely **Uniport, Symport and Antiport**. "The Uniport proteins carry a single solute across the membrane. Symport proteins translocate two different solutes simultaneously in the same direction and Antiport proteins exchange to solute by transporting one into the cell and one out of the cell." All of these types are explained via figure below:



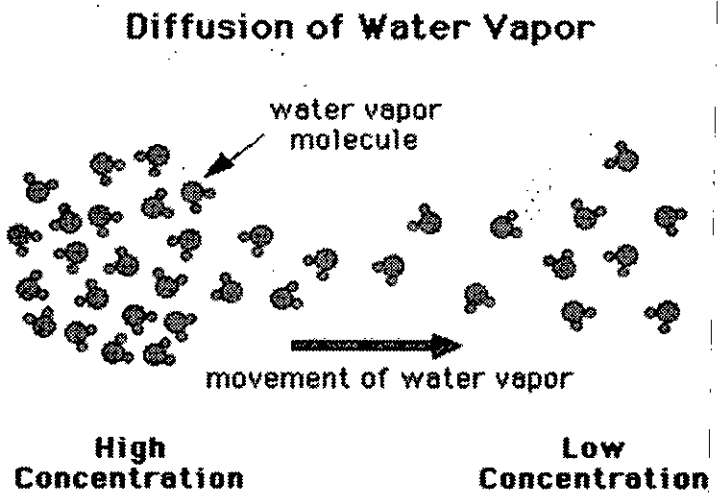
uniport symport antiport

Active Transport –

Active transport use energy in the form of **ATP** in the process of pumping molecules against the concentration gradient. The **ATP** donates a phosphate to a particular gateway molecule which then pumps the desired molecule across membrane, even if goes opposite concentration gradient. Thus, the energy of **ATP** is used to drive the pump. Following figure shows the active transport in cell:



This transport requires energy in the form of ATP



It is an important process in the life of a plant. Movement by this process is passive and may be from cell to cell or from one part of the plant to the cell. Diffusion process does not result in the expenditure of energy and movement of molecules takes place in random fashion.

The substance moves from higher concentration region to lower concentration region. It is a slow process and occurs most likely in liquid and gases. In plants, diffusion is the only means of transport for gases. The rate of diffusion depends on the gradient of concentration, pressure, temperature and permeability of membrane separating them. Following figure shows the diffusion of water vapor from higher concentration to lower concentration.

Facilitated Diffusion

Presence of gradient is important for the process of diffusion and its rate depends on the size of substance. It is important to note that smaller substance diffuse faster as compared to larger ones. Along with size, the rate of diffusion also depends on solubility in lipids and the major constituent of the membrane. The substances with hydrophilic moiety are difficult to pass via membrane and therefore, its movement is facilitated. In this, the site is provided by membrane protein at which such molecules are able to cross the membrane. The concentration gradient is already present for molecules to diffuse even if facilitated by protein and this process is referred as facilitated diffusion.

In this process, special protein helps the substance move across the membrane without the use of energy of **ATP.** It does not cause net transport of molecules and the rate of transport is maximized when all the protein transporters are being used.

Following figure explains the entire process of facilitated diffusion in detail. At the initial step, molecules bind to special protein channel in plasma membrane, and then this protein channel helps the diffusion process and does not require energy. Finally, the molecule is released on the far side of membrane and the protein channel transports only certain molecules across the membrane.

8 ABSORPTION, TRANSPORT AND WATER LOSS IN PLANTS

Transportation in plants is an interesting process. It includes the transport of all the nutrients and water to all parts of the plant for its survival. In case of plants, the biggest concern is the transport of water and it terminates at the limiting factor depending on its growth. To overcome this problem, a tree uses several processes like **Translocation, Storing, Absorption** and **Utilization** of water

Definition of Transportation in Plants

Transportation is the process of transporting water, minerals and food to all parts of the plant body.

Transport in plants occurs at three levels:

- The uptake and release of water and solute by individual cells.
- Short distance transport of substances from one cell to another.
- Long distance transport of sap within xylem and phloem.

Definition of Translocation

Translocation is the movement of materials from leaves to other tissues throughout the plant. Plants produce carbohydrates (sugars) in their leaves by photosynthesis, but non-photosynthetic parts of the plant also require carbohydrates and other organic and nonorganic materials.

In other words, translocation is the movement of water and other nutrients from soil to all parts of the plant.

Direction of Transport

Direction of transport is an important aspect in plants. In case of rooted plants, transport in xylem of both minerals and water is unidirectional from roots to stems. In this, mineral and organic nutrients undergo multidirectional transport. It includes the organic compounds that are formed during photosynthesis are exported to all parts of the plants along with storage organs. Plant growth regulators, hormones and chemical stimuli are also transported in unidirectional or polarized manner, in very small amounts, from where they are formed to other parts.

Means of Transport

There are three means of transport as follows:

- Diffusion
- Active Transport
- Facilitated diffusion
- Diffusion

TABLE 1 The Shoot Apex of Roots and Stems

	Roots	Shoots
Apical meristem	covered by a cup-shaped **root cap**	exposed, no cellular cap
Apical appendages	absent	produce **primordia** (leaves and buds)
Orientation of cell division	occurs in all planes	oriented; two locations: inner (**corpus**) and an outer (**tunica**)
Zones	separate areas of division, elongation, and differentiation	no such recognizable zones present

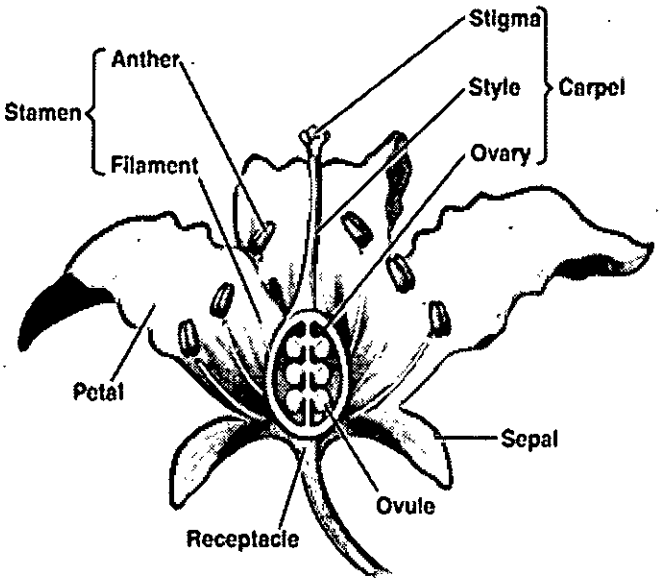
Space for notes

In cymose type of inflorescence, new flowers are generated at the base of the inflorescence.

Structure of the Flower

Each flower has four whorls- Sepals, Petals, Stamens and the Carpels. Sepals are green leafy structures that covers the flower bud. Petals are bright coloured to attract insects for pollination.

Gynoecium are female reproductive structures whereas Androecium is the male reproductive structure.



Structure of the Flower

Gynoecium is composed of carpels. Carpels comprises of three structures: **Ovary**, **Style** and **Stigma**. Ovary comprises of ovules that forms the seed, whereas stigma is the place of landing of pollen at the time of pollination. Ovary finally forms the fruit.

The male part of the flower is known as **Androecium**. Androecium is composed of stamens. Stamen is composed of anther and the filament. Anthers contain the pollen grains, the male gamete

Summary of the chapter

The aboveground, conspicuous part of flowering plants constitutes the **shoot system**, which is composed of erect **stems** on which are attached **leaves**, **flowers**, and **buds**. Leaves are attached to the **stem** at regions called **nodes**. The section of stem between nodes is an **internode**, and the upper angle between the stem and the leaf at the node is called the **leaf axil. Axillary (lateral) buds** located in the leaf axils give rise to **vegetative branch** stems or to **flowers. Terminal buds** are present at the tips of the main stem and branches and contain the **apical meristem** tissues. The shoot originates in the embryo at the end opposite the root and develops a complex **shoot apex**, different from that of the root (see Table).

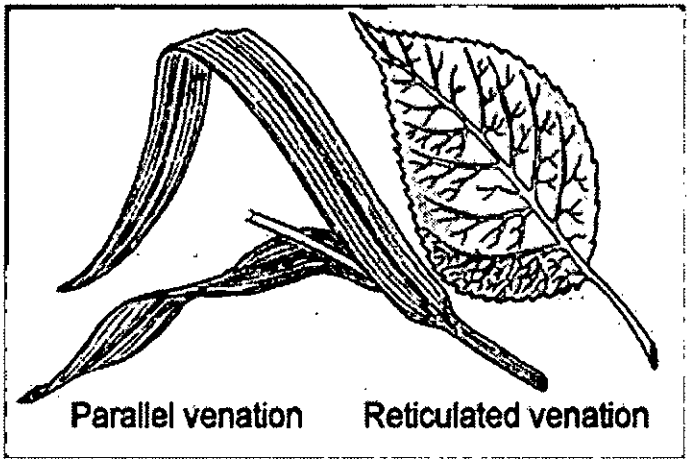
There are basically two types of Venation: **Parallel Venation** and **Reticulate Venation**.

Parallel venation is observed when veins run parallel to each other.

For Example: Monocots

Reticulate venation is observed when veinlets form network.

For Example: Dicots

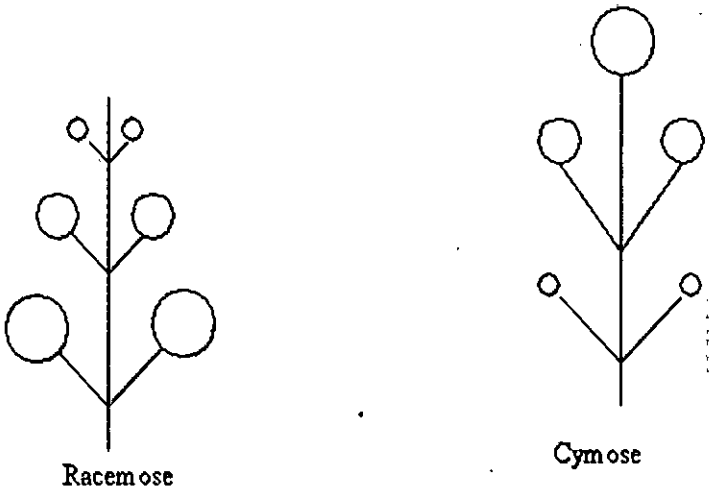


Types of Venation

Flower

The modified shoot is known as **Flower**. The arrangement of flower on the floral axis is known as **Inflorescence**.

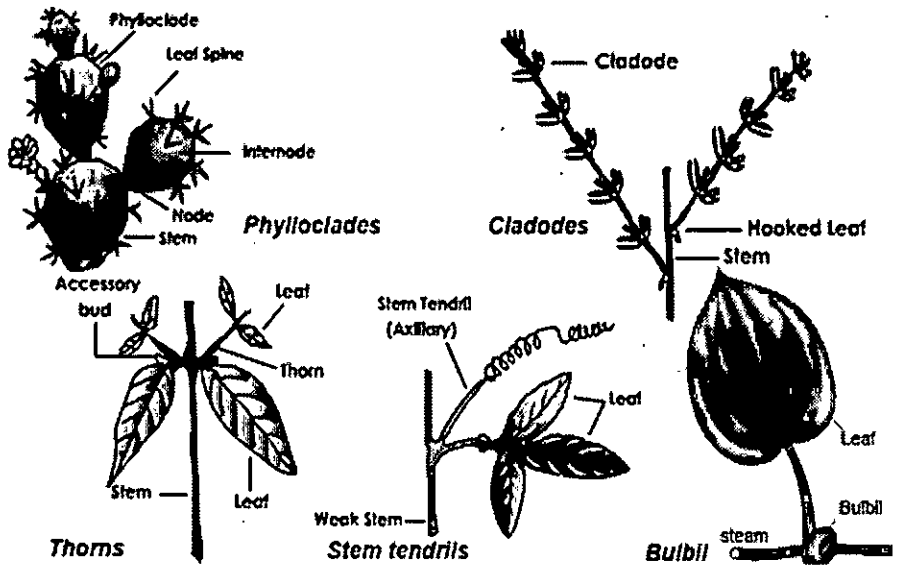
There are two major types of Inflorescence- **Racemose** and **Cymose**.



Types of Inflorescence

In racemose type of inflorescence, new flowers are generated at the tip of the inflorescence.

For Example: Snapdragon

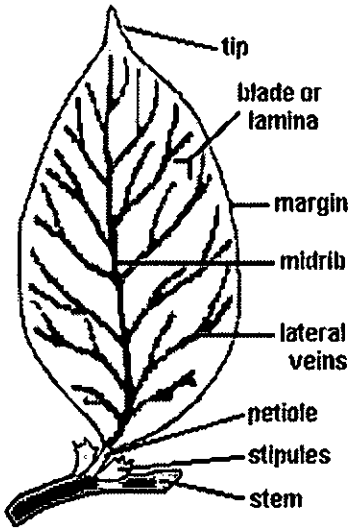


Modifications of Stem

- **Cladodes** are modified stem that perform the function of photosynthesis.
- **Bulbils** are modified stem that becomes fleshy and store food.

Leaf

Leaf is a green dorsoventrally flattened exogenous lateral outgrowth that arises from a node of the stem or a branch. The leaf is a specialized organ of photosynthesis, transpiration and gaseous exchange.



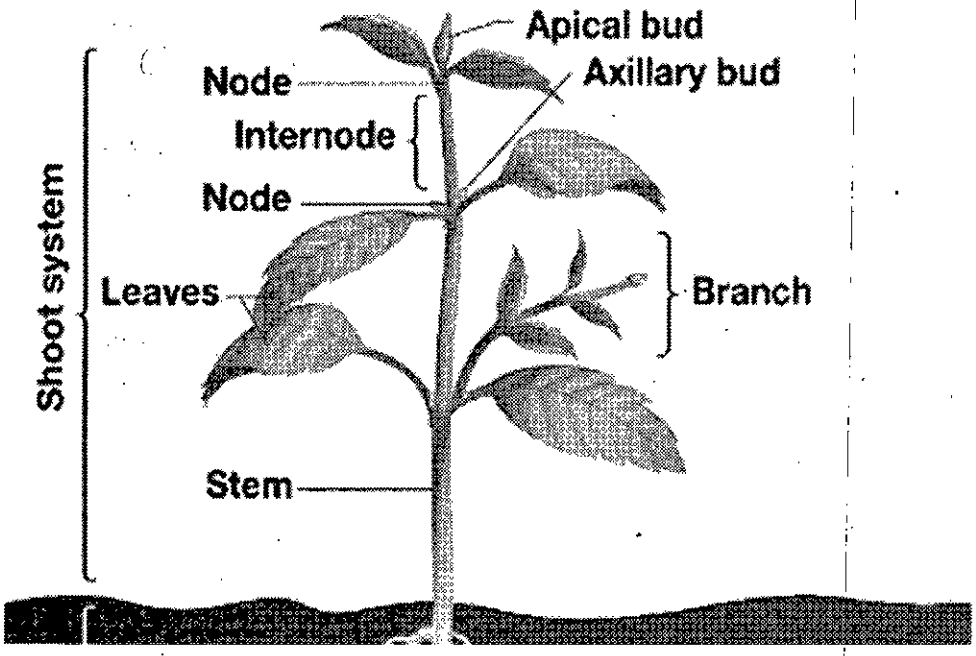
Parts of Leaf

The point of origin of leaf is known as **Node**. It bears bud in its axil. The leaf is attached to the stem by the leaf base and have two lateral leaf like structures called **Stipules**. In monocots, the leaf base is swollen to form pulvinus. The stalk of the leaf is known as **Petiole**. The green exposed part of the leaf is known as lamina. **Lamina** bears the veins or veinlets. The arrangement of veins on the leaf is known as **Venation**.

7 SHOOT SYSTEM

Shoot System

It is an aerial system, usually above the soil and originates from the plumule. It consists of stem, branches, leaves, flowers and fruits.



Shoot System

Stem

It facilitates conduction of water, mineral and food material. The flowers, fruits and seeds form the **reproductive parts of the plants.** The stem bears the nodes and internodes. The point from where the leaf arises is known as **Node** and the part between the two **Nodes** are known as **Internodes**.

Modification of Stems

Similar to roots, the stem is also modified to perform different functions:

Tendrils are slender, twining strands that allow the plant to climb and helps in support. **For Example:** Cucumber.

Thorns are modified stem for protection of the plant. They are hard, woody and sharp outgrowths from the plant. **For Example:** Rose.

4. Roots developing from plant parts other than radicle are
   (a) Epiphyllous
   (b) Epicaulous
   (c) Adventitious
   (d) Fibrous
5. Roots are feebly developed in
   (a) Hydrophytes
   (b) Mesophytes
   (c) Xerophytes
   (d) Halophytes

Answer

1. (a) 2. (b) 3. (b) 4. (c) 5. (a)

Review Questions

1. What are the different types of root systems?
2. What is the function of roots?
3. What are the differences between monocot and dicot roots?
4. What are the primary and secondary roots?
5. Name the plants with taproots.
6. Mention some edible roots.
7. What are fibrous roots?

Space for notes

However, not all plants have their roots underground, some plants have their roots growing above the ground. These are called aerial roots. Alike underground roots, these aerial roots are also responsible for absorbing nutrients, anchoring and affixing the plant by supporting them to the structures such as nearby walls, rocks, trellises, etc.

Few examples of plants with the aerial roots are–Bonsai, Banyan Tree, Mangroves, etc.

Following are the important functions of root:

Roots perform various functions that are necessary for the survival of the plants. They are an integral or integrated system that helps the plant in:

Anchoring: Roots are the reason plants remain attached to the ground. They support the plant body, ensuring that it stands erect.

Absorption: Primary function of the roots is to absorb water and dissolved minerals from the soil. This is crucial as it helps in the process of **photosynthesis**.

Storage: Plants prepare food and store in the form of starch in the leaves, shoots and roots. Prominent examples include carrots, radish, beetroot, etc.

Reproduction: Even though roots are not the reproductive part of plants, they are vegetative parts. In some plants, the roots are a means of reproduction. For instance, new plants arise from creeping horizontal stems called runners (stolons) in jasmine, grass, etc. This type of reproduction is called **vegetative propagation**.

Ecological Function: They check soil erosion, provide sustenance and also habitat to various organisms.

EXERCISE

Multiple Choice Questions

1. Water is absorbed by
   (a) Root hairs
   (b) Root cap
   (c) Root
   (d) Root apex
2. Black pepper is a
   (a) Tree
   (b) Climber
   (c) Shrub
   (d) Herb
3. Pneumatophores occur in plants of
   (a) Sandy soil
   (b) Saline marshy soil
   (c) Marshy soil
   (d) Water

The aerial adventitious roots that arise from the nodes or internodes of weak stemmed plants to climb up their support are called climbing roots, e.g., *Pothos, Piper betel, Vanilla* and *Hedera*.

Many weak stemmed plants climb up their supports in order to expose their leaves efficiently to sunlight.

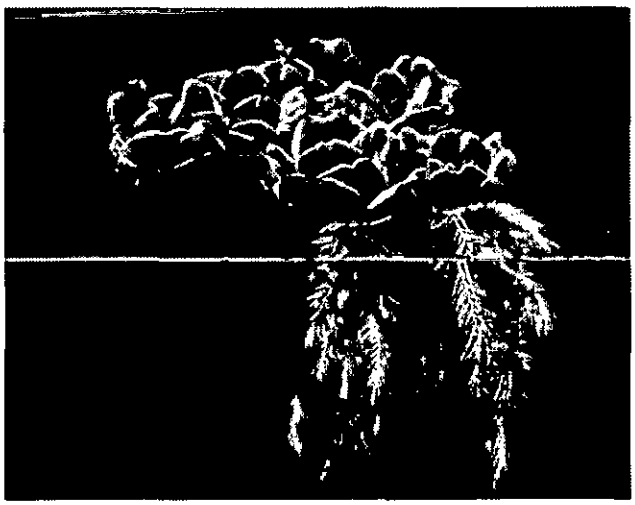
In *Pothos* and *Hedera*, climbing roots develop all over the stem.

In *Vanilla*, single tendril like root arise at each node. Hence, they are called tendrillar roots.

In Piper betel, many short branched, adventitious roots arise at each node. These roots are called clinging roots.

(e) **Floating Roots:**

- These roots develop from the nodes of floating aquatic plants like Jussiaea (=Ludwigia).



They store air, become inflated and spongy, project above the level of water, make the plant light and function as floats.

(f) **Contractile or Pull Roots:**

- Some roots of plants with underground stems contract or swell so that the aerial shoots are kept in a proper depth in the soil.
- These roots are called contractile or pull roots, e.g., Canna, Crocus, Allium, Lilium, Freesia, etc.

(g) **Root thorns:** In aroids like Pothos and many palms (Acanthorhiza and Iriartea) the adventitious roots become hard and pointed hence called root thorns.

Summary of the unit

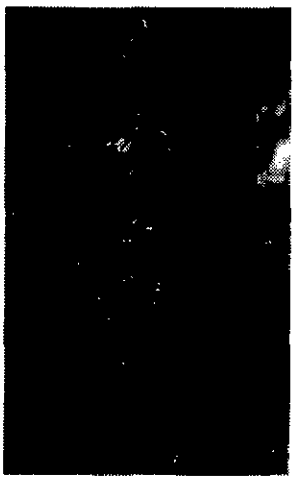
Roots are the important underground part of all vascular plants. This part of the plant is mainly responsible for anchoring it down into the ground and absorbing the **essential mineral elements,** nutrients, and water from the soil. It is also used to store food.

- 
  - Initially, they are hygroscopic in function, become red in moist condition and possess root-caps at their apices.
  - They grow vertically downward, penetrate the soil, become thick and assume the shapes of pillars.
  - They provide support to the spreading branches of tree.
  - Sometimes the main trunk dies and it is replaced by prop roots which assume the shapes of trunks.
  - In India, the biggest banyan tree having large number of prop roots is found at Indian Botanical Gardens, Kolkata and Kadiri (Andhra Pradesh).

(c) **Buttress Roots:**

- The horizontal plank like aerial, adventitious roots that develop at the base of the stem to give additional support are called buttress roots or ballast roots, e.g., Terminalia and Salmalia.
- In some huge and heavy trees, plank like roots develop at the base of the stem on the soil surface.
- These roots give additional support and act like ballasts. Hence these roots are called ballast roots.

(d) **Climbing Roots:**



(d) **Saprophytic roots:** They are also called mycorrhizal roots as here roots are associated with fungal hyphae either superficially (ectomycorrhizae) or internally (endomycorrhizae) for absorption of water and minerals. e.g., Monotropa and Sarcodes.

(e) **Photosynthetic or Assimilatory roots:** These are green, aerial, adventitious roots which prepare food materials by photosynthesis are called photosynthetic roots or assimilatory roots e.g., Taeniophyllum, Trapa and Tinospora. In some epiphytes like Taeniophyllum, the stem and leaves are absent. The entire plant is represented by thin green, ribbon like roots which contain velamen. These roots absorb moisture from the atmosphere and manufacture food materials by photosynthesis. Since the roots are green and perform photosynthetic activity, these roots are called photosynthetic roots or assimilatory roots.

(f) **Reproductive roots:** Some fleshy adventitious root develops buds which can grow in to new plants. These are called reproductive root. These roots serve as means of vegetative propagation. e.g., Sweet potato, Dahlia etc.

For Mechanical Function

(a) **Stilt Roots:**

- 

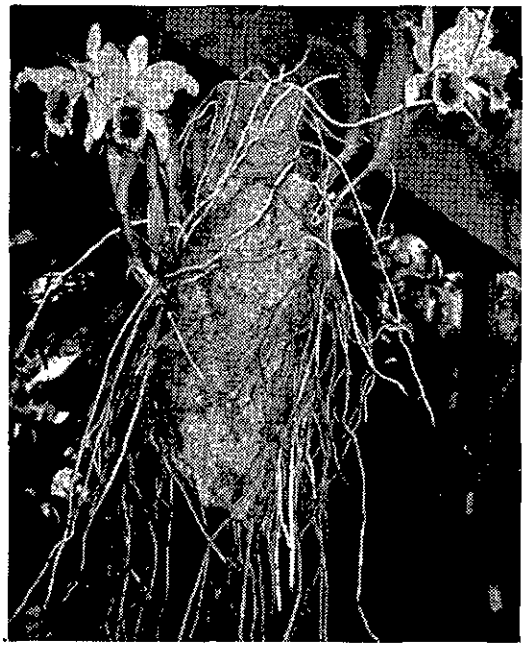
- The aerial, adventitious obliquely growing roots that develop from the lower nodes of the stem to give additional support are called stilt roots.
- This root bears several large overlapping root caps called multiple root caps. *e.g., Sugarcane, Pandanus, Rhizophora, Sorghum* and *Maize. Pandanus* (screw pine) is a common sea shore plant.
- They also help in the absorption of water and minerals from the soil.
- In monocots, these roots arise in whorls from a few basal nodes of stem.

(b) **Prop Roots:**

- These adventitious aerial roots arise from horizontal aerial branches of the trees like Ficus bengalensis (Banyan).

- **Moniliform or Beaded roots:** These adventitious roots are swollen at frequent intervals. This gives the root a beaded appearance. e.g., Portulaca (Rose moss) Momordica (Bitter gourd) Cyperus (Guinea rush).
- **Palmate tuberous roots:** In Orchis there is a pair of succulent tuberous root, one of which perishes every year while another new one is formed by its side. Such orchid roots may sometimes be of palmate shape, therefore, called palmate roots.
- **Annulated roots:** The roots of a medicinal plant, Ipecac (Cephaelis ipecacuanha) yields emetine that looks like discs placed one above another, therefore, called annulated.

(b) **Epiphytic roots:** These roots are also called 'hygroscopic roots. These roots develop in some orchids which grow as epiphytes upon the trunks or branches of trees. They hang freely in the air and absorb moisture with the help of special sponge like tissue called velamen. Velamen is modification of epidermis. e.g., Venda, Dendrobium etc



(c) **Parasitic or Haustorial roots :** Plants which depend on plant partially or totally for their food material are known as parasites. The roots of parasitic plants, which penetrate into the host tissues to absorb nourishment, are called haustorial roots. The haustorial roots of Cuscuta (Dodder, vern. Amarbel) penetrates the host up to phloem and xylem to absorb organic food, water and minerals. The haustorial roots of partial parasite – Viscum (Mistletoe) penetrate up to xylem of host to absorb water and minerals.

- Parasite which absorb their nutrients from the host stem are known as stem parasites while those which absorb their nutrients from the host root are known as root parasite.

Normally, the soil has a large number of small air spaces between the soil particles.

This air is utilized by the plants for their respiration. But the roots of some plants growing in saline marshes (mangrove plants) suffer from the lack of oxygen.

This is due to the water-logged condition of the soil.

To cope with this situation some root branches grow vertically upwards. They become aerial and negatively geostrophic.

- These roots bear many minute pores called pneumathodes towards their upper ends.
- Gaseous exchange takes place through pneumathodes.
- Such aerial, porous negatively geotrophic roots which help in gaseous exchange are called breathing or respiratory roots, breathing roots or pneumatophores roots or pneumatophores e.g., Sonneratia, Heritiera, Rhizophora, Avicennia and Ceriops etc. and are found in Sundarbans of West Bengal.

Modification of Adventitious Roots

(i) For physiological or Vital functions

(a) **Storage roots :** The roots where adventitious roots become swollen to store food.

They are following types:

- **Tuberous roots:** These adventitious roots are swollen without any definite shape e.g., Ipomoea batata or (sweet potato).
- **Fasciculated roots:** These are tuberous roots arising in cluster from the base of the stem. e.g., Dahlia, Ruellia (Menow weed), Asparagus (Asparagus fern) etc.
- **Nodulose roots:** These roots become swollen at their tips due to accumulation of food e.g., Maranta sp. (Arrowroot), Curcuma amanda (Mango – ginger).

(c) **Napiform:** The root is nearly globular or spherical in shape. The basal portion of root is much swollen which suddenly tapers towards the apex giving a top-shaped appearance, e.g., Turnip (Brassica napus, vern, Shalgam)and Beet (Beta vulgaris, vern. **Chukandar**).

(d) **Tuberous:** The storage root having no definite shape is called tuberous, .e.g., Mirabilis Jalapa (4 O'clock plant), Trichosanthes (vern. Parwal), Echinocystis lobata (The tuberous root is lobed and weighs as much as 22 kg.).

(ii) **Branched roots:** They are following types:

(a) **Nodular roots :** The primary tap roots and its branches of leguminous plants, i.e., plants belonging to sub-family papilionatae of the family leguminosae (e.g., Pea, Gram, Ground nut, Beans etc.), bear nodule like swellings, called root nodules.

Did You Know?

- They are red in colour due to the presence of **leg-haemoglobin**.
- The nodules are inhabited by nitrogen fixing bacteria called *Rhizobium leguminosarum*.
- It converts atmospheric nitrogen into nitrates and supply them to the plant.
- In turn *Rhizobium* gets nutrients and shelter from the plant. This type of association between the bacterium and leguminous plant for mutual benefit is known as symbiosis and the organisms involved are called **symbionts**.
- This association is also called mutualism which is obligatory for both *i.e.*, for bacteria and leguminous root.

(b) **Pneumatophores or Respiratory roots :** Roots also breathe and as such they also require air for gaseous exchange.

It is mostly seen in monocotyledonous plants.

In grasses, fibrous root system is present.

It is a type of adventitious root system.

In this case the primary root formed from the radicle disappear soon.

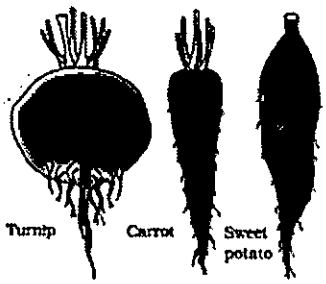
Then many slender roots develop from the base of the stem as cluster of fibres, hence called the fibrous root system.

Shrub like monocots needs additional support because of the adventitious root. *e.g.,* Stilt root in sugarcane.

Modification of Roots

Sometimes the root performs other functions other than fixation, absorption and conduction so get modified structurally. Both tap roots and adventitious roots may undergo such modifications. There are many types of root modifications.

Modification of Tap Roots

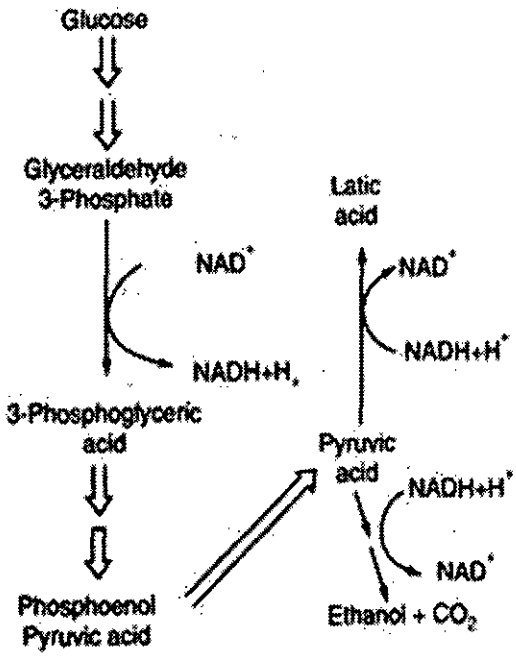


(i) **Storage roots:** In some plants, the primary tap roots are modified for storing reserve food materials. The secondary roots remain thin and they are absorptive in function. The storage roots are usually swollen and assume various forms:

(a) **Conical:** The swollen root is broad at the base and tapers gradually towards the apex giving a shape of **cone**, e.g., Carrot.

(b) **Fusiform:** The root is swollen in the middle and narrow towards both its base and apex giving a shape of spindle, e.g., Radish (Raphanus sativus). Half or less than half portion towards the base of fusiform root is formed by hypocotyl.

Fermentation



In this process, the incomplete oxidation of glucose is carried out under anaerobic conditions via set of reactions where pyruvic acid is converted into ethanol and carbon dioxide. These reactions are catalyzed by two enzymes, i.e. alcohol dehydrogenase and acid-decarboxylase. Other organisms such as bacteria produce lactic acid from pyruvic acid. The detailed steps are depicted in the figure below. In animal cells as well, during muscle exercise, in case of inadequacy of oxygen for cellular respiration, pyruvic acid is reduced to lactic acid by lactate dehydrogenase. **$NADH^+H^+$** are the reducing agent which is oxidized to **NAD^+** in the process.

In both alcohol and lactic acid fermentation, very less energy is released. Both these processes are hazardous because alcohol or acid is produced during the process. Fermentation process is used in our daily life such as in the formation of curd, vinegar, bread and alcoholic drinks.

Aerobic Respiration

For aerobic respiration to take place in mitochondria, pyruvate is transported into mitochondria from cytoplasm. The most important events in this respiration are:

- The hydrogen atoms, that leaves 3 molecules of **CO_2**.
- Passing on of electrons removed as a part of hydrogen atoms to molecular oxygen with simultaneous synthesis of Adenosine Triphosphate (ATP).

Pyruvate, formed during glycolytic catabolism of carbohydrates in cytosol, enters the matrix of mitochondria and it undergoes oxidative decarboxylation by the complex set of reaction. This entire process is catalyzed by pyruvic dehydrogenase and this reaction requires involvement of several coenzymes such as Coenzyme A and NAD^+.

$$\text{Pyruvic acid} + CoA + NAD^+ \xrightarrow[\text{Pyruvate dehydrogenase}]{Mg^{2+}} \text{Acetyl CoA} + CO_2 + NADH + H^+$$

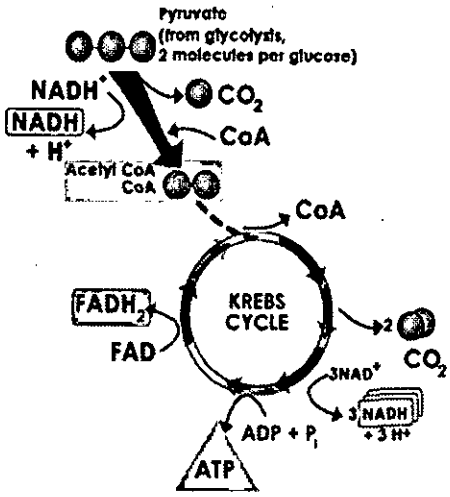
During this entire process, 2 molecules of NADH are produced from the metabolism of 2 molecules of pyruvic acid. The acetyl CoA enters into a cyclic pathway called as Krebs's cycle or tricarboxylic acid. The name Krebs Cycle is mentioned after the name of scientist Hans Kerb who first elucidated this cycle.

Tricarboxylic Acid Cycle

It is the second stage of cellular respiration. It plays an integral role in catabolism of breaking down of organic fuel molecule i.e. glucose, sugar, fatty acid and amino acids. The cycle starts with the condensation of acetyl group with oxaloacetic acid and water to release citric acid. The overall reaction of Krebs cycle is –

$$\mathbf{2\ acetyl\ CoA + 6NAD^+ + 2FAD + 2ADP + 2P_i \rightarrow 4\ CO_2 + 6\ NADH + 6H^+ + 2\ FADH_2 + 2ATP}$$

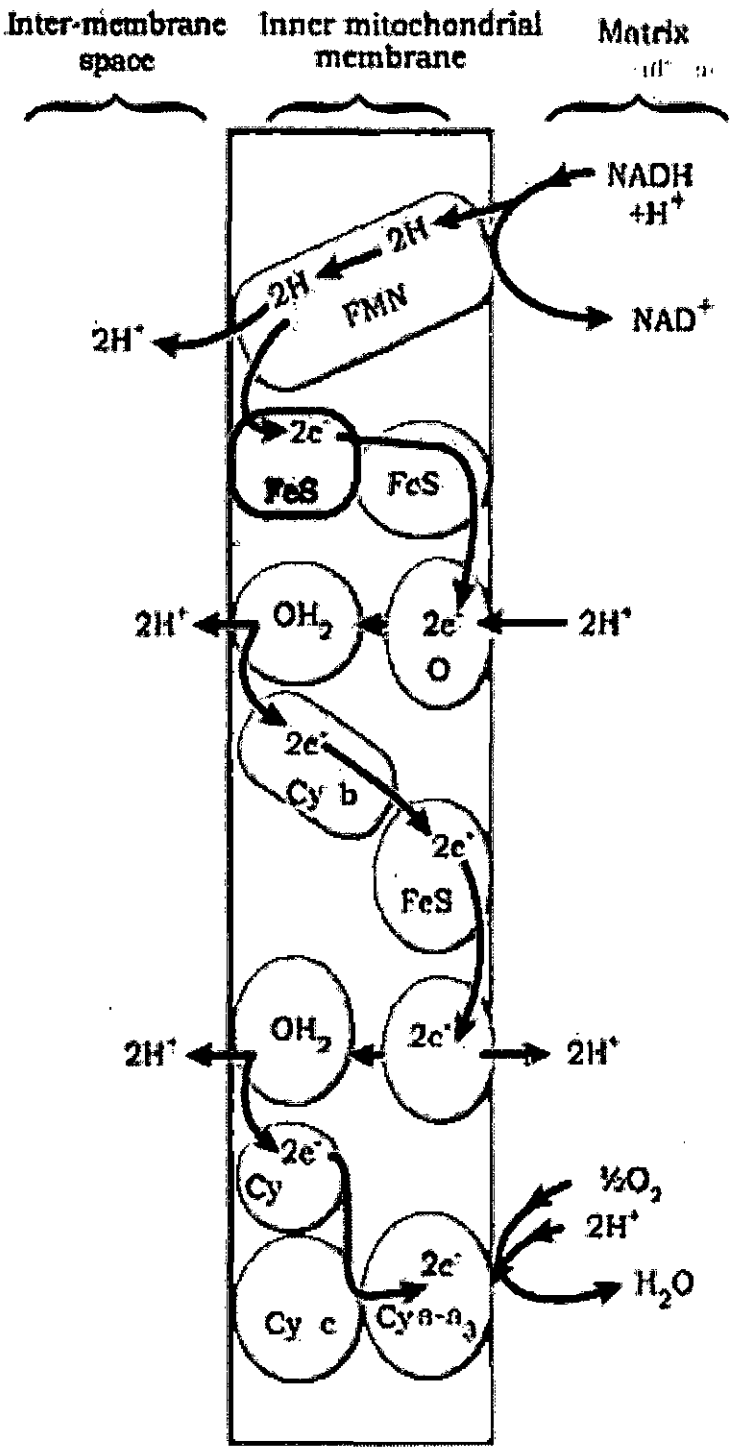
This reaction is catalyzed by citrate synthase enzyme and a molecule of CoA is released. This citrate is then isomerized to isocitrate followed by decarboxylation that results in the formation of α-ketoglutaric acid and succinyl-CoA. Then succinyl-CoA is oxidized to OAA allowing the cycle to continue. During this conversion of succinyl-CoA to succinic acid one molecule of GTP is synthesized. In a coupled reaction GTP is converted to GDP along with the synthesis of ATP from ADP. Added to this, at three places in the entire cycle, NAD^+ is reduced to NADH + H^+ and at one point FAD^+ is reduced to $FADH_2$. The entire cycle is shown in the figure below :



Furthermore, the continued oxidation of acetic acid oxidacid in this cycle requires continued replenishment of oxaloacetic acid, i.e. the first member of the cycle. The summary equation of entire process is given below -

$$\text{Pyruvc acid} + 4NAD^+ + FAD^+ + 2H_2O + ADP + Pi \xrightarrow{\text{Mitlochondrial Matrix}} 3CO_2 + 4NADH + 4H^+ + FADH_2 + ATP$$

Electron Transport System (ETS) and Oxidative Phosphorylation



NADH and $FADH_2$ carry electrons to the Electron Transport System. After the completion of Krebs cycle, oxygen enters in pathway as the electron acceptor at the end of electron transport system. "*The metabolic pathway, through which the electron passes from one carrier to another, is called electron transport system and is present in the inner mitochondrial membrane.*" The electrons produced from NADH in the matrix of mitochondria during Krebs/ citric acid cycle are oxidized

by an NADH dehydrogenase (Complex I). The electrons are then transported to ubiquinone present in the inner membrane. This ubiquinone also receives reducing equivalents by $FADH_2$ (Complex II). This $FADH_2$ is generated during the oxidation of succinate in Krebs cycle. This reduced ubiquinone is oxidized with the transfer of electrons to cytochrome *c* with cytochrome bc_1 complex (Complex III). The small protein cytochrome *c* attached to outer surface of inner membrane acts as mobile carrier that transfers the electrons from Complex III to Complex IV. This Complex IV is cytochrome oxidase complex which contains cytochrome *a* and a_3, along with two copper centers.

When the transference of electron takes place from one carrier to another via complex I to IV, they are coupled to Complex V or ATP synthase for the production of ATP from ADP. The number of molecules of ATP synthesis depends on the nature of electron donor. Oxidation of 1 molecule NADH results in 3 molecules of ATP. Figure given in the right shows the entire Electron Transport System in detail.

It is important to note that presence of oxygen is important for aerobic respiration, but its role is limited in the terminal stage of the process. Presence of oxygen is important because it drives the entire process by eliminating hydrogen from the process or it can be said that oxygen is the final hydrogen acceptor.

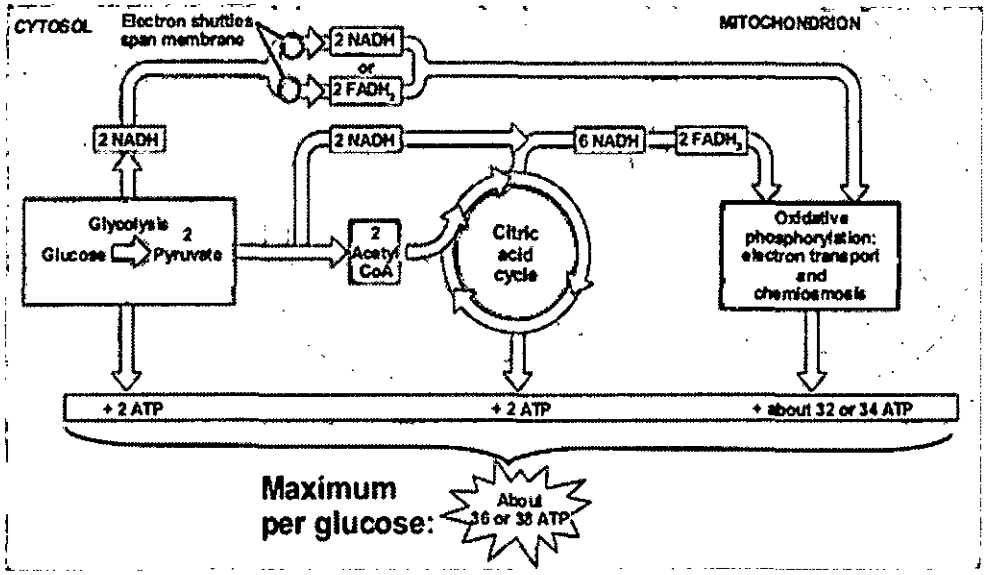
The Respiration Balance Sheet

Theoretically, we can calculate the net gain of ATP for every molecule of oxidized glucose and this calculation is based on following assumptions –

- There is an orderly and sequential functioning of the pathway; with one substrate forming the next with glycolysis, Krebs cycle and Electron Transport System following one after another.
- The NADH formed during glycolysis is transferred into mitochondria and oxidative phosphorylation takes place.
- None of the intermediates in any process is utilized to synthesize any other compound.
- No alternative substrates except glucose are respired.

All of the pathways work simultaneously but none of the above-mentioned assumptions are really valid in living system. Substrate that enters the pathways are extracted as and when required, ATP is utilized as and when required, the rate of enzyme is controlled by several means. On the other hand, doing this exercise is important as it appreciate the efficiency and beauty of the living system in extracting and storing energy. Thus, there can be net gain of 36 ATP molecules from one molecule of glucose in case of aerobic respiration.

Following figures explains the net gain of ATP:



Amphibolic Pathway

The term amphibolic is used to explain *"biological pathway that involves both catabolism and anabolism."*

Example of Amphibolic Pathway

Krebs cycle is an example of Amphibolic Pathway because it includes both catabolism of fatty acids and carbohydrates and synthesis of anabolic precursors for amino acid synthesis. Thus, the pathway with both catabolism and anabolism potential is known as amphibolic pathway.

Respiratory Quotient

This is another aspect of respiration. *"Respiratory quotient is the ratio of CO_2 produced to O_2 consumed while food is being metabolized."*

$$RQ = \frac{\text{Volume of } CO_2 \text{ evolved}}{\text{Volume of } O_2 \text{ consumed}}$$

Where, RQ stands for Respiratory Quotient

RQ depends on the type of respiratory substrate used in respiration. When carbohydrate is used as substrate and is completely oxidized, RQ becomes 1. It implies equal amount of O_2 and CO_2 are consumed and evolved. This reaction is displayed in the figure below –

$$C_6 + H_{12}6O_2 \rightarrow 6CO_2O + \text{Energy}$$

$$RQ = \frac{6CO_2}{6O_2} = 1.0$$

In case, fats are used during the process of respiration, RQ becomes less than 1. Following equation shows the calculation for fatty acid and tripalmitin is used as substrate –

$$2(C_{51}H_{98}O_6) + 145O_2 \rightarrow 102\,CO_2 + 98H_2O + \text{energy}$$

Tripalmitin

$$RQ = \frac{102\,CO_2}{145O_2} = 0.7$$

When protein is used as respiratory substrates the ratio comes out to be 0.9.

Factors affecting Respiration in Plants

There are eight environmental factors that has significant impact on respiration in plants –

- Oxygen content of the atmosphere
- Effect of water content
- Effect of temperature
- Effect of availability of light
- Impact of respirable material
- Effect of concentration of carbon dioxide in atmosphere
- Protoplasmic conditions, i.e., younger tissues have greater protoplasm as compared to older tissues.
- Other factors, i.e., fluorides, cyanides, azides, etc.

Summary of the chapter

Respiration is a chain of chemical reactions that enables all living entities to synthesize energy required to sustain.

It is a biochemical process wherein air moves between the external environment and the tissues and cells of the species. In respiration, inhalation of oxygen and exhalation of carbon dioxide gas takes place. As an entity acquires energy through oxidising nutrients and hence liberating wastes, it is referred to as a metabolic process.

Let us have a look at the respiration in plants notes provided here to know about the process of respiration, and the different types of respiration that occur in plants.

Do Plants Breathe?

Yes, like animals and humans, plants also breathe.

Plants do require oxygen to respire, the process in return gives out carbon dioxide. Unlike humans and animals, plants do not possess any specialized structures for exchange of gases, however, they do possess stomata (found in leaves) and lenticels (found in stems) actively involved in the gaseous exchange. Leaves, stems and plant roots respire at a low pace compared to humans and animals.

Breathing is different from respiration. Both animals and humans breathe, which is a step involved in respiration. Plants take part in respiration all through

their life as the **plant cell** needs the energy to survive, however, plants breathe differently, through a process known as Cellular respiration.

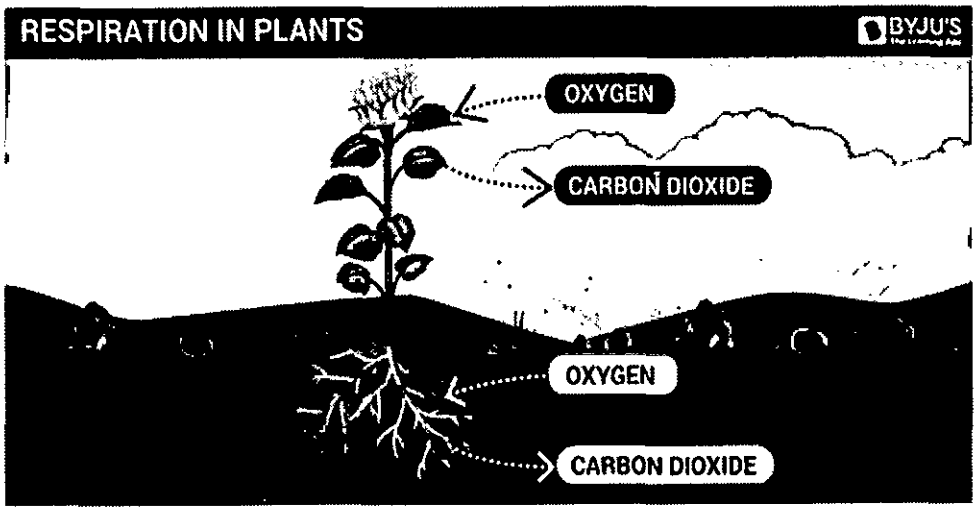
In this process of cellular respiration, plants generate glucose molecules through photosynthesis by capturing energy from sunlight and converting it into glucose. Several live experiments demonstrate the breathing of plants. All plants respire to provide energy for their cells to be active or alive.

Let us take a look at the respiratory process in plants.

The Process of Respiration in Plants

During respiration, in different plant parts, significantly less exchange of gas takes place. Hence, each part nourishes and fulfils its own energy requirements.

Consequently, leaves, stems and roots of plants separately exchange gases. Leaves possess stomata – tiny pores, for gaseous exchange. The oxygen consumed via stomata is used up by cells in the leaves to disintegrate glucose into water and carbon dioxide.



EXERCISE

Multiple Choice Questions

1. Alpha-ketoglutarate dehydrogenase results in
   (a) Oxidation and Decarboxylation
   (b) Reduction
   (c) Oxidation
   (d) None of the above
2. _____ is a product of aerobic respiration
   (a) Malic acid
   (b) Pyruvate
   (c) Ethylene
   (d) Lactose

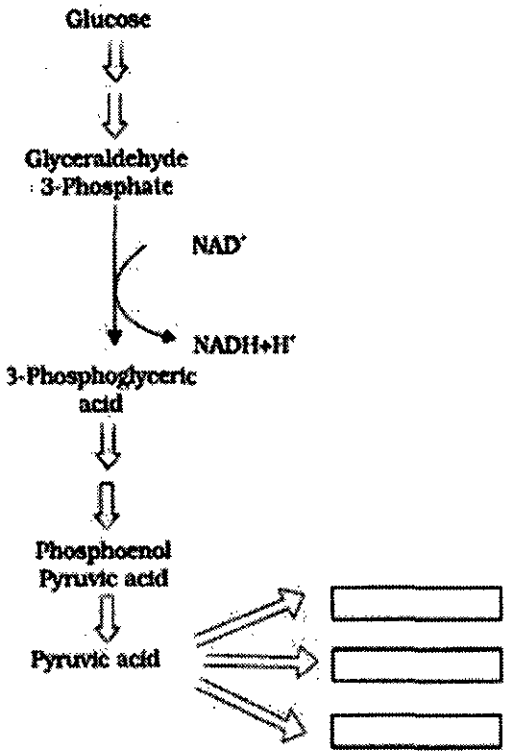
3. Energy gained during aerobic respiration is _____ times more than anaerobic respiration.
   (a) 8
   (b) 12
   (c) 19
   (d) 32
4. Glycolysis is also known as _____
   (a) EMP pathway
   (b) TCA pathway
   (c) carbon sequestration
   (d) None of the above
5. On oxidation of 1 molecule of glucose, _____ ATP is produced through aerobic respiration
   (a) 10
   (b) 25
   (c) 30
   (d) 38
6. Protons accumulate on the _____ in mitochondria.
   (a) Inner membrane
   (b) Intermembrane space
   (c) Outer membrane
   (d) None of the above
7. Oxidative phosphorylation usually refers to _____
   (a) Anaerobic production of ATP
   (b) Citric acid cycle production of ATP
   (c) Alcoholic fermentation
   (d) None of the above
8. The process of cell respiration is carried out by _____
   (a) Mitochondria
   (b) Chloroplast
   (c) Nucleus
   (d) None of the above
9. An important product of the Krebs cycle is
   (a) Water
   (b) Methane
   (c) ATP
   (d) None of the above
10. Acetyl CoA forms a 6-C compound after combining with
   (a) Oxygen
   (b) Pyruvic acid
   (c) Citric acid
   (d) Oxaloacetic acid

Answer Key

1. (a)	2. (a)	3. (c)	4. (a)	5. (d)
6. (b)	7. (b)	8. (a)	9. (c)	10. (d)

Review Questions

1. Why is a person fed with glucose or a fruit juice instead of a cheese sandwich that might give more energy, when a person is feeling dizzy?
2. Aerobic respiration has more efficiency. Justify.
3. The final product of glycolysis is pyruvic acid. Write the three metabolic fates of the pyruvic acid in anaerobic and aerobic conditions as seen in the diagram below.



4. Anaerobic respiration is observed in entities living such as human and angiosperms in aerobic conditions. Why?
5. State why the respiratory pathway is referred to as an amphibolic pathway.

Space for notes

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12 CIRCULATION OF BODY FLUIDS

The Blood, heart, lymph, blood vessels and lymphatic vessels together form a **Circulatory System**. The name is Circulatory System which is also known as **Cardiovascular System**, is an autonomous system that allows blood circulation and transportation of nutrients, O_2, CO_2 and hormones to and from the cells in the body to provide nourishment and help in fighting **Multiple Diseases**.

Blood

Blood is a fluid connective tissue which is composed of **Plasma** and **Blood Cells**. Plasma is made up of water and proteins. The proteins found in plasma includes fibrinogen, albumins and globulins. The other component of blood is blood cells. The following blood cells are found in **Human Blood**:

- **Red Blood Cells** also known as **Erythrocytes** are **Biconcave** in shape. They contain blood pigment haemoglobin which helps in transport of oxygen and carbon-dioxide throughout the body. **RBCs** are without nucleus. The life span of **RBCs** is **120 days**.
- White Blood Cells also known as Leucocytes are Nucleated Cells (with nucleus). They have a very short life span of 3 to 4 days. They are Lmmune System Cells which helps in fighting foreign substances which enter our body. They are of two types: Granulocytes and Agranulocytes.

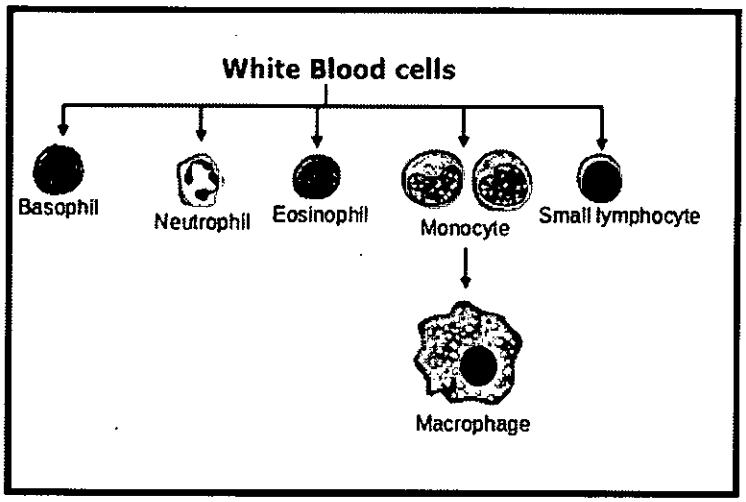


Fig.1. Different types of White Blood Cells

Neutrophils, Eosinophils and Basophils are granulocytes whereas monocytes and macrophages are agranulocytes.

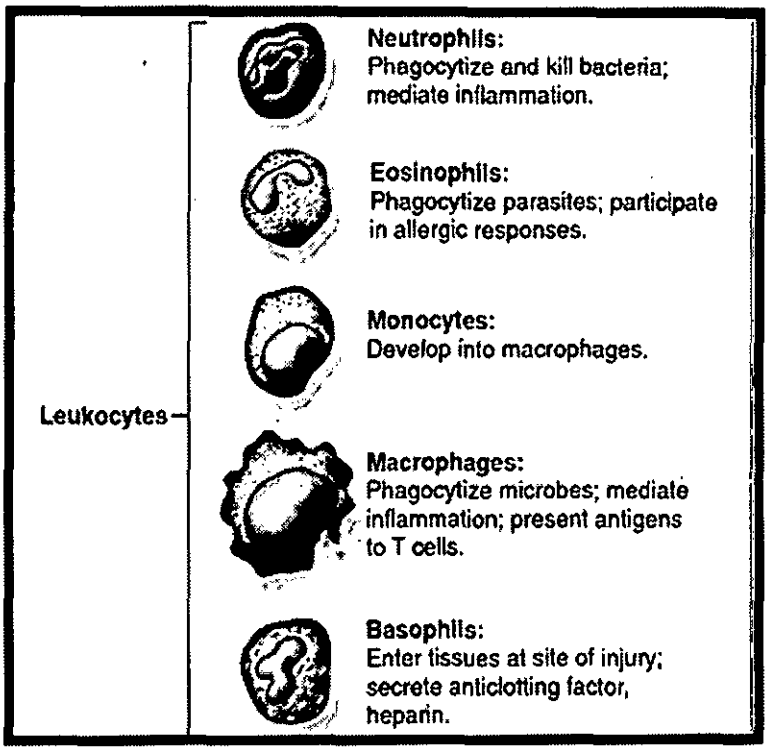


Fig.2. Functions of Different White Blood Cells

- **Blood Platelets** or thrombocytes are cells that helps in blood clotting.

Human Heart and Circulation

The blood circulatory system is of two types- **Open Circulatory System** and **Closed Circulatory System**.

Open Circulatory System does not contain blood vessels rather blood flows in body cavities. This type of circulatory system exists in **Molluscs, Insects, Prawns** etc. The fluid that circulates in these organisms is known as **Haemolymph**.

Closed Circulatory System is a characteristic of higher organisms including humans. They comprise of different types of blood vessels in which blood flow.

Types of Blood Vessels

There are mainly 3 types of blood vessels which are as follows:

- Arteries are thick, muscular and elastic in nature. They carry blood from the heart to different parts of the body. They always carry oxygen rich blood (Oxygenated Blood) except the pulmonary artery (Associated with Lungs) that carries oxygen poor blood (De-oxygenated Blood).
- Veins are non-elastic and thin as compared to arteries. They carry blood from different parts of the body to the heart. They always carry Deoxygenated Blood except the Pulmonary Vein which carry Oxygenated Blood.
- **Blood Capillaries** are thin blood vessels that helps in exchange of **Nutrients, Gases, Metabolites** at tissue level.

The Heart

The main organs that pump the blood throughout is **Heart**. It is a muscular organ located in middle part of the chest. The Heart muscles are known as **Cardiac Muscles**. They help in the contraction and relaxation of the **Heart**.

Chambers of Heart

The Heart comprises of 4 chambers - **Two Auricles/Atrium** and **Two Ventricles.** The right atria and right ventricles is associated with deoxygenated blood whereas left atria and left ventricle is associated with oxygenated blood. The right atria receive blood from two veins-superior vena cava and inferior vena cava. The left atria receive oxygenated blood from the **Lungs** via **Pulmonary Veins**.

Heart Valves

There are 4 valves present in the heart. The valve present between the **Atria** and **Ventricles** is known as **Atrioventricular Valves**. The valve present between right atria and right ventricles is known as **Tricuspid Valve.** The valve present between the left atria and left ventricle is known as **Mitral Valve**. The mitral valve is also known as **Bicuspid Valve**. The valve present between the left ventricle and the aorta is known as **Aortic Valve**.

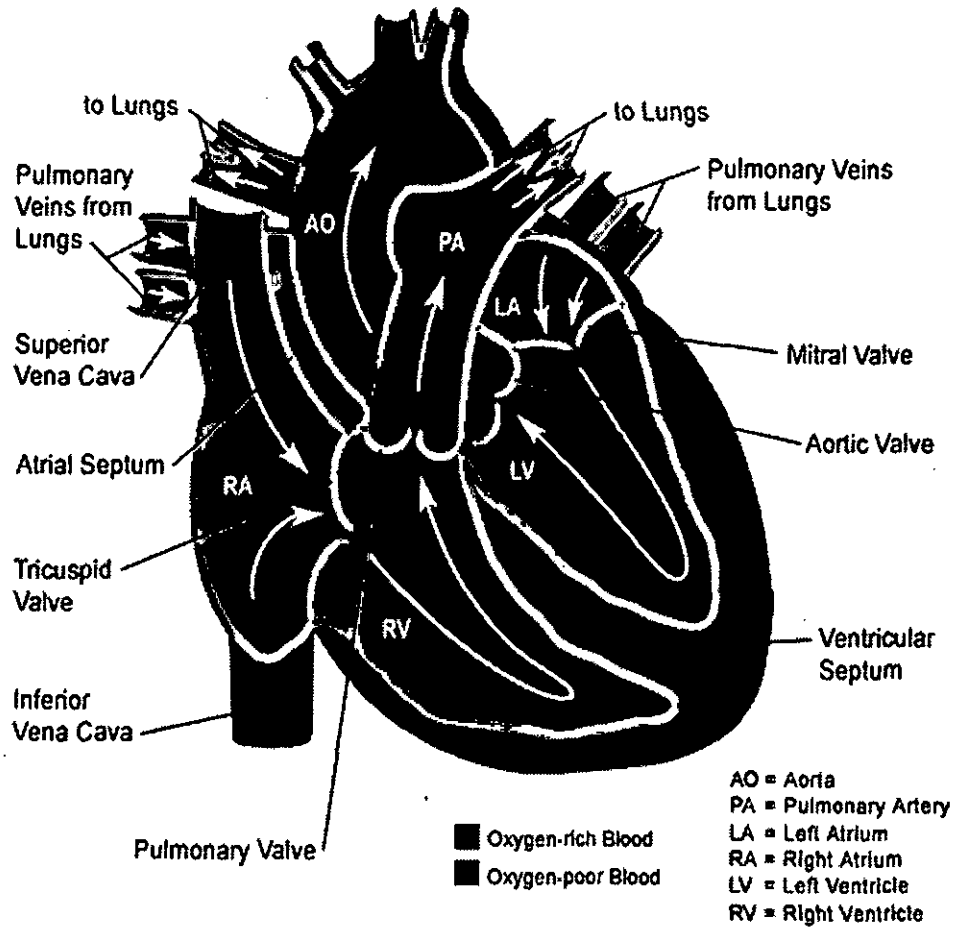
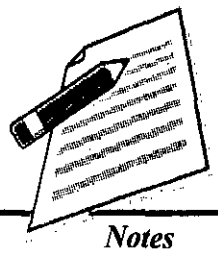


Fig.3. Structure of the Heart



The cartilaginous connection which extends from the wall of the heart in known as **Chordae Tendinae**. The muscles of the heart are known as cardiac muscles. These muscles along with chordae tendineae and papillary muscles help in rhythmic contraction and relaxation of heart.

Note: For detail knowledge of cardiac muscles, kindly refer to the content "Locomotion and movement in animals".

Heart wall

The Heart is made up of 3 layers- **Outermost Epicardium**, **Middle Myocardium** and **Innermost Endocardium**. The middle myocardium layer is made up of **Cardiac Muscles**.

Mechanism of Blood Circulation / Coronary Circulation

The right atrium receives deoxygenated blood and passes it to right ventricle. The right ventricles then pass this blood to lungs for purification. The oxygen rich blood then reaches to left atria from the lungs. Then left atria then pumps this blood to left ventricle. The left ventricle pumps the oxygenated blood to different parts of the body. As blood passes from the heart two times, this type of circulation is known as **Double Circulation**.

When blood passes through the heart once, it is known as single circulation. **For Example:** in fishes.

Lymph

Lymph is a whitish fluid that circulates in a lymphatic system. Lymph returns proteins and excess interstitial fluid to the bloodstream.

Electrocardiogram

Electrocardiogram also known as **ECG** records the electrical activity of the heart over a period of time. It is performed to test the condition of the heart such as heart block, myocardial infarction etc.

Pacemaker

Sinoatrial node is known as the natural pacemaker of the heart. It maintains the rhythm of the heart. It is located in the upper wall of the right atrium. Artificial pacemaker is a small device placed in the chest or the abdomen of the patients suffering from rhythmic problems.

Diseases of the Heart

- Myocardial infarction also known as **Heart Attack** occurs when there is a damage in the cardiac muscles (muscles of the heart).
- Atherosclerosis is a disease of blockage in arteries of the heart due to **Plaque Deposition**.
- Ischemic heart disease is a disease of narrowing the arteries of the heart.

Locomotion and movement

What is Locomotion?

It is defined as the ability of the body to move from one place to another. **For Example**: Walking, Moving, Jumping, Crawling, Propelling etc.

What is the difference between Movement and Locomotion?

Movement can be at organism level, tissue level as well as cell level. **For Example**: Cell moves from one place to another at the time of embryo formation. Whereas Locomotion is termed as movement of a body from one axis to another (or many) in terms of co-ordinates.

It has to be noted that Movement of cell from one place to another cannot be considered as Locomotion. Movement, on one hand, can be voluntary or involuntary. Whereas Locomotion is always voluntary in nature.

What is Locomotor Movements?

Movements that occur over some distance is known as Locomotor Movements. **For Example**: walking, running, etc. Locomotion always occur at the organism level. Locomotion involves locomotory organs that help the body to move from one place to another. Locomotion is always voluntary.

Types of Movement

The three main types of movements are as follows:

- **Ciliary Movement** occurs in internal organs that are lined by ciliated epithelium. **For Example**: movement of ova in oviduct.
- **Amoeboid Movement** occurs by streaming of the protoplasm as observed in amoeba. It occurs in macrophages and leucocytes (cells of the immune system).
- **Muscular Movement** occurs in humans that helps them to move.

Types of Muscles

There are three types of muscles as given below:

- **Skeletal Muscles** appear striped/striations in the microscope. These are voluntary muscles as they are under the control of our will. They help in locomotion and changes in body postures.
- **Cardiac Muscles** are muscles associated with the heart. They help in rhythmic contraction and relaxation of the heart. They also appear striped/striations in the microscope similar to the skeletal muscles.

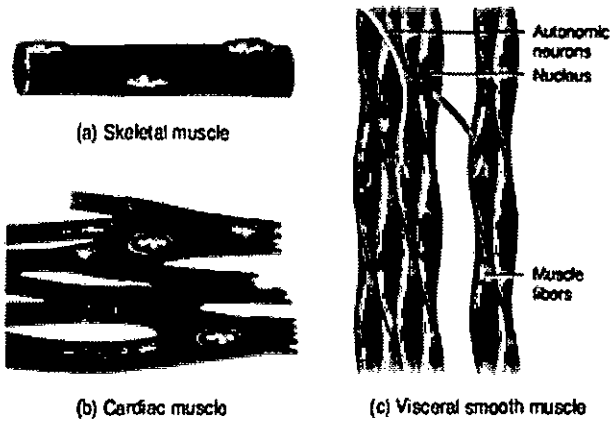


Fig.1. Types of Muscles

- **Smooth Muscles** are involuntary muscles and cannot be controlled by our will. They are present in lining of the alimentary canal, reproductive system etc. They do not exhibit characteristic stripes/striations.

Skeletal System

Skeletal System is made up of bone and cartilages. The skeletal system is divided into - **Axial Skeleton System** and **Appendicular Skeletal System**.

Axial Skeletal System:

It consists of 80 bones in the following regions:

- Skull consists of 22 bones, out of which 21 bones are fused and one is free.
- **Hyoid and Auditory Ossicles**. Hyoid bone holds the trachea so that it can remain open. Auditory ossicles contain the smallest bone that helps in hearing.
- Vertebrae consists of 26 bones. They are named as:
  - Cervical - 7 vertebrae in neck
  - Thoracic - 12 vertebrae in chest
  - Lumbar - 5 vertebrae in lower back
  - Sacrum - 1 vertebra
  - Coccyx - 1 vertebra in tail

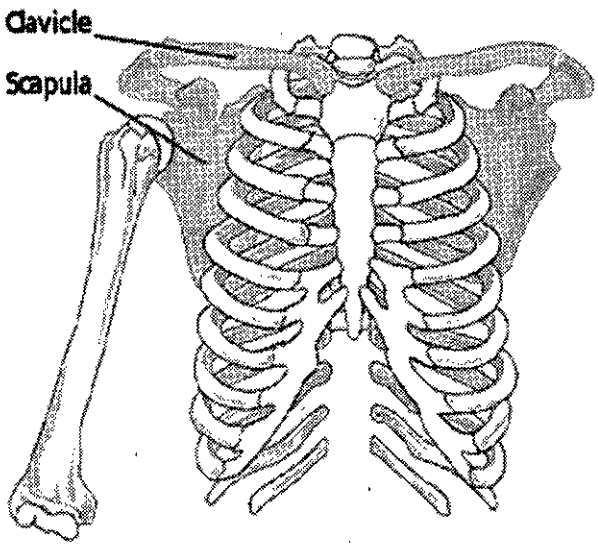


Fig.2. Pectoral Girdle

Ribs and Sternum

There are 12 pairs of ribs which are attached with sternum and forms a rib cage. Out of these 12 pairs, 8th, 9th and 10th pairs of ribs are not attached with the sternum. These ribs are known as **Floating Ribs**.

Pectoral Girdle and Upper Limb

The bones of upper limb are as follows: Humerus, Radius, Ulna, Carpals, Metacarpals and Phalanges. (See Fig. No. 2)

Pelvic Girdle and Lower Limb

Pelvic Girdle connects the leg bones to the axial skeleton. Different bones of legs/lower limb are given below in the form of diagram:

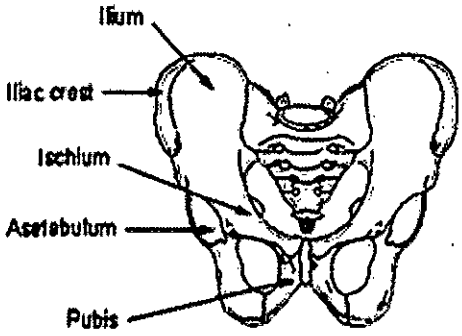


Fig.4. Pelvic Girdle

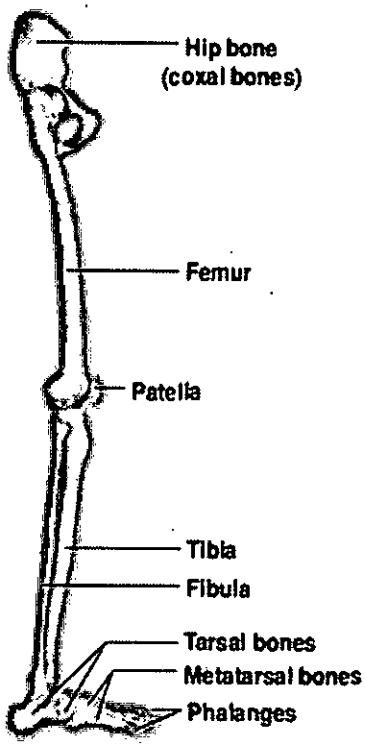


Fig.5. Bones of Right Lower Limb

Ilium, Ischium and **Pubis** are 3 bones of **Pelvic Girdle**. There are 32 bones found in Lower Limb.

Lower limb bones include Femur, Tibia-Fibula, Tarsals, Metatarsals, Phalanges etc. The Lower Limb bones help us to walk, jump, run etc. **(See Fig. No. 5)**

What is the Movement of Cilia?

Cilia is made up of proteins known as microtubules that helps them to move. **Ciliary Movement** is the rhythmic, sweeping movement of epithelial cell

cilia, of ciliate protozoans, or the sculling movement of flagella, effected possibly by the alternate contraction and relaxation of contractile threads (myoids) on one side of the cilium or flagellum.

Neural Control and Coordination

The **Nervous System** is a very important part of the animal body that coordinates voluntary and involuntary actions of the body.

What is Nerve Impulse?

Any stimulus or signal that activate or inhibit any gland, muscle, organ, tissue or any nerve cell as known as Nerve impulse. **For Example:** When we touch a hot plate, a signal is transmitted to brain due to which we respond by removing our hand.

There are two types of **Nervous System** in vertebrates:

- Central Nervous System
- Peripheral Nervous System

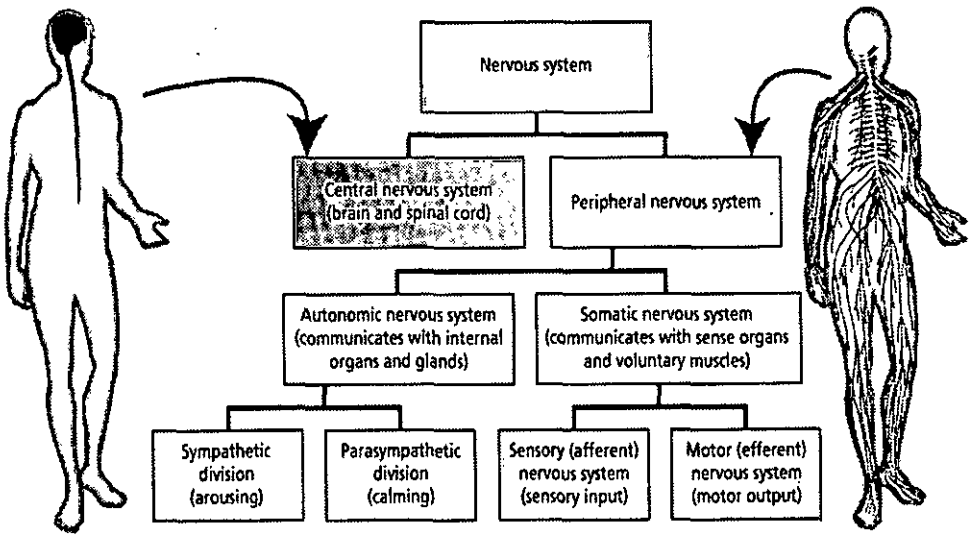


Fig.1. Divisions of Nervous System

What is Central Nervous System?

The central Nervous System comprises of **Brain** and the **Spinal Cord**.

Explain the Structure of Human Brain.

The **Human Brain** is covered by a membrane known as **Meninges**. Meninges are three in number. The **Outermost Duramater, Middle Arachnoid** and **Innermost Piamater**.

The longitudinal fissure divides the brain into two hemispheres known as **Right Cerebral Hemisphere** and **Left Cerebral Hemisphere**.

The **Brain** is divided into three parts: **Forebrain, Midbrain** and **Hindbrain**.

Forebrain

The **Forebrain** comprises of **Cerebrum, Thalamus** and **Hypothalamus**.

- **Cerebrum** is the largest part of the human brain. It is divided into four lobes: **Occipital Lobe**, **Parietal Lobe**, **Temporal Lobe** and **Frontal Lobe**.

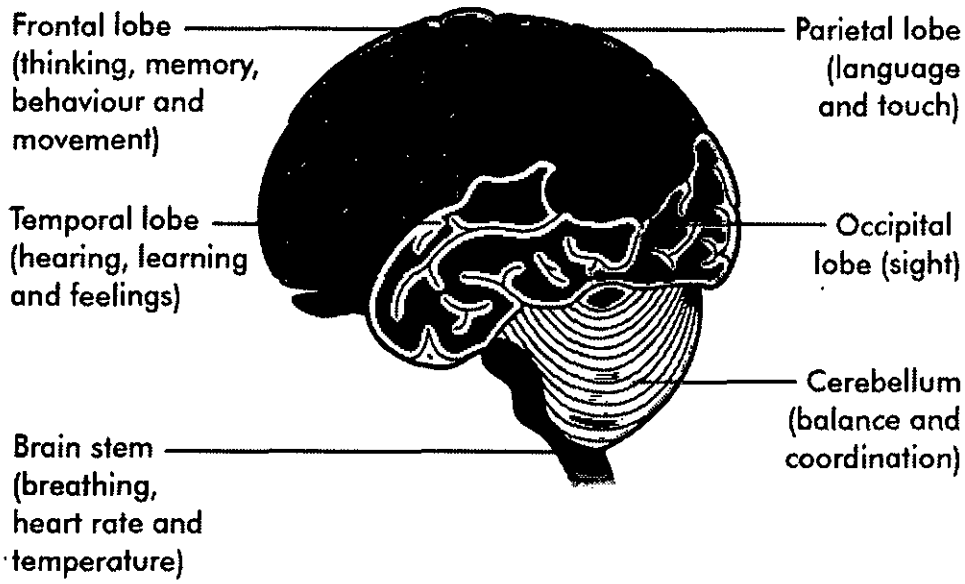


Fig.2. Different Lobes of Cerebrum and their function

Thalamus is olive shaped structure which performs sensory functions. It directs sensory input from the eyes, ears, tongue and from other sense organs.

Hypothalamus is located below the thalamus as the name suggests. It is important in monitoring hormone concentrations, water concentrations, temperature of the body etc.

Midbrain

It is a small part of the brain. It is associated with Vison, Hearing, Sleep, Arousal, Temperature etc.

Hindbrain

It consists of Cerebellum, Pons and Medulla Oblongata.

- Cerebellum is involved in controlling attention, language, equilibrium, posture, etc.
- Pons controls digestive and respiratory movements.
- Medulla Oblongata connects skull with the spinal cord. It helps in controlling Blood Pressure, Heart Rate, Respiratory Movement, Vomiting etc.

What are Neurons/Nerve Cell?

The structural and the functional unit of brain is **Neuron**. **Neuron** is divided into **Cell Body**, **Axon** and **Dendrites**. Cell body/soma of the neuron contain nucleus. It also contains **Nissl Granules**, composed of endoplasmic reticulum. Dendrites are branched projections from the cell body. Axon is a long, slender in shape that transmits nerve impulse from one neuron to another.

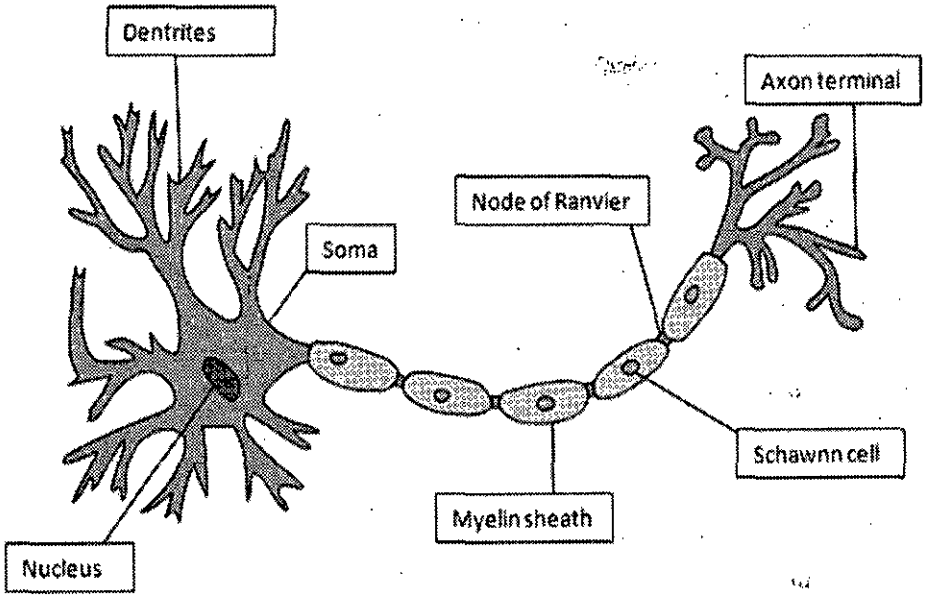
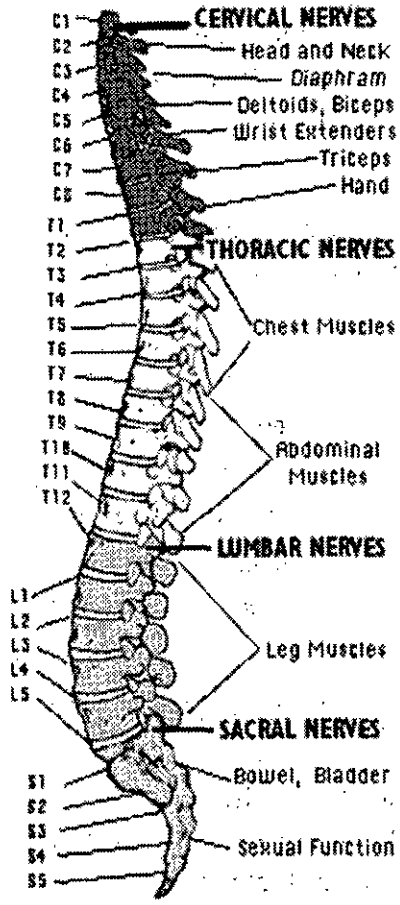


Fig.3. Structure of Neuron

The cells found in axon are known as **Schwann Cell.** Myelin sheath is Schwann cells. Myelin sheath is an electrically insulating layer which is required for fast and efficient nerve impulse transmission. A gap between adjacent **Schawnn Cells** is known as **Nodes of Ranvier**.

Example of different types of Neurons

- **Sensory Neurons** transmit nerve impulses from sensory receptors to central nervous system.
- **Motor Neurons** transmit nerve impulses from central nervous system to muscle or a gland.
- **Inter Neurons** connects different neurons within the brain and spinal cord.



Spinal Cord

It is a thin, tube-like structure which extends from the medulla of the brain to the lumbar region of vertebral column. It helps in transmission of nerve impulses from the brain to the rest of the body. It also coordinates reflex action.

There are 31 pairs of **Spinal Nerves** on each side of the vertebral column. These **Spinal Nerves** are grouped into:

- 8 pairs of cervical nerves
- 12 pairs of thoracic nerves
- 5 pairs of lumbar nerves
- 5 pairs of sacral nerves
- One pair of coccygeal nerves

The **Spinal Cord** is made up of **White Matter** and **Gray Matter**. The butterfly shaped structure present at the center of the spinal cord is known as **Gray Matter**.

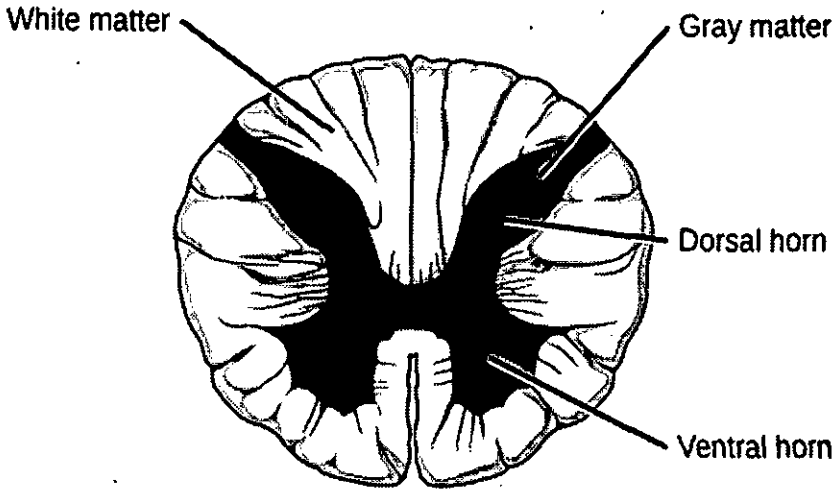


Fig.5. Structure of Spinal Cord

The region around the grey matter is known as **White Matter**. White matter contains nerves that are covered with **Myelin Sheath** whereas grey matter contains nerves without myelin sheath.

What is Reflex Action?

The involuntary response towards any stimulus is known as **Reflex Action**.

What is Reflex Arc?

The pathway of reflex action is known as **Reflex Arc**. Some sensory neurons do not pass directly into the brain; they innervate in the spinal cord. This reduces the time of reflex action.

What is Peripheral Nervous System?

It consists of nerves and ganglia. Ganglia is a cluster of nerves. Peripheral Nervous System connects central nervous system to different organs and limbs.

Peripheral nervous system is divided into **Autonomic Nervous System** and **Somatic Nervous System**. Autonomic nervous system is associated

with communication to internal organs and glands. Somatic nervous system communicates with sensory organs and voluntary muscles.

Autonomic Nervous System is further divided into **Parasympathetic Nervous System** and **Sympathetic Nervous System**.

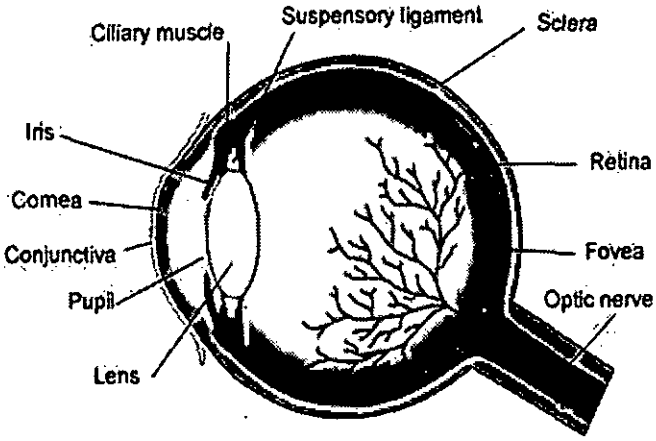
Difference between Sympathetic and Parasympathetic Nervous System

	Sympathetic Nervous System	Parasympathetic Nervous System
Type of Control	Involuntary	Involuntary
Number of neurons per message	Two (Preganglionic shorter than Postganglionic)	Two (Preganglionic longer than Postganglionic)
Location of motor fiber	Thoracolumbar spinal nerves	Cranial (e.g., vagus) and sacral spinal nerves
Neurotransmitter	Norepinephrine	Acetylcholine
Effectors	Smooth and cardiac muscle, glands	Smooth and cardiac muscle, glands

Human Sense Organs

Humans have five sense organs, They are: Eyes, Ears, Nose, Skin and Tongue.

The structure of Eye and Ear is explained below:



Structure of the Eye

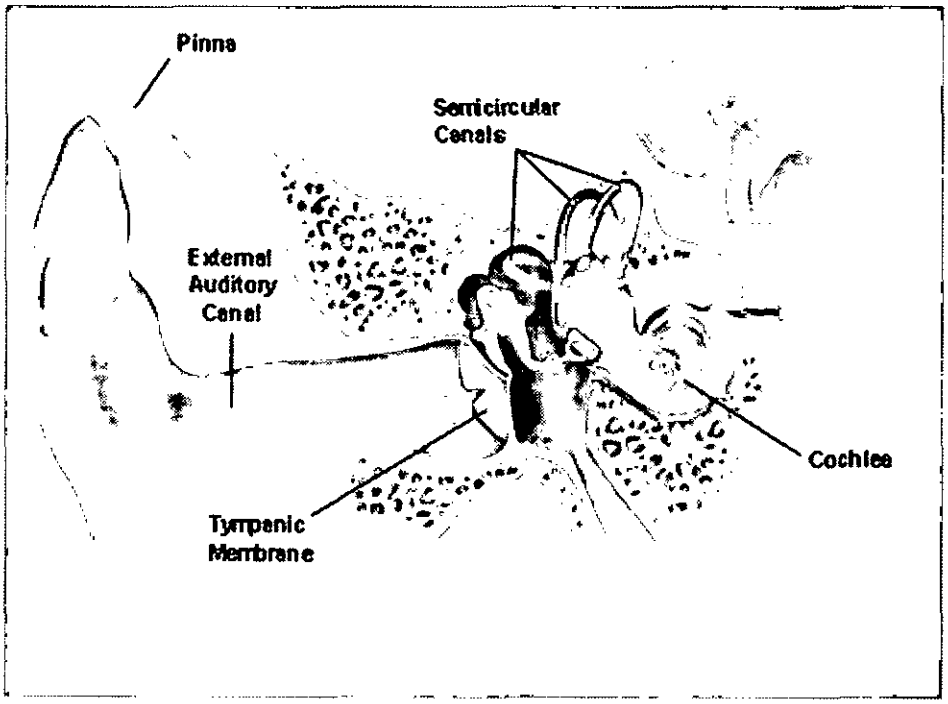
Eye is a sense organ for sight. It consists of three layers: **Outermost Sclera**, **Middle Choroid** which is supplied with blood vessels and **Inner Retina**. The membrane that covers the sclera is known as **Conjunctiva**. Retina contains light sensitive cells known as **Rods** and **Cones.** Rods are cells that allow vision in dim light whereas cones help in colour vision. Light enters the eye via cornea.

The nerve that connect eye to brain is known as **Optic Nerve**. Transparent lens focuses light on retina which helps in vision. The muscles that contracts and relaxes the lens is known as **Suspensory Ligament**. This is dependent on the amount of light that falls on the lens.

The coloured part of the eye that controls the amount of light that enters the eye is known as **Pupil**. Fovea is an exact location where light is focused on the retina.

Structure of Ear

Ear is meant for hearing. The ear is divided into **External Ear, Middle Ear** and **Inner Ear**. The outer part of the ear is known as **Ear Pinna**. Ear pinna is covered by a membrane known as **Tympanic Membrane**.



Structure of the Ear

When sound strikes the pinna it vibrates and vibrations are passed to cochlea which is a part of the inner ear. There are fluid-filled canals present that are attached to cochlea, are known as **Semi-Circular Canals**. These canals help in maintaining equilibrium or balance of the body.

Stimulus and Response

It is defined as any detectable change in the internal or the external environment. The ability of an organism to react against the stimulus is known as **Response**.

Synapse

The junction between the two Nerve cells is known as **Synapse**.

Second Brain in Humans

The Enteric Nervous System is known as **Second Brain** in **Humans**.

Saltatory Conduction

During Nerve Impulse transmission, the nerve impulse jumps over the Nodes of Ranvier. This mode of nerve impulse transmission is known as **Salutatory Conduction**. This is the fast mode of nerve impulse transmission.

13 LOCOMOTION AND MOVEMENT

Locomotion and Movement

Have you ever wondered how a dancer performs intricate dance steps or how a swimmer skilfully does a butterfly stroke? The muscles of our body work simultaneously with one another and with the skeletal system to perform the various movements. Our muscles have two functions: to generate motion and force. All these activities are controlled and coordinated by the skeletal, muscular and nervous system. The human body is capable of a wide range of movements from the gentle blinking of eye to running a 20 km marathon. Movement of organism from one place to another in search of food, shelter, mate and to escape from predators is called locomotion. Locomotion has evolutionary significance.

Types of movement

The different types of movements that occur in the cells of our body are amoeboid, ciliary, flagellar and muscular movement.

Amoeboid movement - Cells such as macrophages exhibit amoeboid movement for engulfing pathogens by pseudopodia formed by the streaming movement of the cytoplasm.

Ciliary movement - This type of movement occurs in the respiratory passages and genital tracts which are lined by ciliated epithelial cells.

Flagellar movement - This type of movement occurs in the cells which are having flagella or whip-like motile organelle. The sperm cells show flagellar movement.

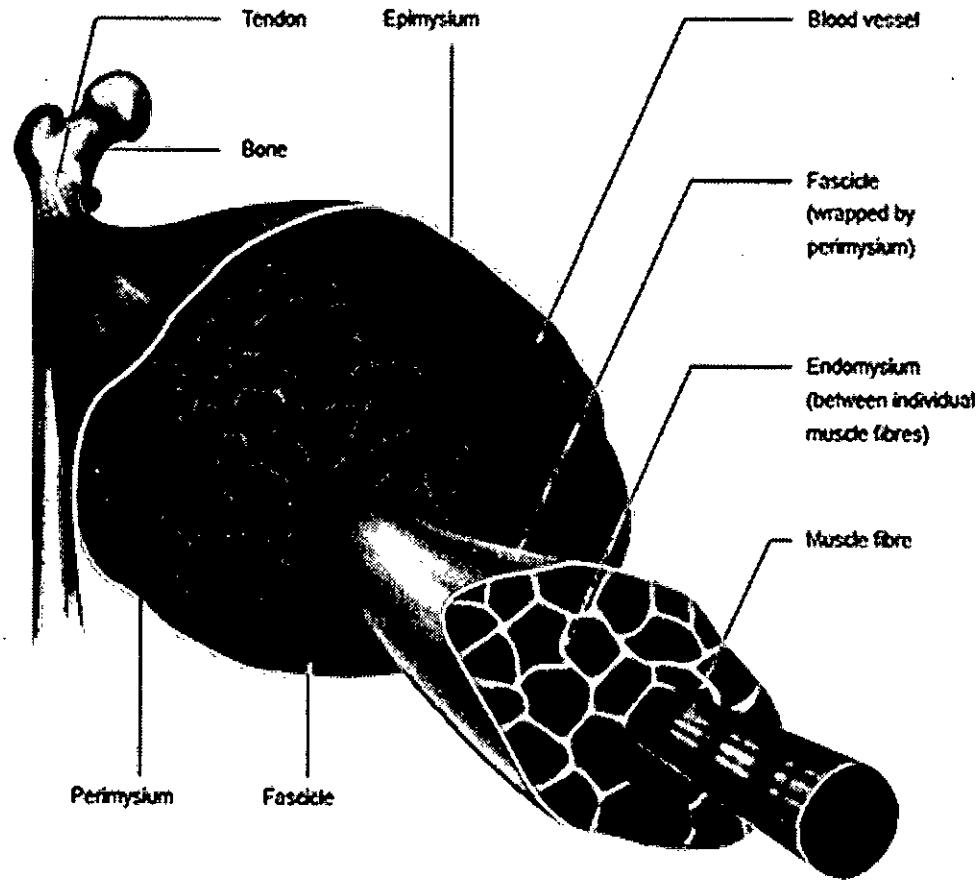
Muscular movement -The movement of hands, legs, jaws, tongue are caused by the contraction and relaxation of the muscle which is termed as the muscular movement

Types of muscles

Muscles are specialized tissues which are derived from the embryonic mesoderm. They are made of cells called myocytes and constitute 40 – 50 percent of body weight in an adult. These cells are bound together by a connective tissue to form a muscular tissue. The muscles are classified into three types, namely skeletal, visceral and cardiac muscles.

Skeletal muscle (Voluntary muscle)

Skeletal muscle is attached to the bone by a bundle of collagen fibres known as **tendon**. Each muscle is made up of bundles of **muscle fibres** called **fascicle**. Each muscle fibre contains hundreds to thousands of rod-like structures called **myofibrils** that run parallel to its length. The connective tissue covering the whole muscle is the **epimysium**, the covering around each fascicle is the **perimysium** and the muscle fibre is surrounded by the **endomysium**. They control the voluntary actions such as walking, running, swimming, writing hence termed as voluntary muscles.

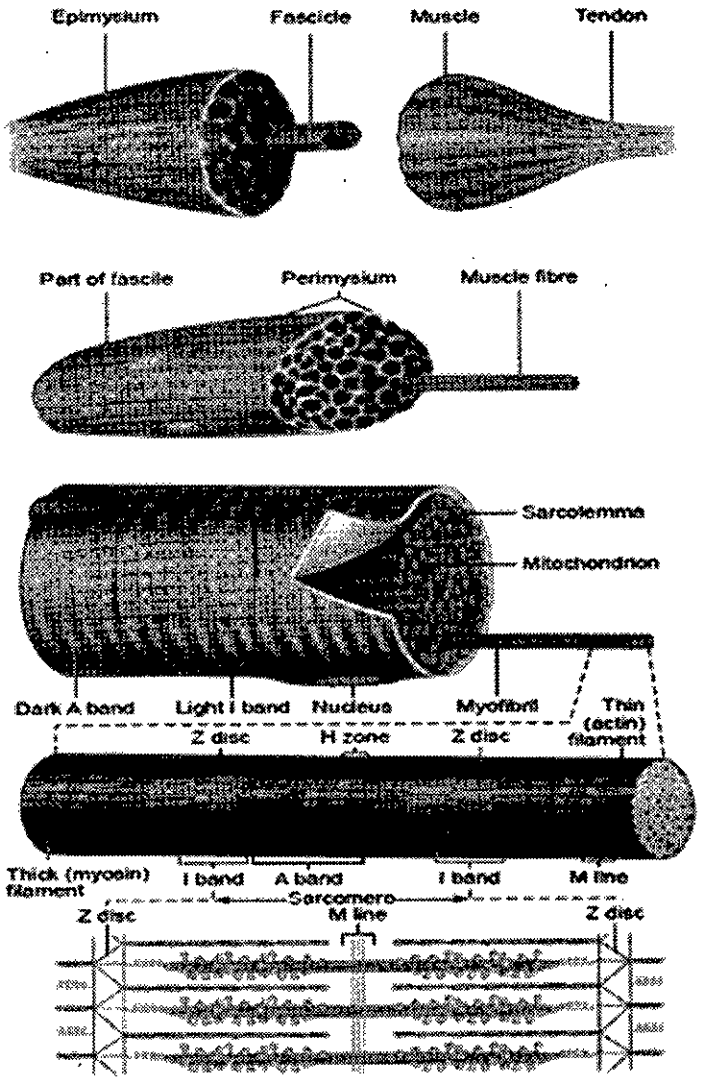


Structure of a skeletal muscle fibre

Each muscle fibre is thin and elongated. Most of them taper at one or both ends. Muscle fibre has multiple oval nuclei just beneath its plasma membrane or sarcolemma. The cytoplasm of the muscle fibre is called the sarcoplasm. It contains glycosomes, myoglobin and sarcoplasmic reticulum. **Myoglobin** is a red-coloured respiratory pigment of the muscle fibre. It is similar to haemoglobin and contains iron group that has affinity towards oxygen and serves as the reservoir of oxygen. **Glycosomes** are the granules of stored glycogen that provide glucose during the period of muscle fibre activity. Actin and myosin are muscle proteins present in the muscle fibre.

General Term	Muscle Equivalent
Cell	Muscle fibre/ Myofibril
Plasma membrane	Sarcolemma
Cytoplasm	Sarcoplasm
Endoplasmic reticulum	Sarcoplasmic reticulum

Along the length of each myofibril there are a repeated series of dark and light bands. The dark **A-bands** (Anisotropic bands) and the light **I-bands** (Isotropic bands) are perfectly aligned with one another. This type of arrangement gives the cell a striated appearance. Each dark band has a lighter region in its middle called the **H-Zone** (H-helles, meaning clear).



Organizational level of a skeletal muscle

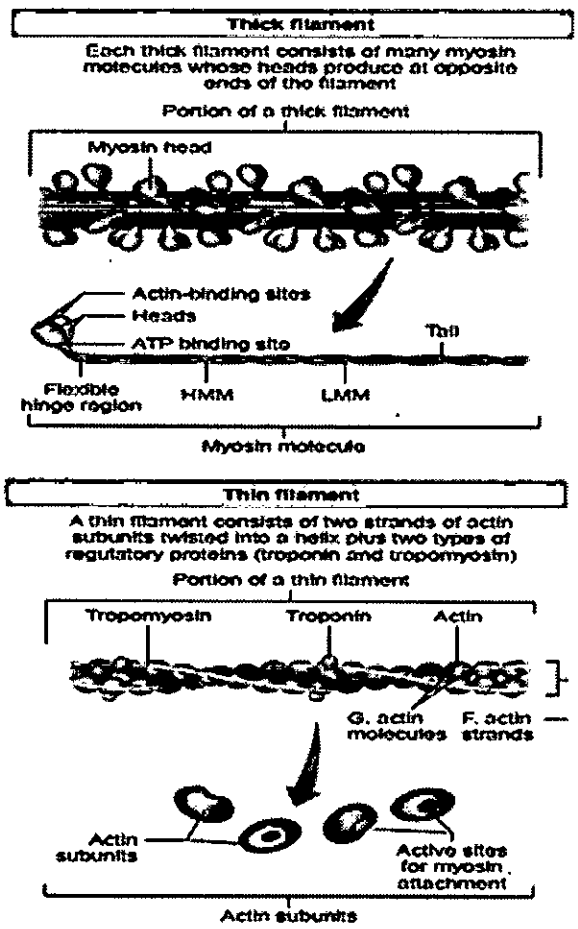
Each H-zone is bisected vertically by a dark line called the M- line (M-for middle). The light I-bands also have a darker mid line area called the **Z–disc** (from the German «Zwischenscheibe» the disc in between the I-bands)

The myofibrils contain the contractile element, the **sarcomere** which is the functional unit of the skeletal muscle. A Sarcomere is the region of a myofibril between two successive Z- discs. It contains an A-band with a half I-band at each end. Inside the sarcomere two types of filaments are present namely the **thick** and **thin filaments**.

The thick filaments extend the entire length of the A-band, the thin filaments extend across the I-band and partly into the A-band. The invagination of the sarcolemma forms transverse tubules**(T–tubules)** and they penetrate into the junction between the A and I-bands

Structure of contractile proteins

Contraction of the muscle depends on the presence of contractile proteins such as **actin** and **myosin** in the myofilaments. The thick filaments are composed of the protein myosin which are bundled together whose heads produce at opposite ends of the filament. Each myosin molecule is made up of a monomer called meromyosin.

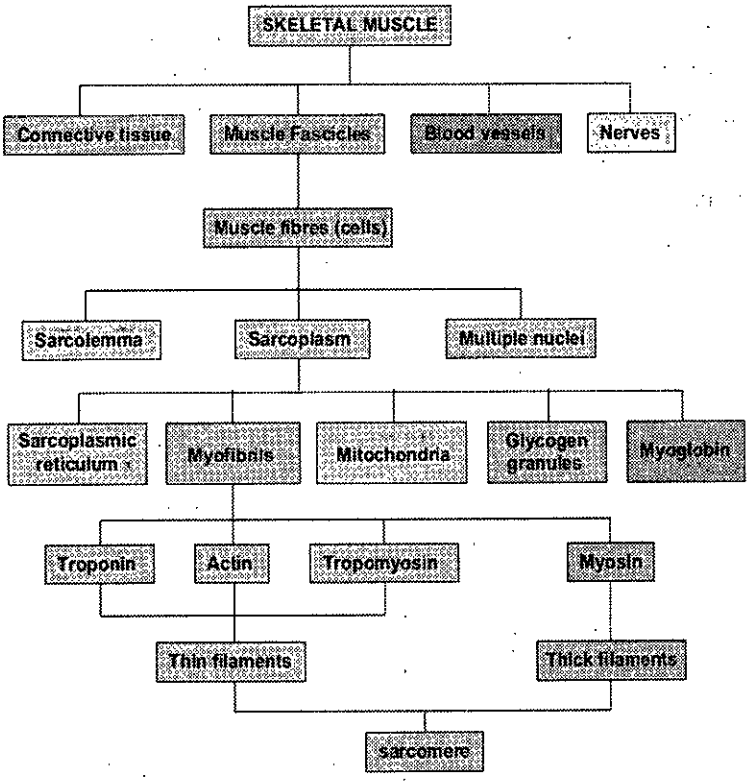


Composition of thick and thin filaments

The meromyosin has two regions, a globular head with a short arm and a tail. The short arm constitutes the heavy meromyosin (HMM). The tail portion forms the light meromyosin (LMM). The head bears an actin- binding site and an ATP- binding site. It also contains ATPase enzyme that split ATP to generate energy for the contraction of muscle. The thin filaments are composed of two inter wined actin molecules. Actin has polypeptide subunits called globular actin or G–actin and filamentous form or F-actin. Each thin filament is made of two F-actins helically wound to each other. Each F-actin is a polymer of monomeric G-actins. It also contains a binding site for myosin. The thin filaments also contain several regulatory proteins like **tropomyosin** and **troponin** which help in regulating the contraction of muscles along with **actin** and **myosin**.

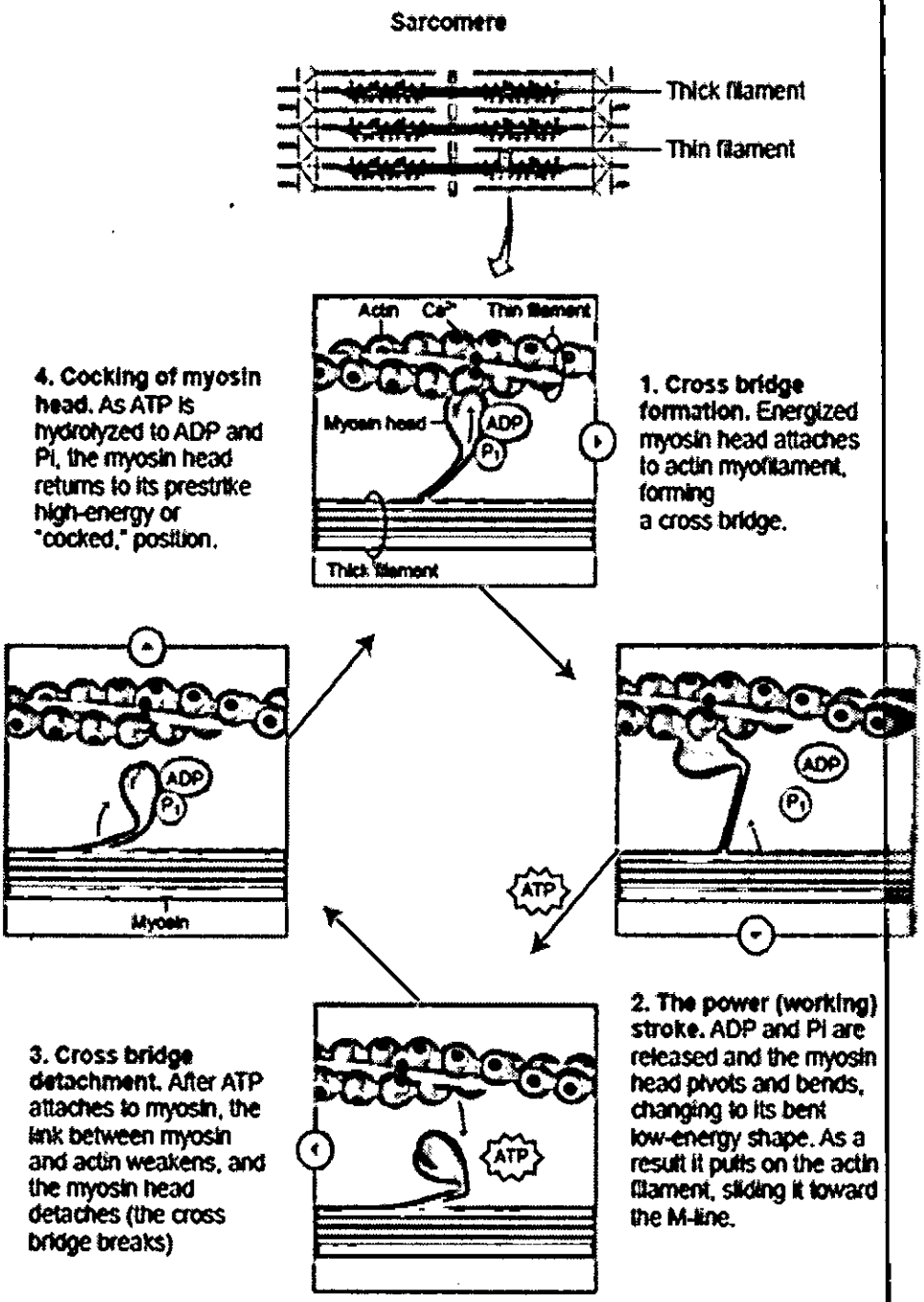
The study of muscle is called myology.

Schematic representation of organizational levels of skeletal muscle.



Mechanism of muscle contraction

Sliding filament theory in 1954, Andrew F. Huxley and Rolf Niedergerke proposed the sliding-filament theory to explain muscle contraction. According to this theory, overlapping actin and myosin filaments of fixed length slide past one another in an energy requiring process, resulting in muscle contraction. The contraction of muscle fibre is a remarkable process that helps in creating a force to move or to resist a load. The force which is created by the contracting muscle is called muscle tension. The load is a weight or force that opposes contraction of a muscle. Contraction is the creation of tension in the muscle which is an active process and relaxation is the release of tension created by contraction.

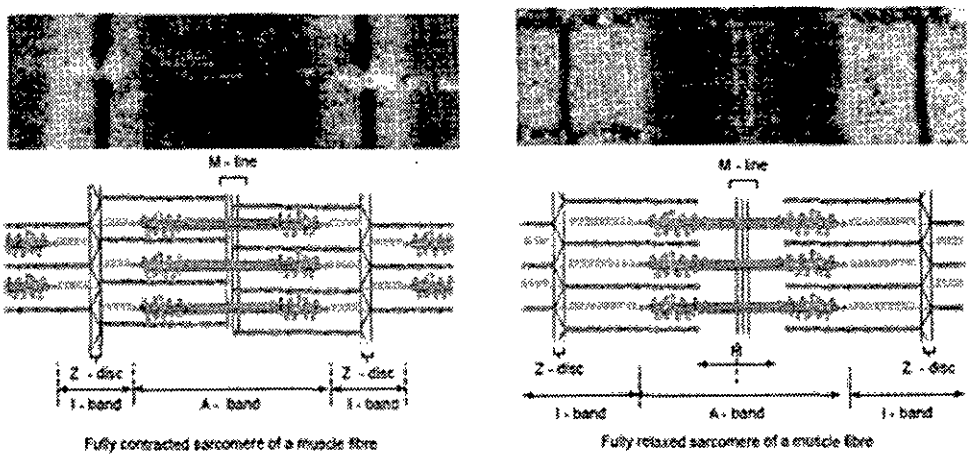


Cross-bridge cycle of muscle contraction

Muscle contraction is initiated by a nerve impulse sent by the central nervous system (CNS) through a motor neuron. The junction between the motor neuron and the sarcolemma of the muscle fibre is called the neuromuscular junction or motor end plate. When nerve impulse reaches a neuromuscular junction, acetylcholine is released. It initiates the opening of multiple gated channels in sarcolemma. The action potential travels along the T-tubules and triggers the release of calcium ions from the sarcoplasmic reticulum. The released calcium ions bind to troponin on thin filaments. The tropomyosin uncovers the myosin-binding sites on thin filaments.

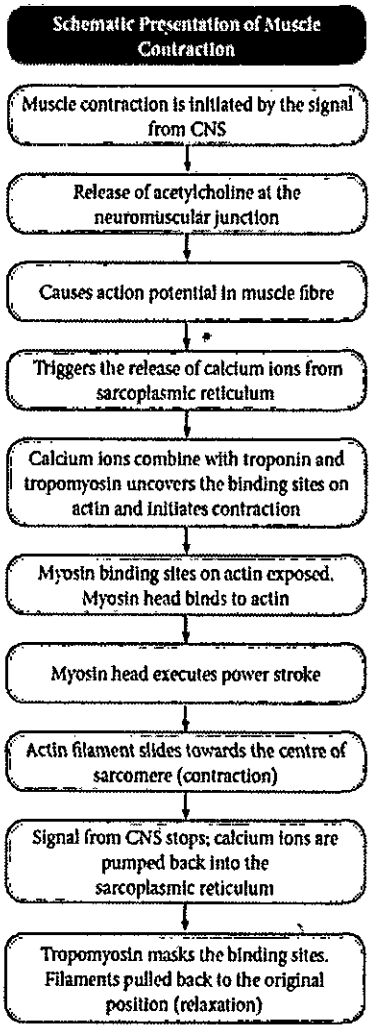
Now the active sites are exposed to the heads of myosin to form a cross-bridge. During cross- bridge formation actin and myosin form a protein complex called actomyosin. Utilizing the energy released from hydrolysis of ATP, the myosin head rotates until it forms a 90° angle with the long axis of the filament. In this position myosin binds to an actin and activates a contraction – relaxation cycle which is followed by a power stroke.

The power stroke (cross-bridge tilting) begins after the myosin head and hinge region tilt from a 90° angle to a 45° angle. The cross-bridge transforms into strong, high-force bond which allows the myosin head to swivel. When the myosin head swivels it pulls the attached actin filament towards the centre of the A-band. The myosin returns back to its relaxed state and releases ADP and phosphate ion. A new ATP molecule then binds to the head of the myosin and the cross-bridge is broken. At the end of each power stroke, each myosin head detaches from actin, then swivels back and binds to a new actin molecule to start another contraction cycle. This movement is similar to the motion of an oar on a boat. At the end of each power stroke, each myosin head detaches from actin, then swivels back and binds to a new actin molecule to start another contraction cycle. The power stroke repeats many times until a muscle fibre contracts. The myosin heads bind, push and release actin molecules over and over as the thin filaments move toward the centre of the sarcomere. The repeatedly formation of cross-bridge cycles cause the sliding of the filaments only but there is no change in the lengths of either the thick or thin filaments.



Sliding filament model of muscle contraction

The Z- discs attached to the actin filaments are also pulled inwards from both the sides, causing the shortening of the sarcomere (i.e. contraction). This process continues as long as the muscle receives the stimuli and a steady flow of calcium ions. When motor impulse stops, the calcium ions are pumped back into the sarcoplasmic reticulum, results in the masking of the active sites of the actin filaments. The myosin head fails to bind with the active sites of actin and these changes cause the return of Z- discs back to their original position, i.e. relaxation.



Types of skeletal muscle contraction

There are two primary types of muscle contractions. They are **isotonic contraction** and **isometric contraction**. The types of contractions depend on the changes in the length and tension of the muscle fibres at the time of its contraction.

Isotonic contraction (iso- same, ton-weight/resistance)

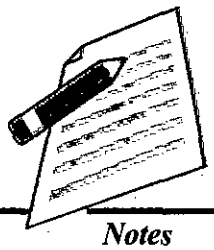
In isotonic contraction the length of the muscle changes but the tension remains constant. Here, the force produced is unchanged. Example: lifting dumbbells and weightlifting.

Isometric contraction (iso- same, metric-distance)

In isometric contraction the length of the muscle does not change but the tension of the muscle changes. Here, the force produced is changed. Example: pushing against a wall, holding a heavy bag.

Types of skeletal muscle fibres

The muscle fibres can be classified on the basis of their rate of shortening, either fast or slow and the way in which they produce the ATP needed for contraction, either oxidative or glycolytic. Fibres containing myosin with high



ATPase activity are classified as fast fibres and with lower ATPase activity are classified as slow fibres. Fibres that contain numerous mitochondria and have a high capacity for oxidative phosphorylation are classified as **oxidative fibres**. Such fibres depend on blood flow to deliver oxygen and nutrients to the muscles. The oxidative fibres are termed as **red muscle fibres**. Fibres that contain few mitochondria but possess a high concentration of glycolytic enzymes and large stores of glycogen are called **glycolytic fibres**. The lack of myoglobin gives pale colour to the fibres, so they are termed as **white muscle fibres**.

Skeletal muscle fibres are further classified into three types based on the above classification. They are slow – oxidative fibres, fast – oxidative fibres and fast – glycolytic fibres.

1. **Slow – oxidative fibres** have low rates of myosin ATP hydrolysis but have the ability to make large amounts of ATP. These fibres are used for prolonged, regular activity such as long-distance swimming. Long – distance runners have a high proportion of these fibres in their leg muscles.
2. **Fast – oxidative fibres** have high myosin ATPase activity and can make large amounts of ATP. They are particularly suited for rapid actions.
3. **Fast – glycolytic fibres** have myosin ATPase activity but cannot make as much ATP as oxidative fibres, because their source of ATP is glycolysis. These fibres are best suited for rapid, intense actions, such as short sprint at maximum speed

Properties of Skeletal Muscles

The four major properties of skeletal muscles are

Excitability/Irritability—The ability to respond or contract in response to chemical and electrical signals.

Contractility—The ability to shorten which causes movement of the structures to which the muscles are attached.

Conductivity—Stimulus acting on one region of muscle fibre spreads to all parts of the muscle is known as conductivity.

Elasticity/Distensibility—The ability to return to the original resting length after a muscle has been stretched.

Skeletal system and its function

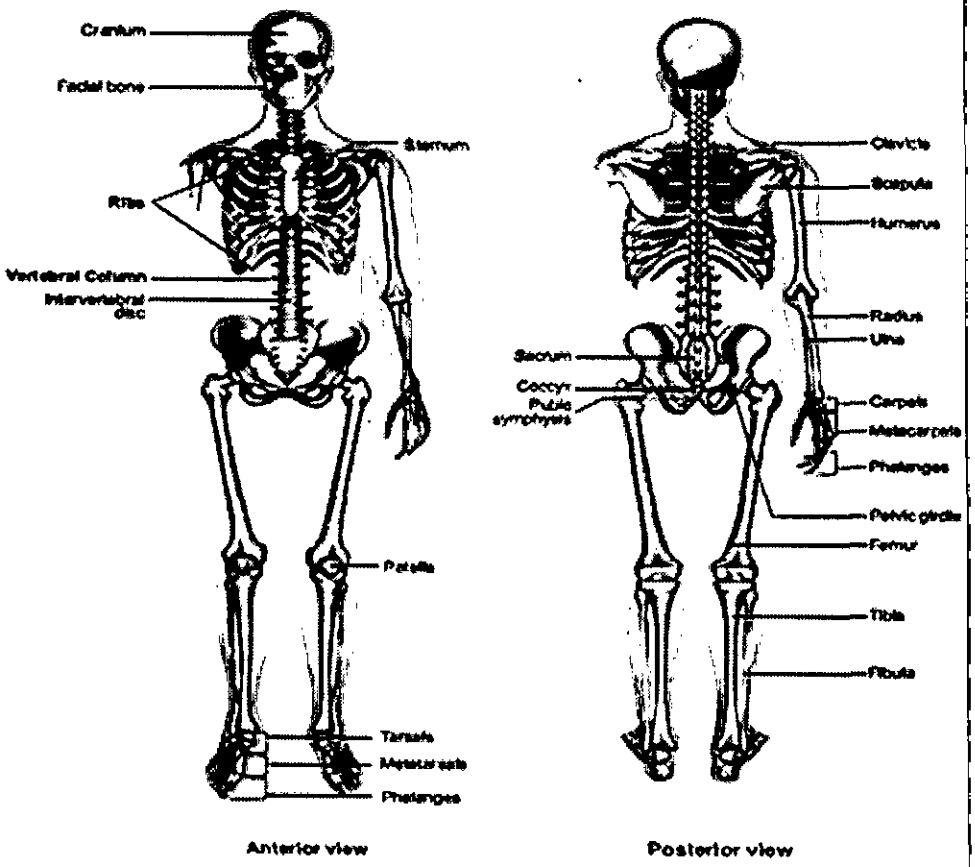
The skeletal system is constituted by a framework of bones and cartilages. It is derived from the embryonic **mesoderm**. Muscles are attached to the bones by means of tendons and provide the necessary force required for the bones of the skeleton to operate as levers. There are three types of skeletal systems. They are,

Hydrostatic skeleton, which is found in soft-bodied invertebrates. It is a fluid filled-cavity encircled by muscles (e.g., Earth worm).

Exoskeleton, which is found in invertebrates. It is a rigid hard case present outside the body of animals (e.g., Cockroach).

Endoskeleton, which is found inside the body of vertebrates. It is composed of bones and cartilages, surrounded by muscles. (e.g. Human being).

In human beings, the skeletal system is made up of 206 bones and cartilages. It is grouped into two principal divisions – the **axial skeleton** and the **appendicular skeleton**. The axial skeleton consists of 80 bones and the appendicular skeleton consists of 126 bones Table.1.



Human skeletal system

Concentration of substances in the blood plasma and in the glomerular filtrate

Substance	Concentration in blood Plasma/g dm^{-3}	Concentration in glomerular filtrate/g dm^{-3}
Water	900	900
Proteins	80.0	0.05
Aminoacids	0.5	0.5
Glucose	1.0	1.0
Urea	0.3	0.3
Uric acid	0.04	0.04
Creatinine	0.01	0.01
Inorganic ions (mainly Na^+, K^+ and Cl^-)	7.2	7.2

Functions of skeletal system

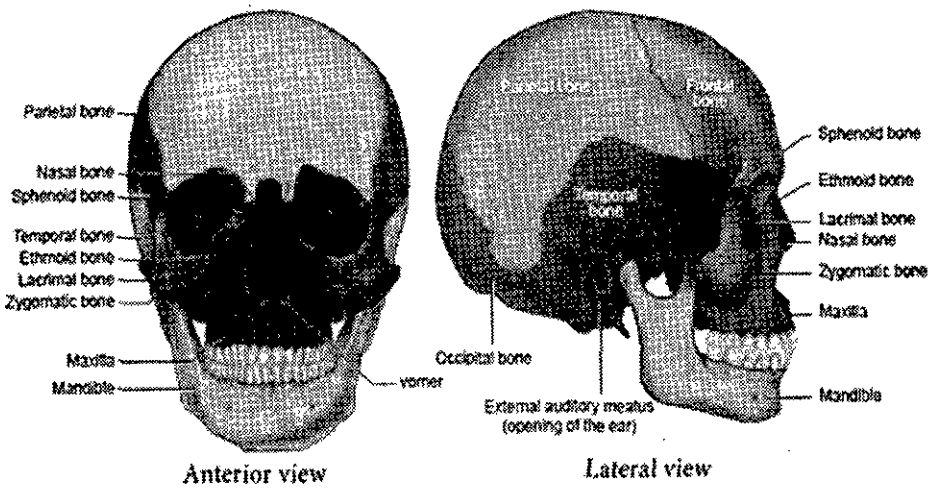
- Support –It forms a rigid framework and supports the weight of the body against gravity.
- Shape - It provides and maintains the shape of the body.
- Protection – It protects the delicate internal organs of the body.
- Acts as reservoir – It stores minerals such as calcium and phosphate. Fat (Triglyceride) is stored in yellow bone marrow and represents a source of stored energy for the body.
- Locomotion – It acts as lever along with the muscles attached to it.
- Strength – It can withstand heavy weight and absorbs mechanical shock.
- As a haemopoietic tissue – Red and White blood cells are produced in the bone marrow of the ribs, spongy bones of vertebrae and extremities of long bones.

The Axial skeleton

Axial skeleton forms the main axis of the body. It consists of the skull, hyoid bone, vertebral column and thoracic cage.

(a) The Skull

The skull is composed of two sets of bones cranial and facial bones. It consists of 22 bones of which 8 are cranial bones and 14 are facial bones. The cranial bones form the hard protective outer covering of the brain and called the brain box. The capacity of the cranium is 1500 cm^3. These bones are joined by sutures which are immovable. They are a **paired parietal, paired temporal** and **individual bones** such as the **frontal, sphenoid, occipital and ethmoid**.



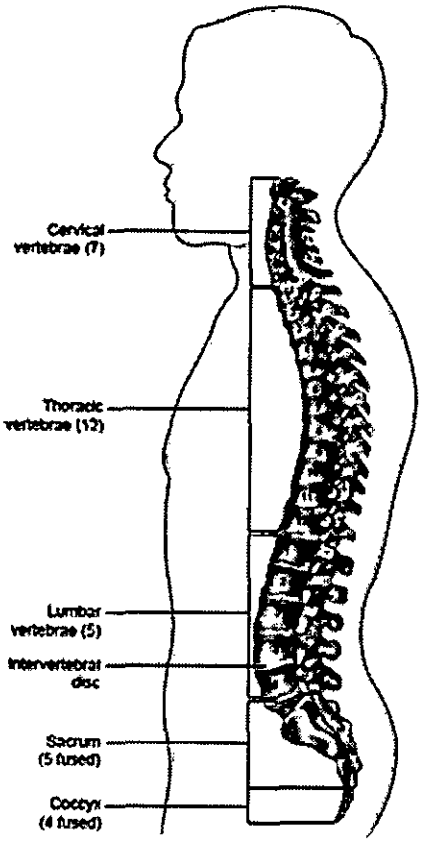
Structure of the skull

The large hole in the temporal bone is the **external auditory meatus**. In the facial bone's **maxilla, zygomatic, palatine, lacrimal, nasal are** paired bones whereas **mandible** or **lower jaw** and **vomer** are **unpaired**

bones. They form the front part of the skull. A single U-shaped **hyoid bone** is present at the base of the buccal cavity. It is the only one bone without any joint. Each middle ear contains three tiny bones - **malleus**, **incus** and **stapes** collectively are called **ear ossicles.** The upper jaw is formed of the **maxilla** and the lower jaw is formed of the **mandible**. The upper jaw is fused with the cranium and is immovable. The lower jaw is connected to the cranium by muscles and is movable. The most prominent openings in the skull are **the orbits** and **the nasal cavity**. **Foramen magnum** is a large opening found at the posterior base of the skull. Through this opening the medulla oblongata of the brain descends down as the spinal cord.

(b) The Vertebral Column

Vertebral column is also called the back bone. It consists of 33 serially arranged vertebrae which are interconnected by cartilage known as intervertebral disc. The vertebral column extends from the base of the skull to the pelvis and forms the main frame work of the trunk. The vertebral column has five major regions. They are, **the Cervical**, **Thoracic**, **Lumbar**, **Sacrum** (5 sacral vertebrae found in the infant which are fused to form one bone in the adult) and **Coccyx** (4 coccygeal vertebrae found in the infant which are fused to form one bone in the adult).



Vertebral Column

Each vertebra has a central hollow portion, the neural canal, through which the spinal cord passes. The first vertebra is called as **the atlas** and the second vertebra is called as **the axis**. Atlas is articulated with the occipital condyles.

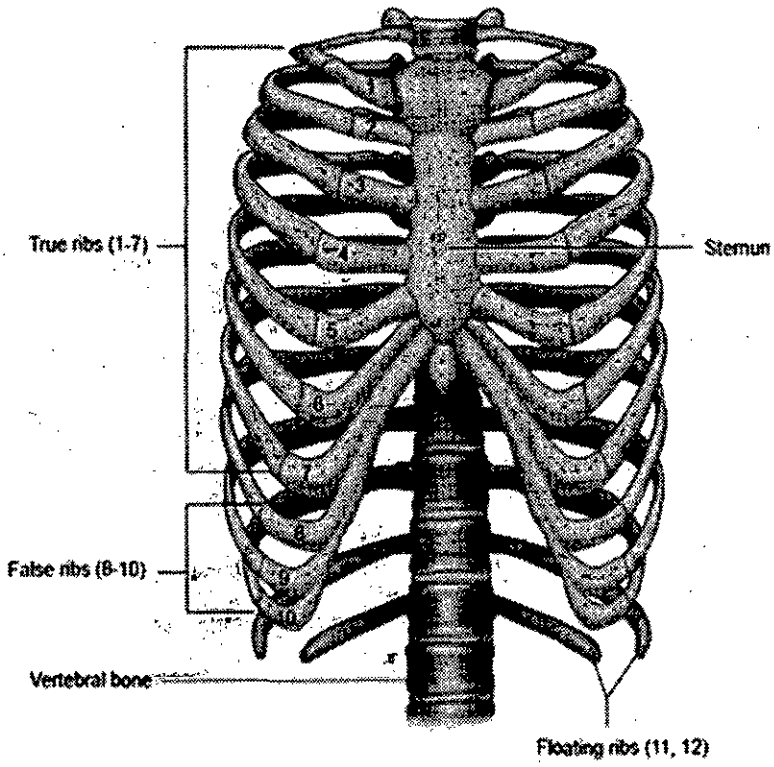
The vertebral column protects the spinal cord, supports the head and serves as the point of attachment for the ribs and musculature of the back.

(c) The Sternum (Chest bone)

Sternum is a flat bone on the mid ventral line of the thorax. It provides space for the attachment of the thoracic ribs and abdominal muscles.

(d) The Rib cage

There are 12 pairs of ribs. Each rib is a thin flat bone connected dorsally to the vertebral column and ventrally to the sternum. It has two articulation surfaces on its dorsal end, hence called bicephalic. The first seven pairs of ribs are called **'true ribs'** or **vertebro–sternal ribs**. Dorsally they are attached to the thoracic vertebrae and ventrally connected to the sternum with the help of hyaline cartilages. The 8th, 9th and 10th pairs of ribs do not articulate directly with the sternum but joined with the cartilaginous (hyaline cartilage) part of the seventh rib. These are called **'false ribs'** or **vertebro -chondral ribs**. The last 11th and 12th pairs of ribs are not connected ventrally. Therefore, they are called as **'floating ribs'** or **vertebral ribs**. Thoracic vertebrae, ribs and sternum together form the ribcage.



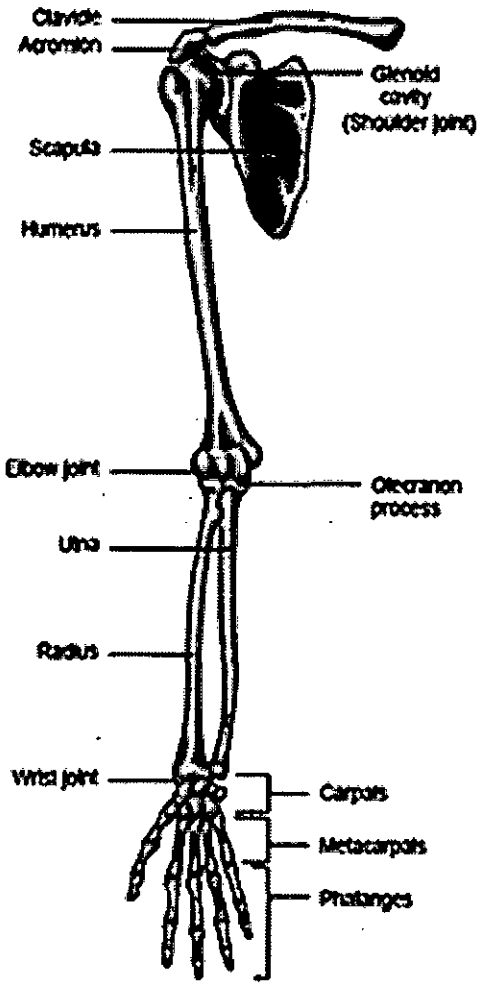
Rib cage

The Appendicular skeleton

The bones of the upper and lower limbs along with their girdles constitute the appendicular skeleton. The appendicular skeleton is composed of 126 bones.

(a) The Pectoral girdle

The upper limbs are attached to the pectoral girdles. These are very light and allow the upper limbs a degree of mobility not seen anywhere else in the body. The girdle is formed of two halves. Each half of the pectoral girdle. consists of **a clavicle** or **collar bone** and a **scapula**. The scapula is a large, thin, triangular bone situated in the dorsal surface of the ribcage between the second and seventh ribs. It has a slightly elevated ridge called the spine which projects as a flat, expanded process called the **acromion**. The clavicle articulates with this process. Below the acromion is a depression called the **glenoid cavity** which articulates with the head of the humerus to form the shoulder joint. Each clavicle is a long slender bone with two curvatures which lies horizontally and connects axial skeleton with appendicular skeleton.



Pectoral girdle with upper limb

The Upper limb

The upper limb consists of 30 separate bones and is specialized for mobility. The skeleton of the arm, the region between the shoulder and elbow is the **humerus**. The head of humerus articulates with the **glenoid cavity** of the scapula and forms the shoulder joint.

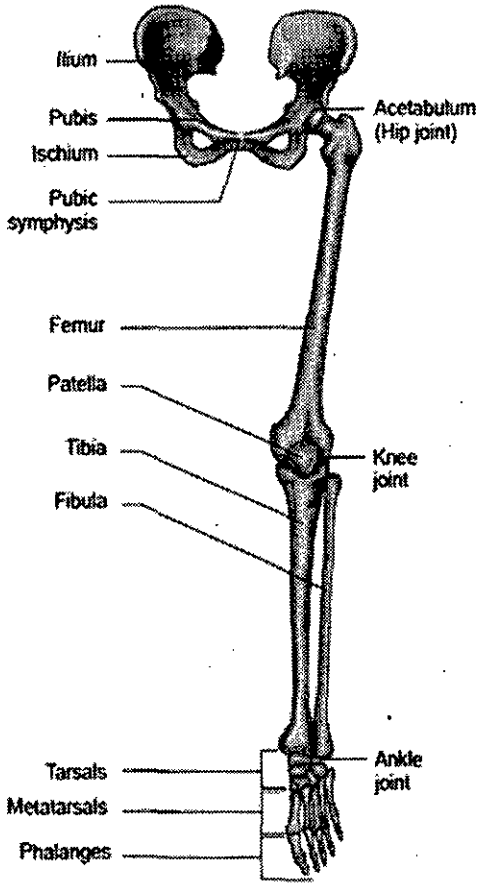
The distal end of humerus articulates with the two forearm bones the radius and ulna. The forearm is the region between the elbow and the wrist. Olecranon process is situated at the upper end of the ulna which forms the pointed portion of the elbow. The hand consists of carpals, metacarpals and phalanges.

Carpals, the wrist bones, 8 in number are arranged in two rows of four each. The anterior surface of the wrist has tunnel-like appearance, due to the arrangement of carpals with the ligaments. This tunnel is termed as **carpal tunnel**.

Metacarpals, the palm bones are 5 in number and **phalanges** the digits bones are 14 in number.

(b) Pelvic Girdle

The pelvic girdle is a heavy structure specialized for weight bearing. It is composed of two hip bones called coxal bones that secure the lower limbs to the axial skeleton. Together, with the sacrum and coccyx, the hip bones form the basin-like bony pelvis.



Pelvic girdle with lower limb

Each coxal bone consists of three fused bones, **ilium, ischium** and **pubis**. At the point of fusion of ilium, ischium, and pubis a deep hemispherical socket called the acetabulum is present on the lateral surface of the pelvis. It receives the head of the femur or thigh bone at the hip joint and helps in the articulation of the femur.

Ventrally the two halves of the pelvic girdle meet and form the **pubic symphysis** containing fibrous cartilage.

The **ilium** is the superior flaring portion of the hip bone. Each ilium forms a secure joint with the sacrum posteriorly. The **ischium** is a curved bar of bone. The V-shaped **pubic bones** articulate anteriorly at the **pubic symphysis**. The pelvis of male is deep and narrow with larger heavier bones and the female is shallow, wide and flexible in nature, and this helps during pregnancy which is influenced by female hormones.

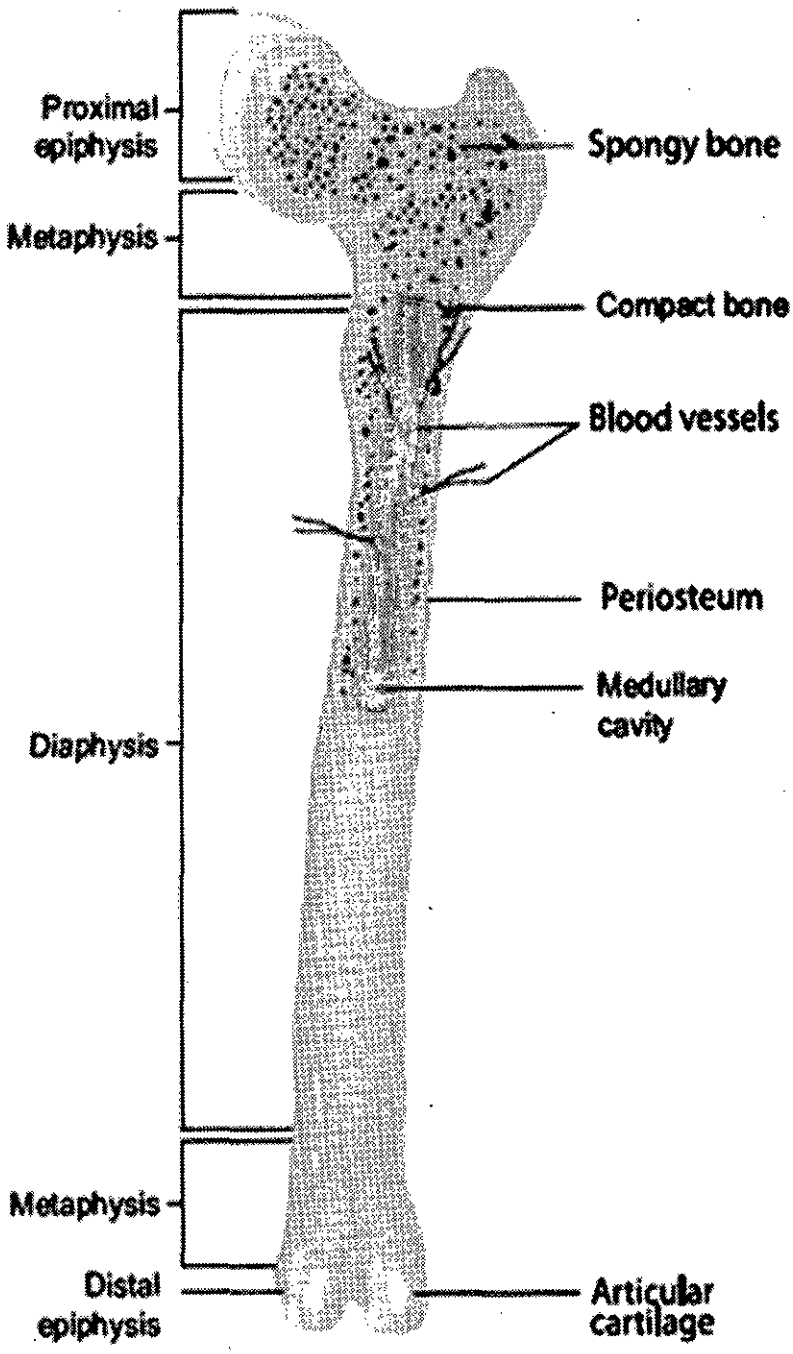
The Lower limb

The lower limb consists of 30 bones which carries the entire weight of the erect body and is subjected to exceptional forces when we jump or run.

The bones of the lower limbs are thicker and stronger than the upper limbs. The three segments of each lower limb are **the thigh**, **the leg** or **the shank** and **the foot**. **The femur** is the single bone of the thigh. It is the largest, longest and strongest bone in the body. The head of femur articulates with **the acetabulum** of the pelvis to form the hip joint. Two parallel bones, **the tibia** and **fibula**, form the skeleton of the shank. A thick, triangular **patella** forms the knee cap, which protects the knee joint anteriorly and improves the leverage of thigh muscles acting across the knee. The foot includes the bones of ankle, **the tarsus**, **the metatarsus** and **the phalanges or toe bones**. The foot supports our body weight and acts as a lever to propel the body forward, while walking and running. **The tarsus** is made up of seven bones called tarsals. **The metatarsus** consists of five bones called metatarsals. The arrangement of the metatarsals is parallel to each other. There are 14 **phalanges** in the toes which are smaller than those of the fingers.

Structure of a typical long bone

A typical long bone has a diaphysis, epiphyses (singular-epiphysis) and membranes. A tubular diaphysis or shaft, forms the long axis of the bone. It is constructed of a thick collar of compact bone that surrounds a central medullary cavity or marrow cavity. The epiphyses are the bone ends. Compact bone forms the exterior of epiphyses and their interior contains spongy bone with red marrow. The region where the diaphysis and epiphyses meet is called the metaphysis. The external surface of the entire bone except the joint surface is covered by a double-layered membrane called the periosteum. The outer fibrous layer is dense irregular connective tissue. The inner osteogenic layer consists of osteoblasts (bone- forming cells) which secrete bone matrix elements and osteoclasts (bone-destroying cells) .



Structure of a long bone

In addition, there are primitive stem cells, osteogenic cells, that give rise to the osteoblasts. The periosteum is richly supplied with nerve fibres, lymphatic vessels and blood vessels. Internal bone surfaces are covered with a delicate connective tissue membrane called the endosteum. The endosteum covers the trabeculae of spongy bone and lines the canals that pass through the compact bone. It also contains both osteoblasts and osteoclasts. Between the epiphysis and diaphysis **epiphyseal plate** or **growth plate** is present.

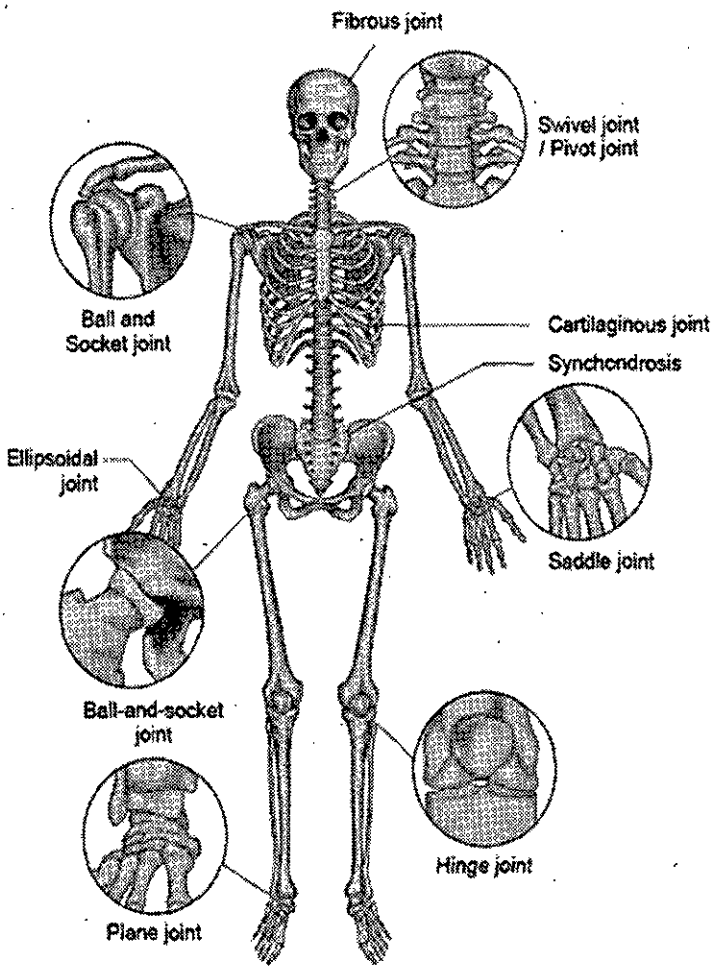
Table:1 Bones of the skeletal system

Skeleton	Name of Bone		Number of bones	Total number of bones
Axial skeleton (80 bones)	Skull	Cranium	8	29
		Facial bone	14	
		Bones of middle ear	6 (2 × 3)	
		Hyoid bone	1	
	Vertebral column	Cervical	7	26 (in adults)
		Thoracic	12	
		Lumbar	5	
		Sacral	5 bones fused to 1 bone	
		Coccyx	4 bones fused to 1 bone	
	Sternum		1	1
	Ribs		12 × 2 = 24	24
Appendicular skeleton (126bones)	Fore limb	Humerus	1	60 (2 × 30)
		Radius	1	
		Ulna	1	
		Carpals	8	
		Metacarpals	5	
		Phalanges	14	
	Hind limb	Femur	1	60 (2 × 30)
		Tibia	1	
		Fibula	1	
		Tarsal	7	
		Metatarsals	5	
		Phalanges	14	
		Patella (Knee bone)	1	
	Pectoral girdle	Scapula	1	4 (2 × 2)
		Clavicle	1	
	Pelvic girdle	Innominate (Ilium, ischium and pubis fused into one bone)	1	2 (1 × 2)

Total number of bones in adults = 206

Types of joints

Joints are essential for all types of movements performed by the bony parts of the body. The joints are points of contact between bones.



Types of joints

Sometimes they are playing a protective role in the process. Force generated by the muscles are used to carry out the movement through joints which helps human functional activity of daily living and ambulation. The joint acts as a fulcrum of a lever.

(i) **Fibrous joints or Synarthroses:** They are immovable fixed joints in which no movement between the bones is possible. Sutures of the flat skull bones are fibrous joints.

(ii) **Cartilaginous joints or Amphiarthroses:** They are slightly movable joints in which the joint surfaces are separated by a cartilage and slight movement is only possible. E.g., Joints of adjacent vertebrae of the vertebral column.

(iii) **Synovial joints or Diarthroses joints:** They are freely movable joints; the articulating bones are separated by a cavity which is filled with synovial fluid. E.g., Pivot joint – between atlas and axis Plane/gliding joint – between the carpals Saddle joint – between the carpal and metacarpal

Ball and socket joint – between humerus and pectoral girdle

Hinge joint – knee joint

Condyloid or Angular or Ellipsoid – joint between radius and carpal

Disorders of muscular and skeletal system

(a) Disorders of muscular system

Myasthenia gravis: An autoimmune disorder affecting the action of acetylcholine at neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscles. Acetylcholine receptors on the sarcolemma are blocked by antibodies leading to weakness of muscles. When the disease progresses, it can make chewing, swallowing, talking and even breathing difficult.

Tetany: Rapid muscle spasms occur in the muscles due to deficiency of parathyroid hormone resulting in reduced calcium levels in the body.

Muscle fatigue: Muscle fatigue is the inability of a muscle to contract after repeated muscle contractions. This is due to lack of ATP and accumulation of lactic acid by anaerobic breakdown of glucose

Atrophy: A decline or cessation of muscular activity results in the condition called atrophy which results in the reduction in the size of the muscle and makes the muscle to become weak, which occurs with lack of usage as in chronic bedridden patients.

Muscle pull: Muscle pull is actually a muscle tear. A traumatic pulling of the fibres produces a tear known as sprain. This can occur due to sudden stretching of muscle beyond the point of elasticity. Back pain is a common problem caused by muscle pull due to improper posture with static sitting for long hours

Muscular dystrophy:

The group of diseases collectively called the muscular dystrophy are associated with the progressive degeneration of skeletal muscle fibres, weakening the muscles and leading to death from lung or heart failure. The most common form of muscular dystrophy is called Duchene Muscular Dystrophy (DMD).

(b) Disorders of skeletal system

Arthritis and osteoporosis are the major disorders of skeletal system.

1. **Arthritis:** Arthritis is an inflammatory (or) degenerative disease that damages the joints. There are several types of arthritis.
   - (i) **Osteoarthritis:** The bone ends of the knees and other freely movable joints wear away as a person age. The joints of knees, hip, fingers and vertebral column are affected.
   - (ii) **Rheumatoid arthritis:** The synovial membranes become inflamed and there is an accumulation of fluid in the joints. The joints swell and become extremely painful. It can begin at any age but symptoms usually emerge before the age of fifty.
   - (iii) **Gouty arthritis or gout:** Inflammation of joints due to accumulation of uric acid crystals or inability to excrete it. It gets deposited in synovial joints.

2. **Osteoporosis:** It occurs due to deficiency of vitamin D and hormonal imbalance. The bone becomes soft and fragile. It causes rickets in children and osteomalacia in adult females. It can be minimized with adequate calcium intake, vitamin D intake and regular physical activities.

Benefits of regular Exercise

Exercise and physical activity fall into four basic categories. Endurance, strength, balance and flexibility.

Endurance or aerobic activities increase the breathing and heart rate. They keep the circulatory system healthy and improve overall fitness.

Strength exercises make the muscles stronger. They help to stay independent and carry out everyday activities such as climbing stairs and carrying bags.

Balance exercises help to prevent falls which is a common problem in older adults.

Many strengthening exercises also improves balance.

Flexibility exercises help to stretch body muscles for more freedom of joint movements. Regular exercises can produce the follow in beneficial physiological changes:

- The muscles used in exercise grow larger and stronger.
- The resting heart rate goes down.
- More enzymes are synthesized in the muscle fibre
- Ligaments and tendons become stronger.
- Joints become more flexible.
- Protection from heart attack.
- Influences hormonal activity.
- Improves cognitive functions.
- Prevents Obesity.

During muscular exercise, there is an increase in metabolism. The O2 need of the muscles is increased. This requirement is met with more oxygen rich RBCs available to the active sites. There is an increase in heart rate and cardiac output. Along with balanced diet, physical activity plays a significant role in strengthening the muscles and bones.

Bone Fracture

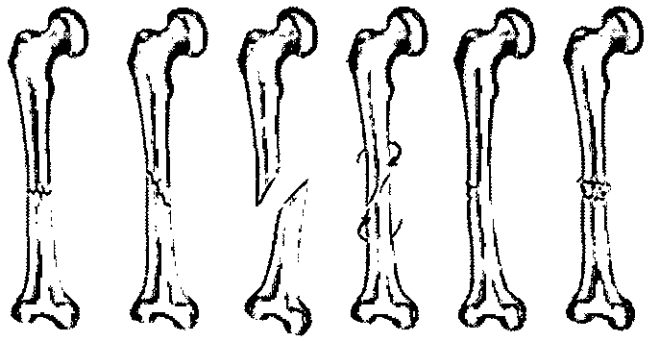
Even though the bones are strong, they are also susceptible to fractures or breaks. Fractures may be classified based on the

(i) Positioning of the bone ends

(ii) completeness of the break

(iii) orientation of the break relative to the long axis of the bone and

(iv) penetration through the skin. In addition to the above classifications, all fractures can be described in terms of the location of the fracture, the external appearance of the fracture or the nature of the break.



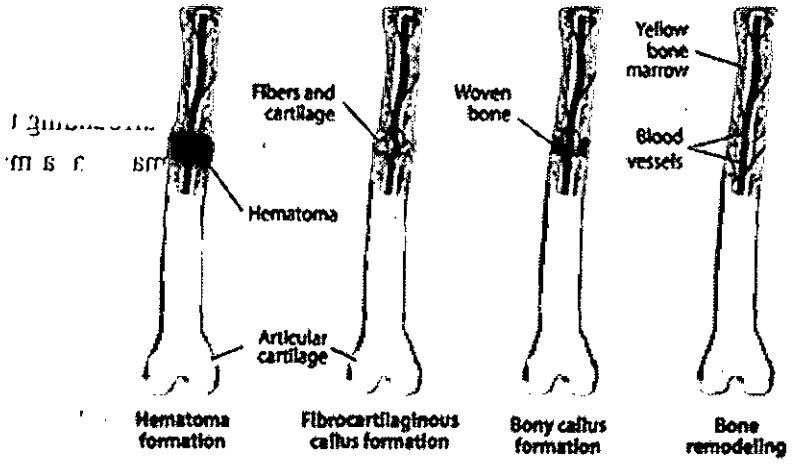
Types of bone fracture

The following are the common types of fractures,

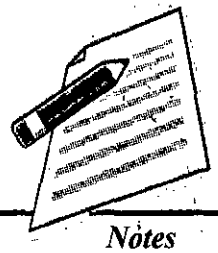
1. Tranverse - A fracture that is at right angle to the bone's long axis.
2. Oblique non-displaced-A fracture that is diagonal to the bone's long axis and the fractured bone is not displaced from its position.
3. Oblique displaced A fracture that is diagonal to the bone's long axis and the fractured bone is displaced from its position.
4. Spiral - Ragged break occurs when excessive twisting forces are applied to a bone (common sports fracture).
5. Greenstick - Bone breaks incompletely, just like a green twig break. It is common in children, because of the flexibility of the bones.
6. Comminuted – Bone fragmented into three or more pieces. Particularly common in the aged, whose bones are brittle (hard but easily broken).

1. Mechanism and healing of a bone fracture

Bone is a cellular, living tissue capable of growth, self-repair and remodelling in response to physical stresses. In the adult skeleton, bone deposit and bone resorption occur. These two processes together constitute in remodelling of bone. There are four major stages in repairing a simple fracture.



Mechanism and healing of bone fracture



1. **Formation of haematoma**

   When a bone breaks the blood vessels in the bone and surrounding tissues are torn and results in haemorrhage. Due to this a haematoma, a mass of clotted blood forms at the fracture site. The tissues at the site becomes swollen, painful and inflamed. The death of bone cells, occur due to lack of nutrition.

2. **Formation of fibrocartilaginous callus**

   Within a few days several events lead to the formation of soft granulation tissue called callus. Capillaries grow into the haematoma and phagocytic cells invade the area and begin to clean up the debris. Meanwhile the fibroblasts and osteoblasts invade from the nearby periosteum and endosteum and begin reconstructing of the bone. The fibroblasts produce fibres. The chondroblasts secrete the cartilage matrix. Within this repair tissue, osteoblasts begin forming spongy bone. The cartilage matrix later calcifies and forms the fibrocartilaginous callus.

3. **Formation of Bony callus**

   New bone trabeculae begin to appear in the fibro cartilaginous callus. Gradually that is converted into a bony (hard) callus of spongy bone. Bony callus formation continues until a firm union is formed about two months later to a year for complete woven bone formation.

4. **Remodelling of Bone**

   Bony callus formation will be continued for several months. After that the bony callus is remodelled. The excess material on the diaphysis exterior and within the medullary cavity is removed and the compact bone is laid down to reconstruct the shaft walls. The final structure of the remodelled area resembles like the unbroken bony region.

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Summary of the chapter

Movement is one of the significant features of living organisms. The different types of movements are amoeboid movement, ciliary movement, flagellar movement and muscular movement. Three types of muscles are present in human beings. They are the skeletal muscle, visceral muscle and cardiac muscle. The skeletal muscles are attached to the bones by tendons.

The most striking microscopic feature of skeletal muscle is a series of light and dark bands. The muscles exhibit the properties such as excitability, contractibility, conductibility and elasticity. There are two types of muscle contraction. They are isotonic and isometric contractions.

The skeletal system consists of a frame work of bones and cartilages. The skeletal system is grouped into two principal divisions: the axial skeleton and the appendicular skeleton. There are three types of joints present in the body: fibrous, cartilaginous and synovial joints.

The disorders related to muscular system are myasthenia gravis, muscular dystrophy, tetany, muscle fatigue, muscle pull, atrophy and rigor mortis. The disorders of the skeletal system are arthritis and osteoporosis. Regular body exercise keeps the body fit and healthy.

A typical long bone has a diaphysis (shaft), epiphyses (singular-epiphysis) and membranes. Even though the bones are strong, they are also susceptible to fractures or breaks. There are four major stages in repairing a simple fracture.

Physiotherapy is the therapeutic exercise to make the limbs work near normally

EXERCISE

Multiple Choice Questions

1. The _____ secretes a fluid that cushions and lubricates the joints
   (a) Cutaneous membrane
   (b) Synovial membrane
   (c) Mucous membrane
   (d) None of the above
2. Which of the following is accurate?
   (a) Humans have 2 pairs of false floating ribs
   (b) Humans have 1 pair of false floating ribs
   (c) Humans have 3 pairs of false floating ribs
   (d) Humans have 7 pairs of false floating ribs
3. _____ is an example of an imperfect joint
   (a) Ball & socket joint
   (b) Pubic symphysis
   (c) Elbow joint
   (d) None of the above
4. The _____ is the largest sesamoid bone in the human body
   (a) Pelvis
   (b) Femur
   (c) Ulna
   (d) Patella
5. The _____ is the only movable part of the skull.
   (a) Nasal Conchae
   (b) Mandible
   (c) Vomer
   (d) Maxilla
6. _____ is the muscle's contractile protein.
   (a) Globulin
   (b) Elastin
   (c) Myosin
   (d) None of the above
7. The _____ is a membrane-bound structure located within the muscle's cells. Its main function is to store calcium ions.
   (a) Sarcoplasmic reticulum
   (b) Fibrin
   (c) Myosin
   (d) None of the above
8. The _____ muscle is responsible for drawing the lower jaw, head and tongue backwards.
   (a) Maximus
   (b) Retractor
   (c) Abductor
   (d) None of the above

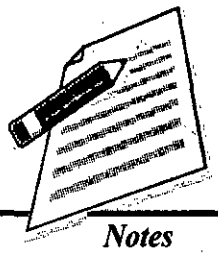
9. The cardiac muscle is found in
   (a) Chest
   (b) Lungs
   (c) Heart
   (d) All of the above
10. _____ is a striated and involuntary muscle
   (a) Abdominal muscles
   (b) Lung tissues
   (c) Cardiac muscle
   (d) Chest muscles
11. The Iris consists of _____
   (a) Involuntary muscle
   (b) Voluntary muscle
   (c) Skeletal muscle
   (d) None of the above
12. _____ is not a skull bone
   (a) Sternum
   (b) Occipital bone
   (c) Vomer
   (d) Pterygoid
13. The _____ is a ring-like bony structure found in the lower part of the trunk
   (a) Malleus
   (b) Vomer
   (c) Pelvic girdle
   (d) None of the above
14. _____ is a bone found in the human hand
   (a) Proximal Phalanges
   (b) Parietal bone
   (c) Tarsal bone
   (d) None of the above
15. _____ is extremely resistant to fatigue
   (a) Cardiac muscles
   (b) Skeletal muscles
   (c) Striped Muscles
   (d) None of the above

Answer

1. (b)	**2.** (a)	**3.** (b)	**4.** (d)	**5.** (b)
6. (c)	**7.** (a)	**8.** (b)	**9.** (c)	**10.** (c)
11. (a)	**12.** (a)	**13.** (c)	**14.** (a)	**15.** (a)

Review Questions

1. Define the following terms with respect to rib cage:
   (a) Bicephalic ribs
   (c) True ribs
   (c) Floating ribs



2. Old people usually suffer from inflamed and stiff joints, name the condition. State the reasons for the symptoms.
3. List two hormones causing fluctuation of Ca++ level.
4. What is Gout?
5. What is the significance of locomotion in animals?
6. Where do muscle contractions derive their energy from?

Space for Notes

Module 3 REPRODUCTION AND HEREDITY

Module Content

Objective of the module

This module is designed to highlight the diverse methods of reproduction in living beings from unicellular organisms to complex forms including humans. This module highlights the increase in human population all over the world and also provides adequate information about the methods of family planning and birth control. The principles and mechanisms of heredity in determining the characteristics of organism have also been discussed in this module.

14 REPRODUCTION IN PLANTS

Introduction

Reproduction in Plants

All living organisms have a characteristic that they can produce their own kind. This production of the offspring from the parents is called **Reproduction**.

Modes of Reproduction in Plants

Plants have two kinds of parts:

Vegetative Parts - These are the parts of the plant that plays a major role in the life cycle of a plant such as preparation of food, transportation of food, water and nutrients etc. For Example, roots, stems and leaves.

Reproductive Parts - These are the parts of a plant that play a major role in the reproduction process in plants, For Example, flowers, fruits

Reproduction in plants can be categorized into two types:

Asexual Reproduction – The new plants are produced without using the seeds. In this process, generally, the leaves, stems and roots participate in reproduction.

Sexual Reproduction – The new plants are produced with the help of the seeds of a plant. In this process, the flowers of the plants participate in reproduction.

Shoot – A young plant is often termed as a shoot. Generally, a shoot is regarded as a part of the plant which has stems, leaves and flowers.

Node – It is a part of the stem or branch of a plant from where the leaf arises.

Vegetative Buds – Sometimes buds are present in the leaves that are capable of developing into shoots. These are called **Vegetative Buds**.

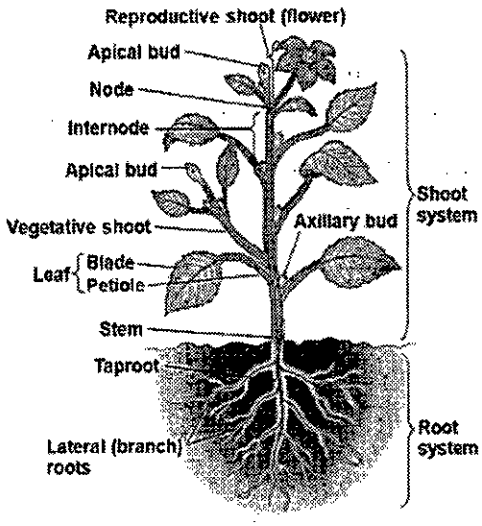


Figure 1: Roots and Shoot in a Plant

Different types of Asexual Reproduction:

1. Vegetative Propagation

As the name suggests this type of reproduction takes place with the help of the vegetative parts of the plant. Only one parent can produce the identical offspring in vegetative propagation.

Natural means of Vegetative Propagation:

Vegetative Propagation by Roots

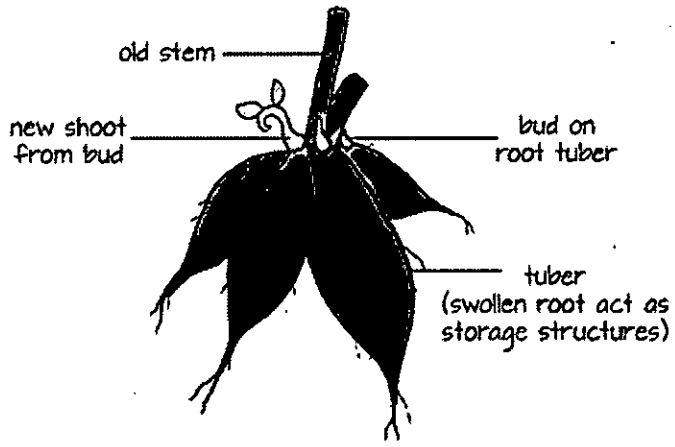


Figure 2: Vegetative propagation by roots in Sweet Potato

- Plants that have tuberous roots, that is, roots which are used as a storage organ in plants participate in vegetative propagation.
- In order to grow new plants, these tuberous roots are sown in the soil.
- There are buds present on the fruits that grow above the ground and a new plant is formed.
- Example: Sweet potato and dahlia

Vegetative Propagation by Stem

- **Stem Tubers**: Just like tuberous roots, some plants have tuberous stems. These stem tubers store the nutrients and bear nodes. These notes bear buds that form the new plants. Example: Potato

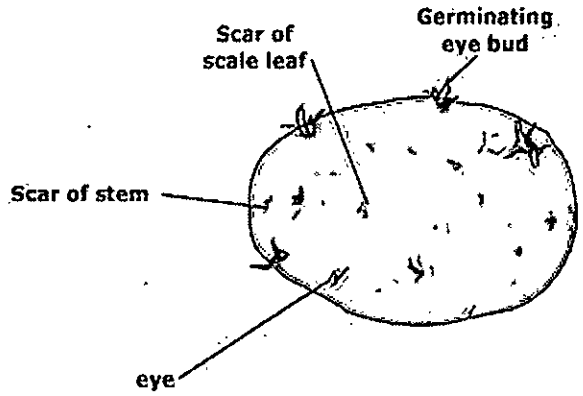


Figure 3: Vegetative propagation by stem in Potato

- **Runners**: Some plants grow along the ground and contain modified stems called **Runners**. These runners contain buds that can produce roots and stems. Example: Strawberries

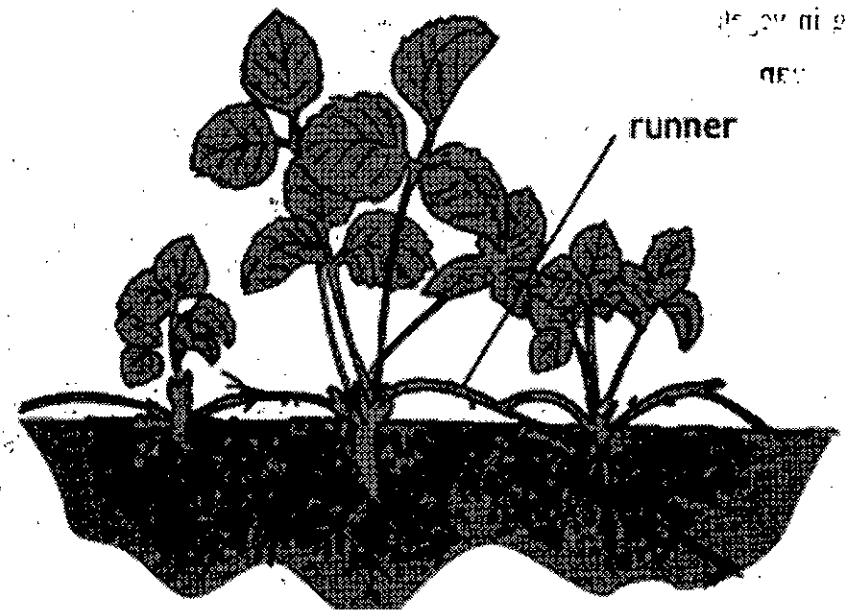
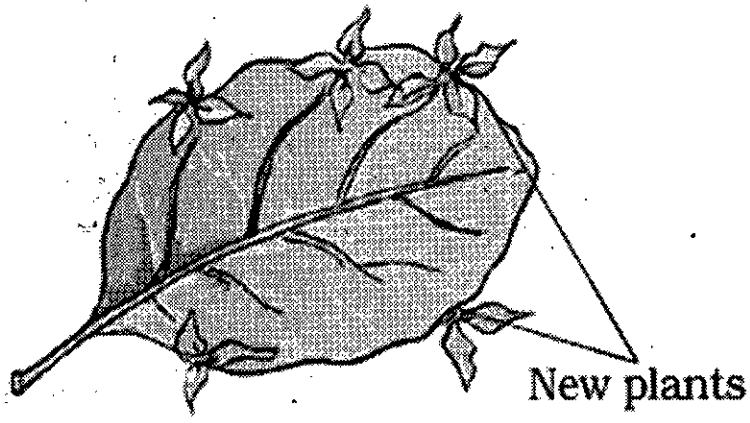


Figure 4: Vegetative propagation by runners stems

Vegetative Propagation by Leaves

- Some plants have leaves that contain buds that can develop into a new plant. Example: Bryophyllum



Leaf of Bryophyllum with buds in the margin

Figure 5: Vegetative propagation by leaves of Bryophyllum

Artificial means of Vegetative Propagation

- **Cutting** - It is a method in which a cutting from a plant is taken and planted. This cutting is a part of the stem or the branch of the plant. Example: Roses

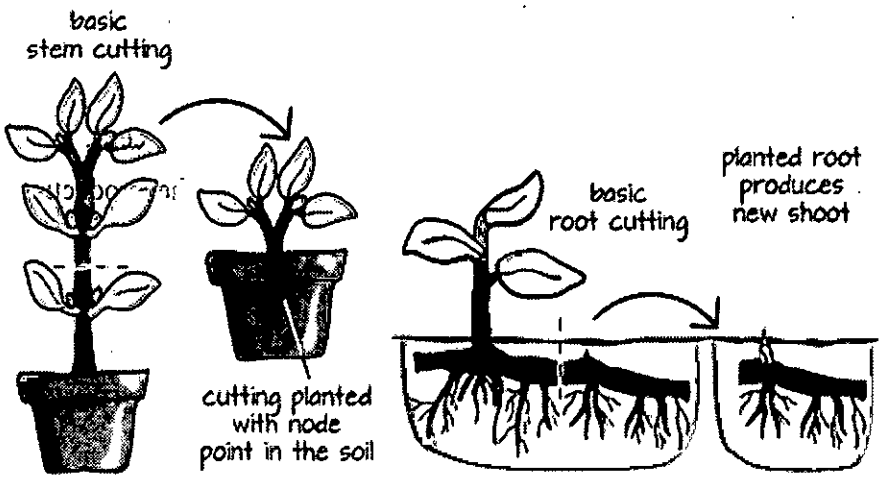


Figure 6: Cutting

- **Grafting** - Sometimes two plants are joined together so that both of them can provide the desired characteristics to the new plant. One plant remains rooted in the ground, which is called the Stock, and provides the essential nutrients and water while the other plants' stem is attached to it. In this way, a new plant develops. Example: Apples

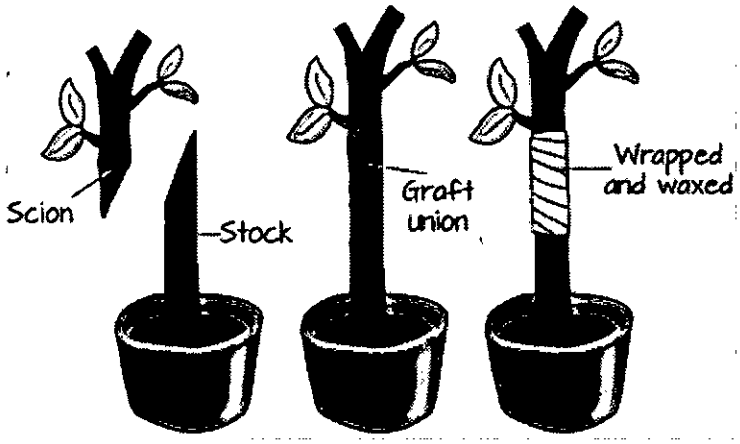


Figure 7 Grafting

Advantages of Vegetative Propagation

- The plants that are produced with vegetative propagation grow faster than those that are produced with sexual reproduction.
- The plants that reproduce with vegetative reproduction have fruits and flowers ahead of time.
- The plants that are produced have exactly the same characteristics as that of their parents.

2. Budding

- Yeast is an organism that contains a single cell. It is a fungi not a plant.
- It can propagate every few hours if the proper amount of nutrients are available to it.

- As the yeast finds favourable conditions, a small bulb-like projection produces from the yeast called **Bud**.
- The bud grows gradually and then gets detached from the parent yeast.
- This new cell then grows measures and produces more cells.

Sometimes a chain of buds is formed which leads to the production of a large number of yeasts altogether.

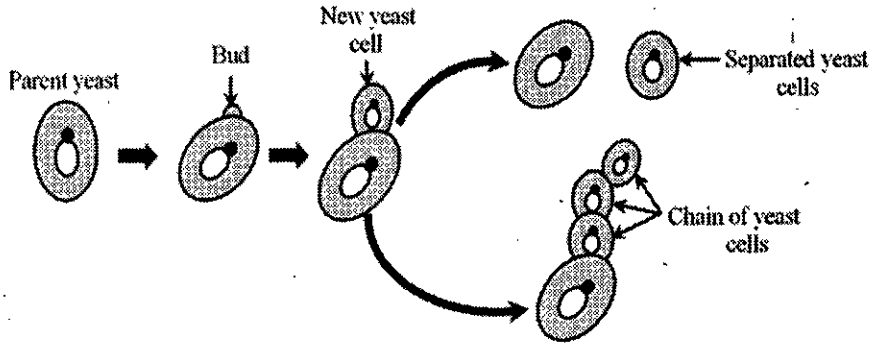


Figure 8: Budding in Yeast

3. Fragmentation

- Algae like Spirogyra generally reproduce by the process of fragmentation in which they divide themselves into multiple parts.
- As soon as the algae find enough water and nutrients, it fragments and grows into new individuals.
- This process continues and algae multiply quickly in a short period of time.

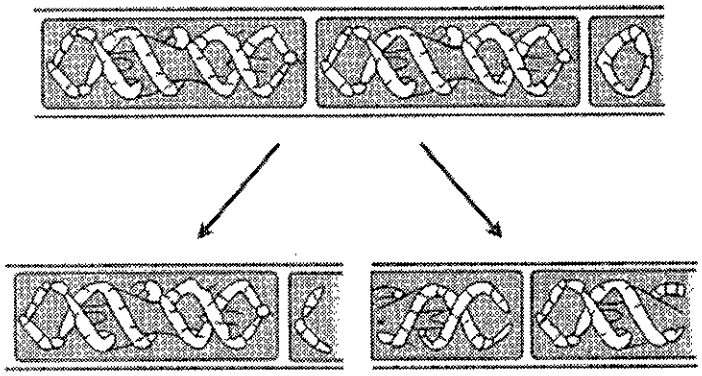


Figure 9: Fragmentation in Algae

4. Spore Formation

- Some plants contain spores that float in the air and cause asexual reproduction.
- A spore has a hard protective cover which protects it from the unfavourable environmental conditions like temperature and humidity.
- As a result, the spores can travel long distances and survive for a long duration of time.

- As soon as they find favourable conditions such as moisture and nutrients, they germinate and form new plants.
- For Example, Moss and ferns propagate in this way.

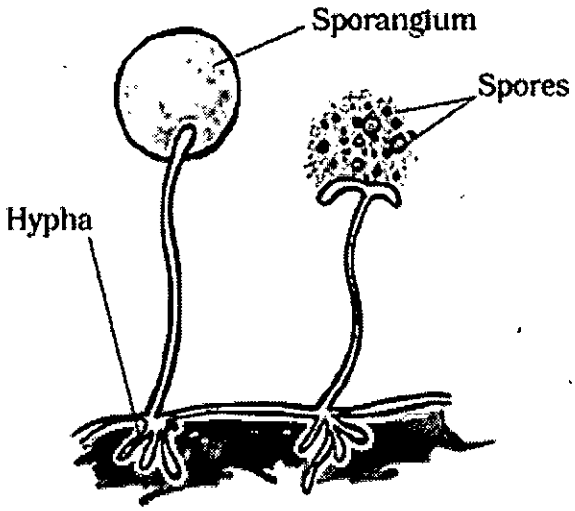


Figure 10: Spore Formation in Fungus

Sexual Reproduction in Plants

- The flowers of a plant are its reproductive organs that participate in the sexual reproduction process.
- The male reproductive parts of a plant are called **Stamen**.
- The female reproductive parts of a plant are called **Pistil**.
- Some flowers contain both stamen and pistil and are called **Bisexual Flowers**. E.g. Lily, rose, brinjal, hibiscus, petunia, mustard etc.
- Some flowers contain either the statement or the pistil and hence are called **Unisexual Flowers**. E.g. papaya, watermelon, cucumber, coconut etc.
- The new plant produced contains the characteristics of both plants that participate in the sexual reproduction.
- The stamen consists of **Anther** that has **pollen grains**. These pollen grains produce male gametes.

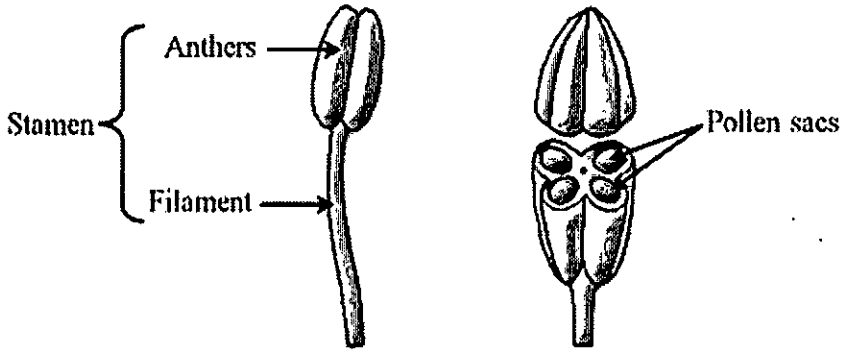


Figure 11: Stamen

- The pistil consists of three parts:
  - **Stigma** – It is a sticky surface where pollen grains get attached.
  - **Style** – It is a tube-like structure which connects the stigma and the ovary.
  - **Ovary** – It contains eggs in which the female gametes or eggs are formed.

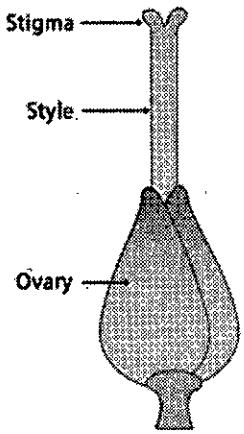


Figure 12: Pistil

How the male gametes reach the female gametes in plants?

- The male and female gametes fuse and form a **zygote**.
- The male gametes reach the female gametes by the process of pollination.
- The pollen grains have a tough covering which allows them in surviving the different climatic conditions.
- Due to their lightweight, winds and water often carry them away to different plants. Sometimes the pollen grains also get attached to insects which carry them to different flowers.
- This process of transfer of pollen grains from one stigma to another is called Pollination.

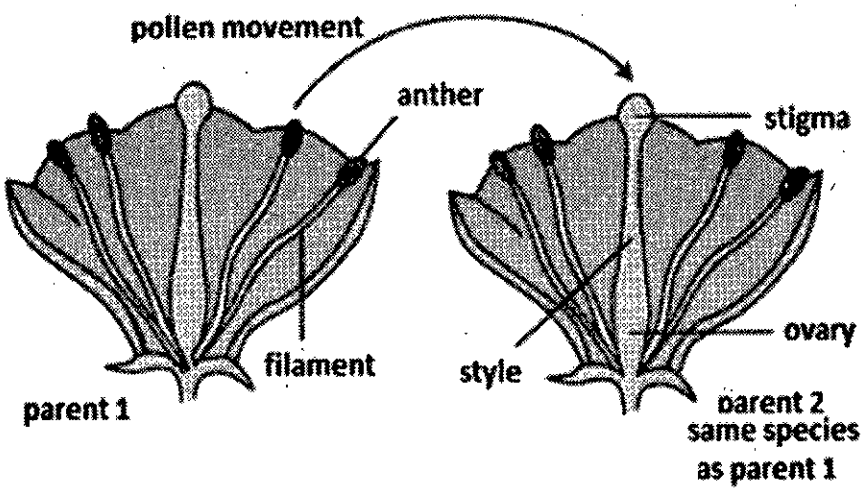


Figure 13: Pollination

- There are two types of pollination:
  - **Self-pollination/ Autogamy**: When the pollen grains land on the stigma of the same flower.
  - **Cross-pollination/ Xenogamy**: When the pollen grains land on the stigma of a different flower, whether of similar kind or different kind.

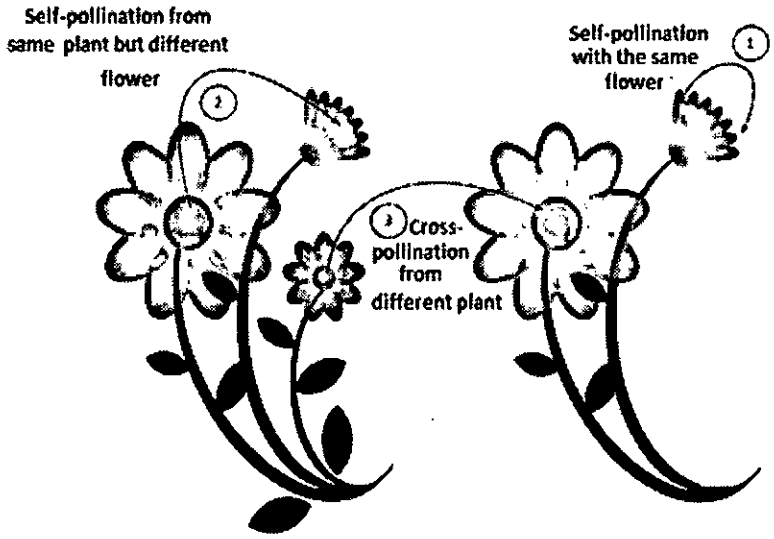


Figure 14: Self-pollination and Cross-pollination

The Fertilization Process

- A zygote is formed as the fusion between the male and female gametes occurs.
- This process of formation of the zygote is called **Fertilization**.
- Then the zygote develops and turns in an embryo.

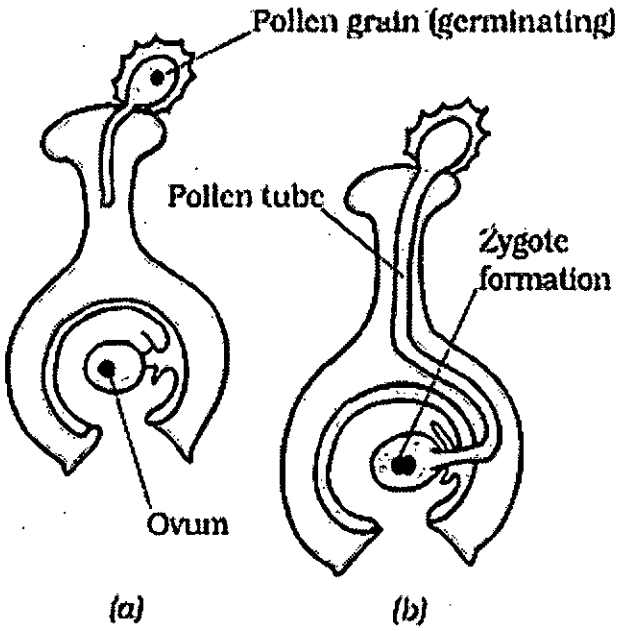


Figure 15: Fertilization

How fruits and seeds are formed?

- After the fertilization process, the ovary of the flowers grows and develops into a fruit.
- The remaining parts of the flower fall off.
- The ovules develop and form the seeds of the fruits.
- The embryo is enclosed inside the seeds.
- Some fruits are fleshy and juicy such as mango, apple and orange. Some fruits are hard like almonds and walnuts

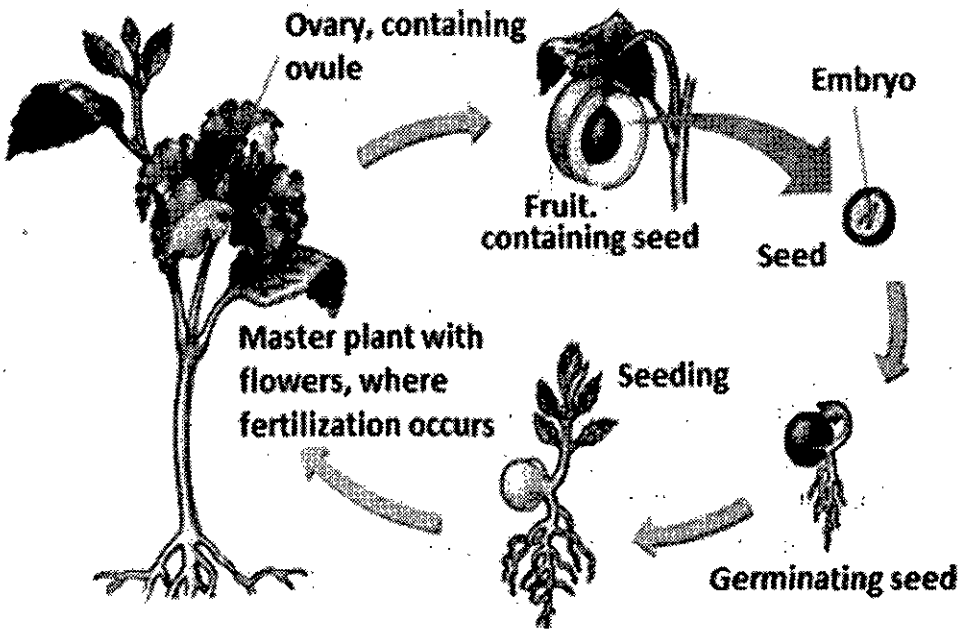
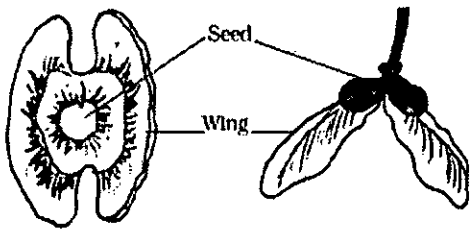
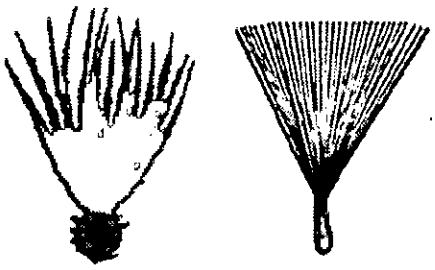
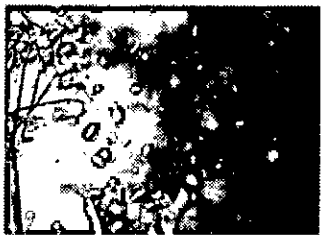


Figure 16: Formation of Fruits and Seeds

What is seed dispersal?

- The transportation of seeds from the parent plant to different places is called seed dispersal.
- Seed dispersal allows growth of the same kind of plants in different regions.
- This is helpful because it minimizes the competition for food, sunlight, water and minerals among the plants of the same kind in the same area.
- It also allows them to grow in different habitats.

How the dispersion of seeds occurs?

Distribution Factors	Types of Seeds that propagate	
Winds	Drumstick, Maple (Winged Seeds) Grasses (Light weight Seeds) Aak (Hairy Seeds) Sunflower (Hairy Fruits)	 (a) (b) *Seeds of (a) drumstick and (b) maple*  (a) (b) *(a) The hairy fruit of sunflower and (b) hairy seed of madar (aak)*
Water	Coconut (Seeds with spongy and fibrous coating so to float in water)	 **Figure 19: Coconut Seed**
Animals	Spiny seeds like Xanthium and Urena get attached to bodies of animals	 *Xanthium*
Fruit Bursts	Castor, Balsam	 **Figure 21: Seed Dispersal in Balsam Plant**

Summary of the chapter

All organisms multiply or reproduce their own kind.

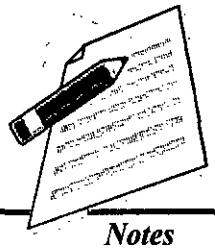
- In plants there are two modes of reproduction, asexual and sexual.
- There are several methods of asexual reproduction such as fragmentation, budding, spore formation and vegetative propagation.
- Sexual reproduction involves the fusion of male and female gametes.
- In vegetative propagation new plants are produced from different vegetative parts such as leaves, stems and roots.
- Flower is the reproductive part of a plant.
- A flower may be unisexual with either the male or the female reproductive parts.
- A bisexual flower has both the male and the female reproductive parts.
- The male gametes are found inside the pollen grains and female gametes are found in the ovule.
- Pollination is the process of transfer of pollen grains from the anther of one flower to the stigma of the same or another flower.
- Pollination is of two types, self-pollination and cross-pollination. In self-pollination, pollen grains are transferred from the anther to the stigma of the same flower. In cross-pollination, pollen grains are transferred from the anther of one flower to the stigma of another flower of the same kind.
- Pollination takes place in plants with the help of wind, water and insects.
- The fusion of male and female gametes is called fertilisation.
- Fertilised egg is called zygote. Zygote develops into an embryo.
- Fruit is the mature ovary whereas ovule develops into a seed, which contains the developing embryo.
- Seed dispersal is aided by wind, water and animals.
- Seed dispersal helps the plants to
  (i) prevent overcrowding,
  (ii) avoid competition for sunlight, water and minerals and
  (iii) invade new habitats.

EXERCISE

Multiple Choice Questions

1. What is the function of filiform apparatus in an angiosperm embryo sac?
   (a) Brings about opening of the pollen tube
   (b) Guides the pollen tube into a synergid
   (c) Prevents entry of more than one pollen tube into a synergid
   (d) None of these

2. The female gametophyte of a typical dicot at the time of fertilisation is
   (a) 8 – celled
   (b) 7 – celled
   (c) 6 – celled
   (d) 5 – celled
3. Polygonum type of embryo sac is
   (a) 8 – nucleate, 7 – celled
   (b) 8 – nucleate, 8 – celled
   (c) 7 – nucleate, 7 – celled
   (d) 4 – nucleate, 3 – celled
4. Both chasmogamous and cleistogamous flowers are present in
   (a) Helianthus
   (b) Commelina
   (c) Rosa
   (d) Gossypium
5. Even in absence of pollinating agents seed-setting is assured in
   (a) Commelina
   (b) Zostera
   (c) Salvia
   (d) Fig
6. Male and female flowers are present on different plants (dioecious) to ensure xenogamy, in
   (a) papaya
   (b) bottle gourd
   (c) maize
   (d) all of these.
7. Feathery stigma occurs in
   (a) pea
   (b) wheat
   (c) Datura
   (d) Caesalpinia
8. Plants with ovaries having only one or a few ovules are generally pollinated by
   (a) bees
   (b) butterflies
   (c) birds
   (d) wind
9. Which of the following is not a water pollinated plant ?
   (a) Zostera
   (b) Vallisneria
   (c) Hydrilla
   (d) Cannabis



10. Spiny or sticky pollen grains and large, attractively coloured flowers are associated with
    (a) hydrophily
    (b) entomophily
    (c) ornithophily
    (d) anemophily

Answer Key

1. (b) Guides the pollen tube into a synergid
2. (b) 7 – celled
3. (a) 8 – nucleate, 7 – celled
4. (b) Commelina
5. (a) Commelina
6. (a) papaya
7. (b) wheat
8. (d) wind
9. (d) Cannabis
10. (b) entomophily

Review Questions

2. Describe the different methods of asexual reproduction. Give examples.
3. Explain what you understand by sexual reproduction.
4. State the main difference between asexual and sexual reproduction.
5. Sketch the reproductive parts of a flower.
6. Explain the difference between self-pollination and cross-pollination.
7. How does the process of fertilisation take place in flowers?
8. Describe the various ways by which seeds are dispersed.

Space for Notes

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15 GROWTH AND DEVELOPMENT IN PLANTS

Definition of Growth

Growth is defined as *"an irreversible permanent increase in size of an organ or its part or even of an individual cell."*

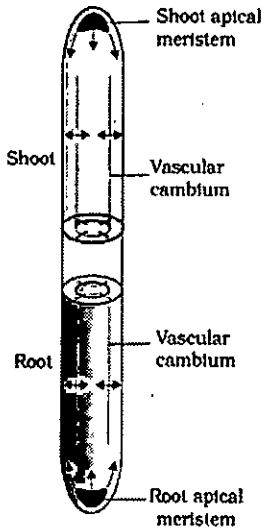
In other words, Growth is the most fundamental and conspicuous characteristics of living beings and is accompanied by several metabolic processes that occurs at the expense of energy. These metabolic processes may be catabolic or anabolic. In case of plants, seed germinates, develops into seedling and later it takes the shape of an adult plant are different stages of growth. Plants displays indefinite growth.

On the other hand, animals show uniform and fixed growth.

Characteristics of Growth

- **Plant Growth is generally Indeterminate – Plants** possess the ability of growth throughout their life. This is due to the presence of meristems at certain locations in their body and these meristems have the ability to divide and self –perpetuate.
- **Growth is Measurable** – At cellular level, Growth is the consequence of increase in protoplasm and this increase is difficult to measure. Growth, in plants, is measured via different methods like increase in dry weight, volume, cell number, volume or increase in fresh weight.

The following diagram represents the location of root apical meristem, shoot apical meristem and vascular cambium. The arrows display the direction of growth of cells and organs.



The Growth of Plants has three phases:

Formative Phase – Cell division is the basic event in the growth of plant. All cells are the result of division of **pre-existing cells.** Mitosis is the type of cell division that happens during growth and includes both quantitative and qualitative division of cells. This division is carried out in two steps – **Division of Nucleus**, which is referred as **Karyokinesis** and division of cytoplasm referred as **Cytokinesis**. In case of higher plants, an increase of cells is carried out in meristematic region, whereby some daughter cells retain this meristematic activity while some enter in the next phase of growth, i.e., the phase of cell enlargement.

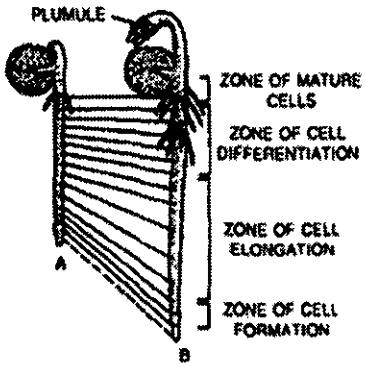
Cell Enlargement and Cell Differentiation – At this stage, the size of tissues and organs is increased and this enlargement occurs by forming **Protoplasm, Hydration** (absorbing water), developing vacuoles and then adding new cell wall to make it permanent and thicker.

Cell Maturation – At this stage, the enlarged cells acquire specific size and forms as per their location and role. Thus, several cells are differentiated from simple and complex tissues which perform different functions.

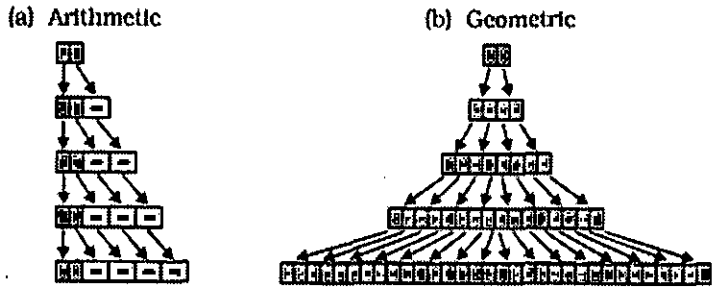
Experiment to Study Phases of Growth

In order to study the phases of Growth, Germinate few seeds of peas in moist saw dust. Select the couple of seedlings with **2 – 3 cm** of length, wash them and blot the surface water. Then, mark the radicles from tip to base with **10 – 15** point at interval of **2 mm** via water proof ink. After drying of ink, place those seedlings on moist blotting paper and allow them to grow for **1 – 2** days. Finally measure the intervals between the marks and we can clearly observe the different phases of growth.

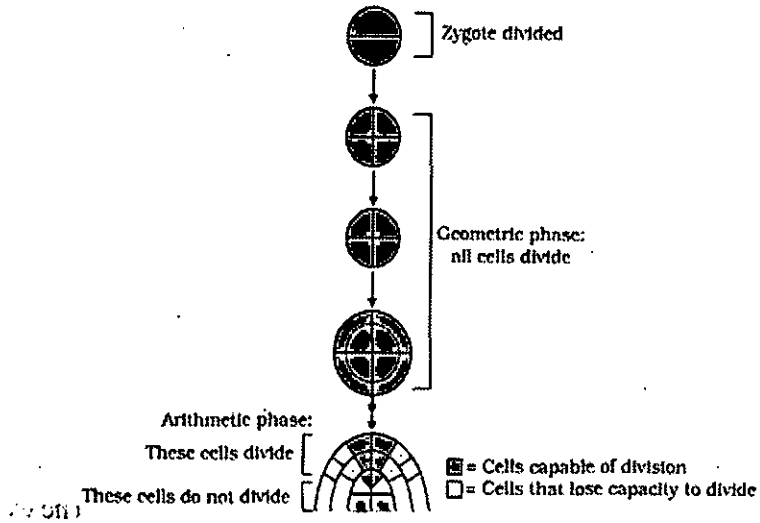
Following diagram shows the phases of growth in root. A is the marked radicle of seedling at the beginning of experiment and B is the condition of seedling after **48** hours. We can clearly identify zone of cell formation, cell elongation, cell differentiation and zone of matured cells.



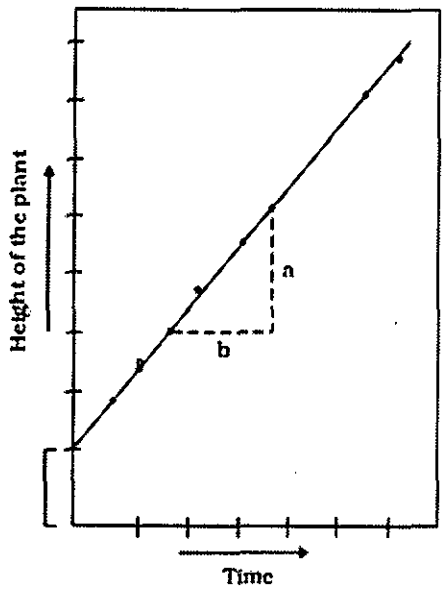
"The increased growth per unit time is termed as **Growth Rate**. Thus, the rate of growth is expressed mathematically." An organism can produce cells in several ways and display **Geometric** as well as **Arithmetic Growth.** Following diagram shows both types of growth in plants:



The following diagram displays the various stages of embryo development showing both **Geometric** and **Arithmetic Phases**. Here dark blue blocks **represent** the cells capable of division while light blue blocks represents the cells that have lost the capacity to divide:



Thus, in **Arithmetic Growth**, only one daughter cell continues to divide while other differentiates and matures. The following graph represents the length of an organ against time, whereby a linear curve is obtained. We can clearly observe the constant linear growth against time t.



In **Mathematical Terms, Growth Rate** is expressed as:

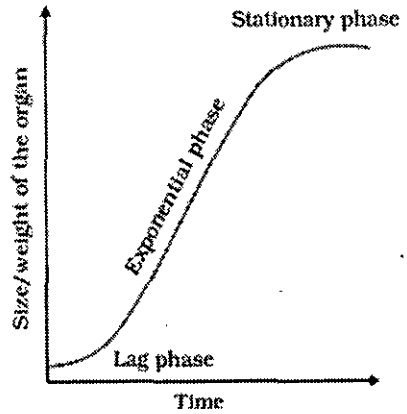
$L_t = L_o + rt$

Where, L_t = length at time "t"

L_o = length at time "zero"

r = growth rate or elongation per unit time.

Now focusing on **Geometrical Growth,** in majority of systems, Initial Growth is slow and is referred as lag phase. Then, it increases rapidly at an exponential rate referred as log phase or exponential phase. The growth of plant slows down in cases of limited nutrient supply and results in stationary phase. When we plot the growth against time, it results in **S-Curve** or **Sigmoid Curve**. Following graph represents an idealized sigmoid growth curve typical of cells in culture and many higher plants and plant organs.



The above sigmoid curve is the characteristic of living organism growing in natural environment and is typical for all cells, tissues and organs. The exponential growth in expressed as:

$W_1 = W_o e^{rt}$

Where,

W_1 = final size (weight, height, number etc.)

W_o = Initial size at the beginning of the period

r = relative growth rate and the measure of the ability of plant to produce new plant material

t = time of growth

e = base of natural logarithms

Types of Growth

There are five types of **Growth**:

- **Primary and Secondary Growth:** "The mitotic divisions of meristematic cells present at the root and shoot apex increases the length of the plant body. This is referred as **Primary Growth** and the **Secondary** meristem that results in an increase in diameter of the body of plant is called as **Secondary Growth**."

- **Unlimited Growth:** This is the stage, when root and shoot of plant continuously grow from germination stage to death and throughout the entire lifespan.
- **Limited Growth:** This is the stage, when fruits, leaves and flowers stop growing after attaining certain size. It is also called determinate type of **Growth**.
- **Vegetative Growth:** The Growth of Plant before flowering is called **Vegetative Growth**. This **Growth** includes producing of stems, leaves and branches.
- **Reproductive Growth:** At this stage, plants start flowering, which is the reproductive part of the plant.

Factors Affecting Plant Growth

External Factors: The Growth of Plant primarily depends on habitat in which it is growing. Along with this, external factors also play an integral role in the growth of plants. It includes availability of Oxygen, Water and Nutrients followed by Temperature and Light.

Temperature plays important role in the growth of plants. The minimum, optimum and maximum temperature varies and from species to species. As the temperature increases above minimum, growth is accelerated until the optimum temperature is attained, when the growth gets slower and is completely retarded. Effect of duration for which a plant is exposed to certain temperature also varies amongst different species. **For Example:** The plant shows good growth when it is exposed to **86°F** for a short duration and the same temperature has negative impact if maintained for longer duration.

Light also affect the growth and development of plant. Several factors of light like light intensity, duration of light and quality of light influences several physiological processes like movement of stomata, chlorophyll synthesis, temperature of aerial organs, formation of anthocyanin, absorption of minerals streaming of protoplasm and rate of transpiration. Intensity of light also influences plant growth and the variation in intensity has significant impact on growth pattern. Most ornamental plants and crops, such as Peas, Corn, Tobacco and Peas makes stocky and vigorous growth will full sun and thus, is also called "**Sun Plant**."

Difference in wave length of light also effects the growth of plant. Several experiments have proved that plants that has full spectrum of visible light shows proper development and increase in dry weight. Plants grown in violet and blue light tend to dwarf, while plants in red light are taller and spindly.

Duration of light also affects the plant growth as it affects the rate of photosynthesis. For instance, during winters when days are short, the growth is very slow, while, it increases during summers when the days are longer.

The plants with lesser availability of oxygen show retarded growth while it is vice versa in the presence of ample of oxygen. It is important to note that

plants in flooded areas, results in deficiency of soil aeration which on the other hand, results in poor plant growth.

Water is very important for plants and inadequate water results in poor growth. Plants grow well only in the presence of optimum water. Plants respond to deficiency of moisture as well. For instance, peppers, spinach and radishes wilt and cease to grow when the percentage of water in soil is lower.

Soil nutrients, their quantity and nature also affect the growth of plant. **For Luxuriant Growth**, it is important to have adequate amount of nutrients.

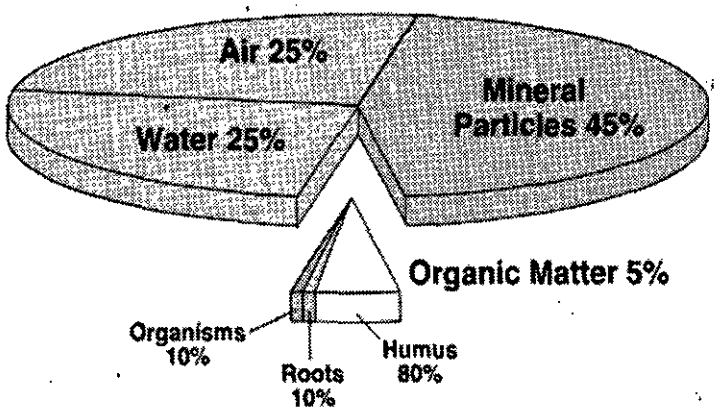
External Factors: *The Growth of Plant primarily depends on habitat in which* it is growing. Along with this, external factors also play an integral role in the growth of plants. It includes availability of Oxygen, Water and Nutrients followed by temperature and light. These factors include growth regulators, **C/N** ratio and genotype and genetic factor.

There are several classes of growth regulators. Some promote the growth like Auxins, Florigen, Cytokinins, Gibberellins, etc., while some are growth inhibitors like ethylene, abscisic and chlorocholine chloride.

The ratio of carbohydrates and nitrogen also govern the growth of plants. Presence of more carbohydrates as compared to nitrogen facilitates vegetative growth, fruiting and flowering while presence of more nitrogenous compounds results in poor vegetative growth.

Following diagram shows the percentage contribution of various factors in the growth of plants. According to it, the percentage of mineral particles is **45%** and air & water is **25%**.

Genotypes are responsible for controlling all the metabolic activities, growth and development of plant. Expression of genes in the correct sequence is controlled by two things, i.e. environment and genes. These genes are located in chromosomes and transcribe information to **m-RNA** that translates in enzyme and structural protein.



Differentiation, Dedifferentiation and Redifferentiation

"The cells derived from root apical and shoot – apical meristems and cambium differentiate and mature to perform specific function and this act leading

to maturation is termed as differentiation." During this process, several structural changes are carried out in cells and protoplasm. For instance, In order to form a tracheary element, cells would lose protoplasm and develop elastic, strong and lignocellulosic secondary cell walls in order to transport water even in extreme tensions.

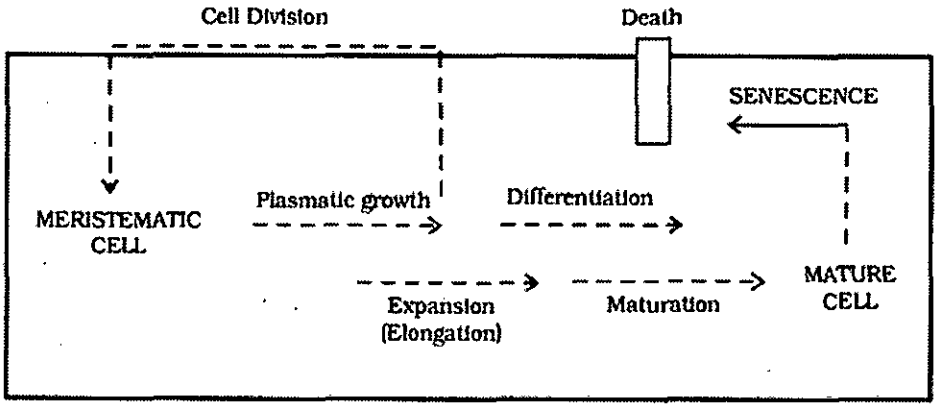
In plants, we can study another interesting phenomenon, i.e. dedifferentiation. In this **Phenomenon**, the living differentiated cells that have lost the capacity to divide regain it under certain conditions. **For Example:** Formation of Meristems – cork cambium and interfascicular cambium form fully differentiated parenchyma cells and in such condition, tissues and meristems are able to divide and produce cells even after losing the capacity to divide.

"While the product of dedifferentiated cells or tissue which lost the ability to divide are called redifferentiated cells/ tissue and this event is referred as redifferentiation."

Development

Development is the term that includes all the changes an organism goes throughout its life cycle right from germination of seeds to attaining senescence.

Following diagram shows the sequence of the development process in a plant cell. This process is also applied to **Tissues** or **Organs**.



Plants follow several pathways or phases of life in response to environment in order to attain different kind of structures and this ability is referred as plasticity, such as heterophylly in coriander, cotton and larkspur. In these plants, leaves of juvenile plant are entirely different in shape as compared to the matured plant. Added to this, there is a vast difference in shape of leaves of plant produced in air and water.

Following diagram shows heterophylly development because of environment, in which

(a) Represents larkspur and (b)is buttercup.

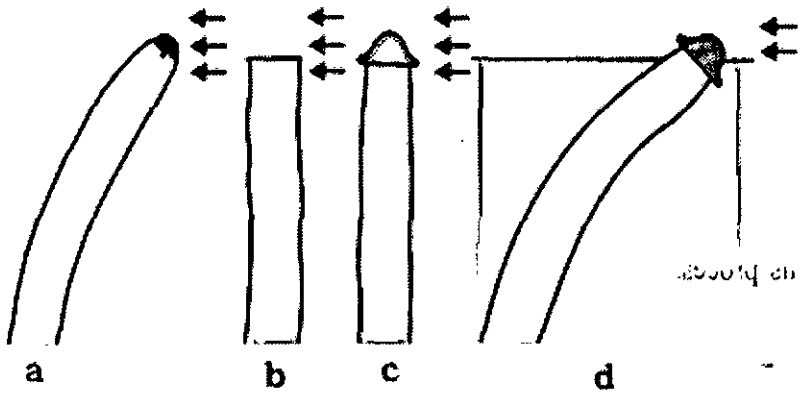
Thus, it can be said that growth, development and differentiation are three concepts which are closely related with the events of life. To summarize,

development is the sum total of growth and differentiation and is under the control of several extrinsic and intrinsic factors.

Plant Growth Regulators

"Plant growth regulators function as chemical messengers for intercellular communication." These regulators work in coordination with each other to enforce growth and development of cells. The discovery of **PGR** is entirely accidental. All this started with the observation of **Charles Darwin** and **Francis Darwin** (son). They observed the process of photoperiodism in the tip of coleoptile, whereby the canary grass responded to unilateral illumination by growing towards source of light.

Following diagram shows the experiment to demonstrate the tip of coleoptile is the source of auxin and arrows indicate the direction of light. a, b, c, d are the different stages of grass:



Example of Plant Growth Regulators

Auxins, Cytokinins, Gibberellins, Ethylene and Abscisic Acid (ABA)

Characteristics of Plant Growth Regulators

- These are small and simple molecules with diverse chemical composition. These are described as **Plant Growth Substances, Phytohormones** or **Plant Hormones**.
- These could be adenine derivatives; indole compounds, derivatives of carotenoids or terpenes.
- PGR are divided in two groups on the basis of functions in a Living Plant Body:
  - **First Group** is involved in growth promoting activities like cell division, Enlargement, Tropic Growth, Fruiting, Pattern Formation, Flowering and Formation of seed. These are also referred as plant growth promoters such as gibberellins, auxins and cytokinins.
  - **Second Group** responses to wounds and stresses of abiotic and biotic origin. These are involved in growth inhibiting activities such as abscission and dormancy.

Physiological Effect of Plant Growth Regulators

- **Auxins:** This was first isolated from the urine of human beings and is applied to **indole – 3 – acetic acid** (IAA) and several other synthetic and natural compounds possessing growth-regulating properties. Auxins are produced by growing apices of roots and stems and are used extensively in horticultural and agricultural practices. Auxins initiate rooting in stem cutting and promote flowering. Auxins are used in inducing parthenocarpy and are widely used as herbicide. It also used to prepare weed free lawns and control the differentiation of xylem.
- **Gibberellins:** These are another kind of **PGR** and more than **100** gibberellins are widely reported in different organisms. These are denoted as GA_1, GA_2, GA_3 and so on. Amongst these, GA_3 was the first gibberellins to be discovered. These are acidic in nature and possess ability to cause an increase in length of axis. It causes fruits to elongate and improve shape and also delay senescence. Gibberellins results in an increase in the length of stem, promotes bolting and fastens the maturity period.
- **Cytokinins:** These were discovered as kinetin and it does not occur in plants naturally. Natural cytokinins are formed in those regions where cell division occurs rapidly. These help in overcoming apical dominance and promote nutrient mobilization.
- **Ethylene:** It is **PGR** in gaseous form which is synthesized in large amount by tissues undergoing senescence and ripening of fruits. It is highly effective in ripening of fruits and improves rate of respiration referred as respiratory climactic. Ethylene breaks bud and seed dormancy, sprouting of potato tubers and germination of peanut.
- **Abscisic Acid (ABA):** It acts as general growth inhibitor as it inhibits seed germination. It stimulates closure of stomata and increase tolerance of plants in response to various kinds of stresses, therefore also referred as stress hormone.

Photoperiodism

Definition of Photoperiodism

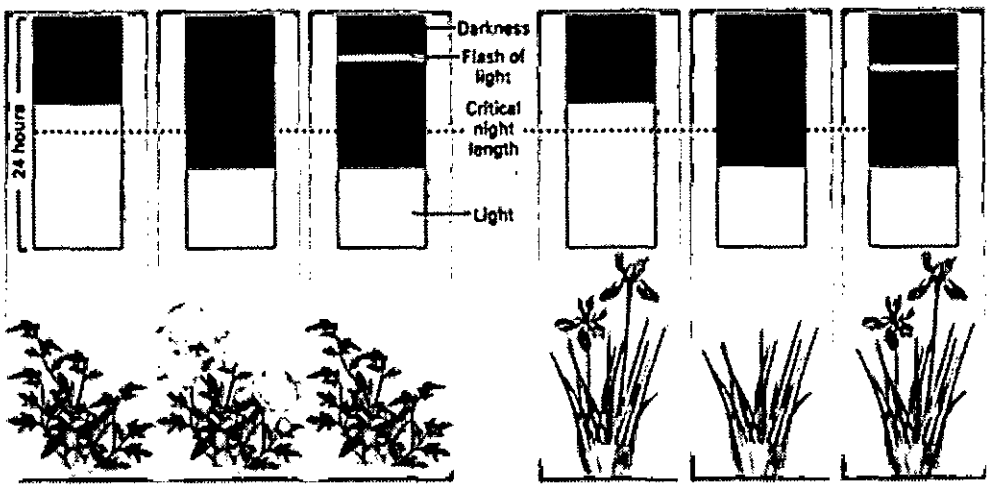
"Photoperiodism is the physiological reaction of organisms to the length of day or night. It occurs in both animals and plants it can also be defined as the developmental responses of plants to the relative lengths of light and dark periods."

Thus, the term photoperiodism is coined to explain the ability of plants to flower in response to changes in the relative length of day and night. It is observed that there are several plants which require periodic exposure to light in order to induce flowering.

Plants are grouped as per their response to the length of day, in the following manner:

- **Long Day Plants:** These plants begin flowering when they are exposed to longer days. Below the critical photoperiod, these plants show only vegetative growth. The critical photoperiod varies from species to species and plants to plants. Some of the common examples of long day plants are Radish, Barley, Spinach, Onion, Carrot and Henbane.
- **Short Day Plants:** These plants flower when the length of day is shorter than their critical photoperiod. When these plants are exposed to more than the critical period, it shows vegetative growth. Some of the common examples of short-day plants are Tobacco, Soybean, Sugarcane and Cock – Lebur.
- **Day Neutral Plants:** These plants flower only after completely the period of vegetative growth irrespective of the duration of day and night. Some of the common examples include Tomato, Maze, Cucumber, Cotton, some varieties of Pea, etc.

Following diagram shows short day and long day plants. Here short-day plants flower when the length of day is shorter and on the contrary, long day plants flower when the length of day is longer.



a. Short-day (long-night) plants b. Long-day (short-night) plants

Vernalization

There are several plants in which flowering are qualitatively or quantitatively dependent on the exposure to low temperature. This phenomenon is referred as vernalization.

In other words, temperature plays an integral role in metabolic activities of plants, germination of seeds and their flowering. Plants of temperate zone, germinate at relatively low temperature while plants in tropical areas germinate in higher temperature. There are several plants that do not flower before they experience low temperature. This dependency on the temperature to flower is referred as *vernalization*.

Example of Vernalization

Food plants like barley, wheat rye are of two varieties, i.e. winter and spring varieties. In this, spring variety is planted in spring and winter variety in winters. These plants grow in their respective seasons, flower and produce grains before the end of the growing season.

Another example can be observed in biennial plants. These are monocarpic plants that normally flower and die in second season. Some of the common biennials are Carrot, Cabbages and sugar beet.

Summary of the unit

Growth is one of the most conspicuous events in any living organism. It is an irreversible increase expressed in parameters such as size, area, length, height, volume, cell number etc. It conspicuously involves increased protoplasmic material. In plants, meristems are the sites of growth. Root and shoot apical meristems sometimes along with intercalary meristem, contribute to the elongation growth of plant axes. Growth is indeterminate in higher plants. Following cell division in root and shoot apical meristem cells, the growth could be arithmetic or geometrical. Growth may not be and generally is not sustained at a high rate throughout the life of cell/tissue/organ/organism. One can define three principal phases of growth – the lag, the log and the senescent phase. When a cell loses the capacity to divide, it leads to differentiation. Differentiation results in development of structures that is commensurate with the function the cells finally have to perform. General principles for differentiation for cell, tissues and organs are similar. A differentiated cell may dedifferentiate and then dedifferentiate. Since differentiation in plants is open, the development could also be flexible, i.e., the development is the sum of growth and differentiation. Plant exhibit plasticity in development. Plant growth and development are under the control of both intrinsic and extrinsic factors. Intercellular intrinsic factors are the chemical substances, called plant growth regulators (PGR). There are diverse groups of PGRs in plants, principally belonging to five groups: auxins, gibberellins, cytokinin's, abscisic acid and ethylene. These PGRs are synthesised in various parts of the plant; they control different differentiation and developmental events. Any PGR has diverse physiological effects on plants. Diverse PGRs also manifest similar effects. PGRs may act synergistically or antagonistically. Plant growth and development is also affected by light, temperature, nutrition, oxygen status, gravity and such external factors. Flowering in some plants is induced only when exposed to certain duration of photoperiod. Depending on the nature of photoperiod requirements, the plants are called short day plants, long day plants and day-neutral plants. Certain plants also need to be exposed to low temperature so as to hasten flowering later in life. This treatment is known as vernalisation.

EXERCISE

Multiple Choice Questions

1. Coconut milk contains a cytokinin called _____ which promotes plant growth.
   (a) Naphthalene acetic acid
   (b) Indole-3-acetic acid
   (c) Gelatin
   (d) Zeatin
2. One of the following is not an auxin
   (a) Indole-3-acetic acid
   (b) Malic Hydrazide
   (c) Indole butyric acid
   (d) Naphthalene acetic acid
3. _____can stimulate the germination of barley seeds
   (a) α-amylase
   (b) Abscisic acid
   (c) Benzoic acid
   (d) Coumarin
4. Seed dormancy is triggered by
   (a) Indole-3-ethanol
   (b) Abscisic acid
   (c) Carbon dioxide
   (d) None of the above
5. The significance of the day length in plants was first shown in:
   (a) Barley
   (b) Lettuce
   (c) Tobacco
   (d) Tomato
6. Uneven distribution of auxins may lead to
   (a) Phototrophic curvature
   (b) Day-neutral curvature
   (c) Both (1) and (2)
   (d) None of the above
7. Tendrils of garden peas coiling around any support signifies:
   (a) Seismonasty
   (b) Thigmotaxis
   (c) Gravitropism
   (d) Thigmotrophism
8. _____ tissues synthesize natural cytokinins
   (a) Old
   (b) Rapidly dividing
   (c) Storage
   (d) None of the above

9. _____ is a plant hormone generally present in the gaseous state
   (a) Ethylene
   (b) Ethane
   (c) Argon
   (d) None of the above
10. _____ is a colourless gas that serves as a signalling hormone.
   (a) Benzene
   (b) Nitric Oxide
   (c) Ozone
   (d) None of the above

Answer Key

1. (d)	**2.** (b)	**3.** (a)	**4.** (b)	**5.** (c)
6. (a)	**7.** (d)	**8.** (b)	**9.** (a)	**10.** (b)

Review Questions

1. Define growth, differentiation, development, dedifferentiation, redifferentiation, determinate growth, meristem and growth rate.
2. Why is not any one parameter good enough to demonstrate growth throughout the life of a flowering plant?
3. Describe briefly: (a) Arithmetic growth (b) Geometric growth (c) Sigmoid growth curve (d) Absolute and relative growth rates
4. List five main groups of natural plant growth regulators. Write a note on discovery, physiological functions and agricultural/horticultural applications of any one of them.
5. What do you understand by photoperiodism and vernalisation? Describe their significance.
6. Why is abscisic acid also known as stress hormone?
7. 'Both growth and differentiation in higher plants are open'. Comment.
8. 'Both a short-day plant and a long day plant can produce can flower simultaneously in a given place'. Explain.

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16 REPRODUCTION AND POPULATION CONTROL

Reproduction and Population Control

A population comprises of the considerable number of people of similar species possessing a particular geological zone at a given time. It positions subordinate to species. A species may have a solitary population or numerous populations limited to unmistakable zone. The primary **cause of high rate of population explosion** is an extending crevice between birth rate and death rate, increased food production and improvement of public health. The developing urban population made numerous issues for urban zones and rural zones.

Population Explosion Effects

In Urban Territories

1. It has prompted to the capacity of sustenance, crude materials and extensive variety of products.
2. It has prompted to contamination and ecological imbalance.

In **Rural Territories**, the urban developing population has prompted to

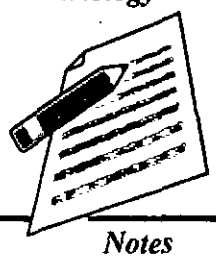
1. To diminish in the woodland areas.
2. Left pernicious impact on soil fertility.

Importance of Population Control

The main advantage of population control seems to be the increase in economic stability and better living conditions, while the most common disadvantages are the difficulty in enforcing such a policy and the lack of success because of this according to a report published by the University of **Omaha**.

Reproductive Health

The term **Reproductive Health** basically alludes to healthy reproductive organs with typical functions. In any case, it has a more extensive point of view and incorporates the emotional and social parts of proliferation moreover. As per the **World Health Organization** (WHO), reproductive health implies an aggregate prosperity in all parts of reproduction, **For Example:** Physical, emotional, behavioural and social. Thusly, a general public with individuals having physically and functionally ordinary reproductive organs and typical emotional and behavioural associations among them in all sex-related viewpoints may be called reproductively healthy. A total viewpoint of human reproductive health is fundamental to individual thriving and not withstanding interpersonal associations.



Youths are dynamic, delicate and inclined to experimentation and hazard taking; accordingly they are the most defenceless population to the extent reprobate conduct and state of mind is concerned. Each choice has its own particular outcome. Any wrong choice can prompt to grievous outcome, which thus can demolish one's life. Sexual alteration is a piece of aggregate identity conformity. Self-regard is the way to sexual development.

Expansive based community and support of various institutions for reproductive health is the key.

Adolescence Reproductive and Sexual Health (ARSH)

- Points are to be dealt with to disperse the myths and misguided judgment about this imperative perspective with concentrate on:
- Reducing dangerous conduct
- Theories which clarify what impacts individuals' sexual decisions and conduct
- Reinforced message about sexual conduct and hazard diminishment
- Providing exact data about, the dangers connected with sexual movement; about contraception anti-conception medication, techniques for conceding or avoiding intercourse
- Dealing with associate and other social weights on youngsters; giving chances to practice correspondence, transaction and attestation aptitudes
- Uses an assortment of ways to deal with instructing and discovering that include and draw in youngsters and help them to customize the data
- Uses ways to deal with instructing and realizing which are suitable to youngsters' age, encounter and social foundation

Population Explosion and Birth Control

(a) The rapid increase in human population size over a relatively short period is called human population-explosion.

(b) Population growth rate depends on factors like fertility, natality, mortality, migration, age and sex structure.

(c) Increased health facilities and better living conditions are the cause behind population explosion.

(d) Out of 6 billion world population 1.3 billion populations is of Indians.

(e) Rapid decline in death rate, **Maternal Mortality Rate** (MMR) and **Infant Mortality Rate** (IMR) are major cause of population growth.

(f) Growth rate of Indian population is around 1.7 percent.

(g) Most of the urban people are uneducated.

(h) The regulation of conception by preventive methods or devices to limit the number of offspring is called **Birth Control**.

(i) A birth control method which deliberately prevents fertilization are referred to as contraception.

(j) Contraceptive methods are preventive methods and are of two types – **Temporary** and **Permanent**.

Characteristics of an ideal contraceptive are:

(a) User friendly
(b) Easily available
(c) Nor or least side-effects
(d) No way interferes with sexual drive

Types of Birth Control

- ***Continuous abstinence***
- **Natural family planning/rhythm method**
- ***Barrier methods***
  - Contraceptive sponge
  - Diaphragm, cervical cap, and cervical shield
  - Female condom
  - Male condom
- **Hormonal methods**
  - Oral contraceptives — combined pill ("The pill")
  - Oral contraceptives — progestin-only pill ("Mini-pill")
  - The Patch
  - Shot / Injection
  - Vaginal Ring
- **Implantable devices**
  - Implantable Rods
  - Intrauterine Devices
- **Permanent birth control methods**
  - Sterilization Implant
  - Surgical Sterilization
- **Emergency contraception**

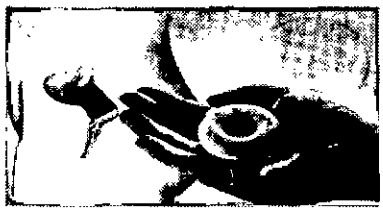
The above-mentioned ways are discussed in details as follows:

Continuous abstinence: This implies not engaging in sexual relations at any time (vaginal, oral, or anal). It is the main, beyond any doubt approach to counteract pregnancy and secure against **Sexually Transmitted Infections** (STIs), including AIDS.

Natural family planning/rhythm method: This strategy is the point at which you don't have intercourse or utilize a barrier technique on the days you are most fruitful (destined to end up getting pregnant). A woman who has a normal menstrual cycle has around at least 9 days every month when she can get pregnant. These prolific days are around 5 days before and 3 days after ovulation, and in addition the day of ovulation.

Barrier methods: Utilize a block, or boundary, to keep sperm from penetrating the egg.

Contraceptive Sponge



Sponge

This barrier strategy is a delicate, disc- shaped gadget with a loop for taking it out. It is made out of polyurethane (pah-lee-YUR-uh-thayn) froth and contains the spermicide (SPUR-muh-syd) nonoxynol-9. Spermicide kills the sperm.

One and only sort of preventative sponge is sold in the United States. It is known as Today Sponge. Women sensitive to the spermicide nonoxynol-9 ought not to utilize the sponge.

Diaphragm, Cervical Cap, and Cervical Shield

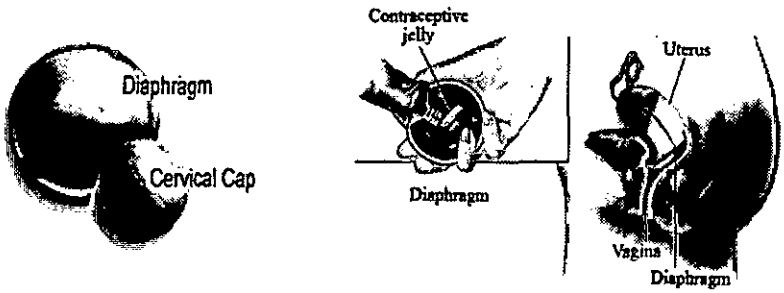


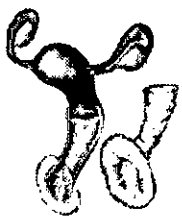
Fig: How to use a diaphragm

These barrier techniques hinder the sperm from entering the cervix (the opening to your womb) and achieving the egg.

- The diaphragm is a shallow latex container.
- The cervical cap is a thimble-molded latex glass. It regularly is called by its brand name, FemCap.
- The cervical shield is a silicone glass that has a one-way valve that creates suction and helps it fit against the cervix. It regularly is called by its brand name, Lea's Shield.

Female Condom

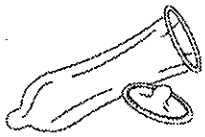
Female Condoms are the barriers worn by the woman inside their vagina. It keeps sperm from getting into their body and fusing with egg. It is made of thin, adaptable, synthetic elastic and is bundled with a lubricant.



Female Condom

Male Condom

Male Condoms are a thin sheath put over a penis in an erect position to keep sperm from entering a woman›s body. Condoms can be made of polyurethane, latex, or «regular/lambskin». The regular types do not ensure against STIs or STDs. Condoms are the best option when utilized with a vaginal spermicide, which leads to the sperm killing. Also, you have to utilize a new condom with every sex demonstration.



Hormonal Methods: Pregnancy is prevented by meddling with ovulation, treatment, or potentially implantation of the fertilized egg.

Oral contraceptives — combined pill ("The pill")

The pill contains the hormones estrogen and progesterone. It is taken day by day to keep the ovaries from discharging an egg. The pill additionally causes changes in the coating of the uterus and the cervical bodily fluid to keep the sperm from fusing with the egg.

A few women incline toward the "extended cycle" pills. These have 12 weeks of pills that contain hormones (dynamic) and 1 week of pills that don't contain hormones (dormant). While taking amplified cycle pills, women just have their period three to four times each year.

Contraceptive Pills

The Patch

Likewise called by its brand name, Ortho Evra, this skin patch is worn on the lower abdomen, bottom, external arm, or abdominal area. It discharges the hormones progestin and estrogen into the circulatory system to prevent the ovaries from discharging eggs in to the fallopian tubes. It additionally thickens the cervical bodily fluid, which keeps the sperm from joining with the egg. You put on another patch once every week for 3 weeks. You don't utilize a patch the fourth week to have a period.

Women ought to hold up three weeks after delivery before utilizing conception prevention that contains both estrogen and progestin. These strategies increment the danger of perilous blood clots that could frame in the wake of conceiving an offspring. Women who had a caesarean segment or have other hazard variables for blood clots, for example, history of blood clots, obesity, smoking, or preeclampsia, ought to hold up for six weeks.

Shot / Injection

The contraception shot frequently is called by its brand name Depo-Provera. With this strategy you get infusions, or shots, of the hormone progestin in the rear end or arm at regular intervals. Another sort is infused under the skin. The anti-conception medication shot prevents the ovaries from discharging an egg in numerous women. It additionally causes changes in the cervix that keep the sperm from joining with the egg.

The shot ought not be utilized over 2 years as a part of a line since it can bring about an impermanent loss of bone thickness. The misfortune expands the more extended this strategy is utilized. The bone starts to develop after this technique is ceased. Yet, it might expand the danger of fracture or osteoporosis if utilized for quite a while.

Vaginal Ring

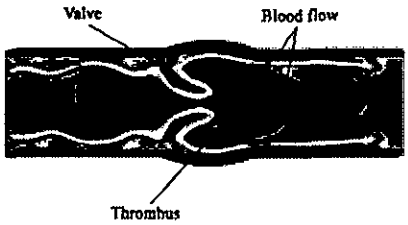
Vaginal Ring

This is a thin, adaptable ring that discharges the hormones progestin and estrogen. It works by preventing the ovaries from discharging eggs. It likewise thickens the cervical bodily fluid, which keeps the sperm from joining the egg.

It is ordinarily called NuvaRing, its brand name. You press the ring between your thumb and pointer and embed it into your vagina. You wear the ring for 3 weeks, take it out for the week that you have your period, and afterward put in another ring.

Women ought to hold up three weeks after delivery before utilizing conception prevention that contains both estrogen and progestin. These strategies increment the danger of perilous blood clots that could frame in the wake of conceiving an offspring. Women who had a caesarean segment or have other hazard variables for blood clots, for example, history of blood clusters, obesity, smoking, or preeclampsia, ought to hold up for six weeks.

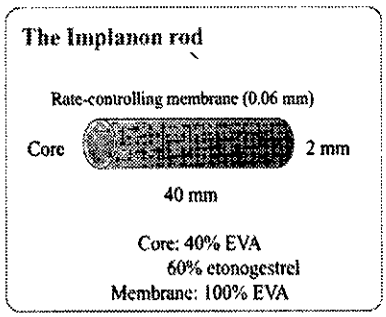
Blood Clot Diagram

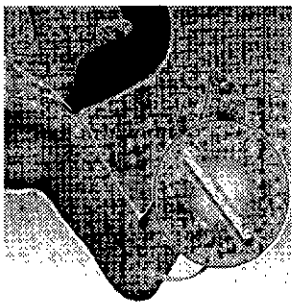


Implantable Devices: Devices embedded into the body and left set up for a couple of years.

Implantable Rod

This is a matchstick-measure, adaptable rod that is put under the upper arm skin. It is regularly called by its brand name, Implanon. The rod discharges a progestin, which causes changes in the coating of the uterus and the cervical bodily fluid to keep the sperm away from penetrating an egg. Less frequently, it prevents the ovaries from discharging eggs. It is powerful for up to three years.



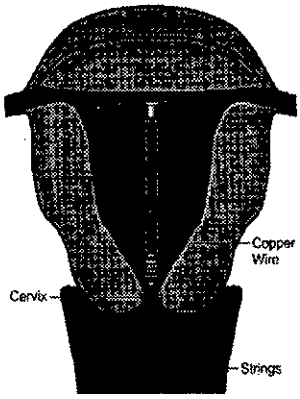


Implanon Diagram

Intrauterine Devices or IUDs

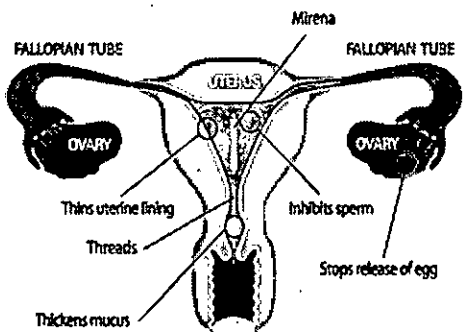
An IUD is a little device molded like a "T" that goes in your uterus. There are two sorts:

- **Copper IUD** — The copper IUD passes by the brand name ParaGard. It discharges a little measure of copper into the uterus, which keeps the sperm from coming to and fusing with the egg. On the off chance that fertilization occurs, the IUD keeps the egg from embedding in the coating of the uterus. A specialist needs to put in your copper IUD. It can remain in your uterus for five to ten years.



Copper IUD

- **Hormonal IUD** — the hormonal IUD passes by the brand name Mirena. It is often called an intrauterine system, or IUS. It discharges progestin into the uterus, which keeps the ovaries from discharging an egg and causes the cervical bodily fluid to thicken so sperm cannot reach out for the egg. It additionally influences the capacity of a fertilized egg to effectively embed in the uterus. A specialist needs to put in a hormonal IUD. It can remain in your uterus for up to five years.



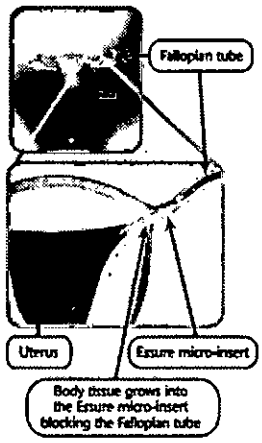
Mirena IUD

Permanent Birth Control Methods: For individuals who are certain they never need to have a youngster or they don't need more kids.

Sterilization Implant (Essure)

Essure is the main non-surgical strategy for disinfecting ladies. A thin tube is utilized to string a minor spring-like gadget through the vagina and uterus into each fallopian tube. The gadget works by bringing about scar tissue to conform or wrap around to the coil. This hinders the fallopian tubes and prevents the egg and sperm from joining.

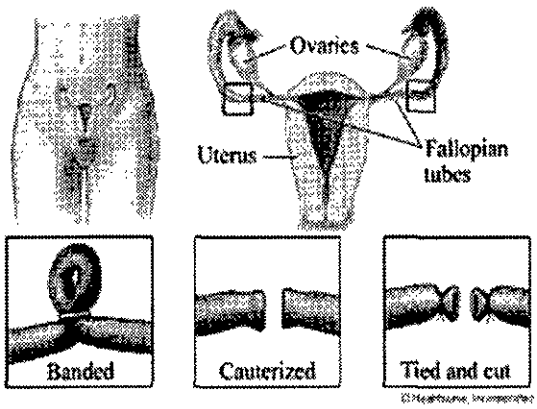
It can take around three months for the scar tissue to develop, so it's imperative to utilize another type of contraception amid this time. At that point you will need to come back to your specialist for a test to check whether scar tissue has completely hindered your tubes.



Essure

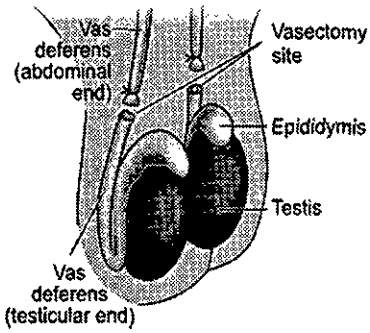
Surgical Sterilization

In women, surgical disinfection shuts the fallopian tubes by being cut, tied, or fixed. This prevents the eggs from being fertilized by preventing them going down to the uterus. The surgery should be possible in various ways. Once in a while, a woman having caesarean birth has the technique done in the meantime, in order to abstain from having extra surgery later.



Tubectomy

For men, having a vasectomy (vuh-SEK-tuh-mee) keeps sperm from heading off to his penis, so his discharge never has any sperm in it. Sperm remains in the framework after surgery for around 3 months. Amid that time, utilize a reinforcement type of anti-conception medication to counteract pregnancy. A basic test should be possible to check if all the sperm is gone; it is known as a semen investigation.

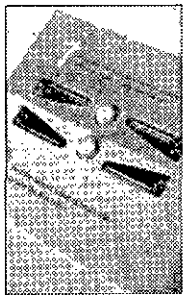


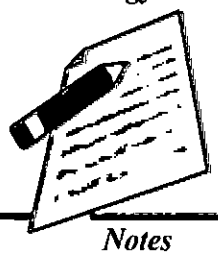
Vasectomy

Emergency contraception: Utilized if a woman's essential strategy for anti-conception medication fizzles. It ought not to be utilized as a customary technique for contraception.

Emergency contraception can be taken as a solitary pill treatment or in two dosages. A solitary measurement treatment acts and in addition two dosages and does not have more reactions. It works by preventing the ovaries from discharging an egg or keeping the sperm from joining with the egg.

A solitary pill measurement or two-pill dosage of emergency contraception is accessible over-the-counter (OTC) for women ages seventeen and older.



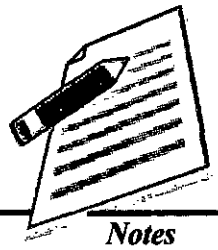


Summary of the unit

Reproductive health refers to a total well-being in all aspects of reproduction, i.e., physical, emotional, behavioural and social. Our nation was the first nation in the world to initiate various action plans at national level towards attaining a reproductively healthy society. Counselling and creating awareness among people about reproductive organs, adolescence and associated changes, safe and hygienic sexual practices, sexually transmitted infections (STIs) including AIDS, etc., is the primary step towards reproductive health. Providing medical facilities and care to the problems like menstrual irregularities, pregnancy related aspects, delivery, medical termination of pregnancy, STIs, birth control, infertility, post-natal child and maternal management is another important aspect of the Reproductive and Child Health Care programmes. An overall improvement in reproductive health has taken place in our country as indicated by reduced maternal and infant mortality rates, early detection and cure of STIs, assistance to infertile couples, etc. Improved health facilities and better living conditions promoted an explosive growth of population. Such a growth necessitated intense propagation of contraceptive methods. Various contraceptive options are available now such as natural, traditional, barrier, IUDs, pills, injectables, implants and surgical methods. Though contraceptives are not regular requirements for reproductive health, one is forced to use them to avoid pregnancy or to delay or space pregnancy. Medical termination of pregnancy is legalised in our country. MTP is generally performed to get rid of unwanted pregnancy due to rapes, causal relationship, etc., as also in cases when the continuation of pregnancy could be harmful or even fatal to either the mother, or the foetus or both. Infections or diseases transmitted through sexual intercourse are called Sexually Transmitted Diseases (STIs). Pelvic Inflammatory Diseases (PIDs), still birth, infertility are some of the complications of them. Early detection facilitates better cure of these diseases. Avoiding sexual intercourse with unknown/multiple partners, use of condoms during coitus are some of the simple precautions to avoid contracting STIs. Inability to conceive or produce children even after 2 years of unprotected sexual cohabitation is called infertility. Various methods are now available to help such couples. In Vitro fertilisation followed by transfer of embryo into the female genital tract is one such method and is commonly known as the 'Test Tube Baby' Programme

Review Questions

1. What do you think is the significance of reproductive health in a society?
2. Suggest the aspects of reproductive health which need to be given special attention in the present scenario.
3. Is sex education necessary in schools? Why?
4. Do you think that reproductive health in our country has improved in the past 50 years? If yes, mention some such areas of improvement.
5. What are the suggested reasons for population explosion?



6. Is the use of contraceptives justified? Give reasons.
7. Removal of gonads cannot be considered as a contraceptive option. Why?
8. Amniocentesis for sex determination is banned in our country. Is this ban necessary? Comment.
9. Suggest some methods to assist infertile couples to have children.
10. What are the measures one has to take to prevent from contracting STDs?

Space for notes

17 PRINCIPLES OF GENETICS

What is Heredity?

Heredity is a process of transmission of traits from parents to their offspring's either via asexual reproduction or sexual reproduction. These characteristics or traits are located on the chromosomes in the form of genes.

Gregor Johann Mendel- "Father of Genetics"

Mendel was born in 1822 in Heinzen Dorf, which was a part of Czechoslovakia. His genetic experiments were conducted on garden pea, *Pisum sativum* in 1856 in the garden at the monastery.

Mendel used the pea plant for his experiments because of the following reasons:

- Life span of pea plant is short
- Flowers are self-pollinated.
- Flowers were hermaphrodite as well as bisexual.

Mendel's Laws

There were 3 laws that were proposed by Mendel after different experiments on Pea plant.

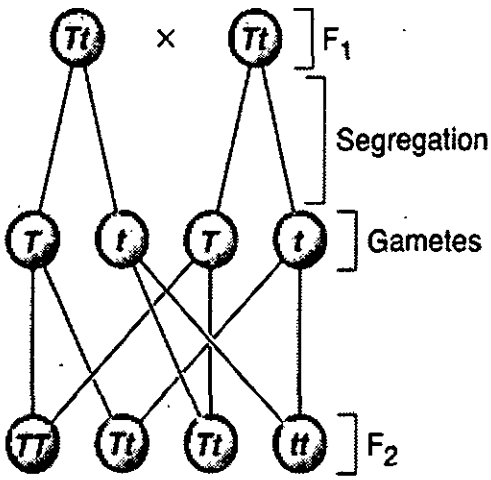


Fig.1. Example of law of segregation of alleles.
In this A is dominant over a.

1. **Law of dominance-** The effect of recessive allele is masked by the dominant allele. Only dominant allele expresses its phenotype.

   For example: "Allele for tallness is dominant over allele for dwarfism"

2. **Law of segregation of genes**- Each individual possesses two alleles of a gene and each allele separates or segregates at the time of meiosis, that is, during the formation of gametes. The monohybrid cross (cross of single trait) was used to explain the law of segregation of genes. (See Fig. 1).
3. **Law of independent assortment** – It states that alleles for separate traits are passed independently from parents to the offspring. Mendel used dihybrid (cross of two different traits) cross in order to explain independent assortment. **(See Fig. 2)**

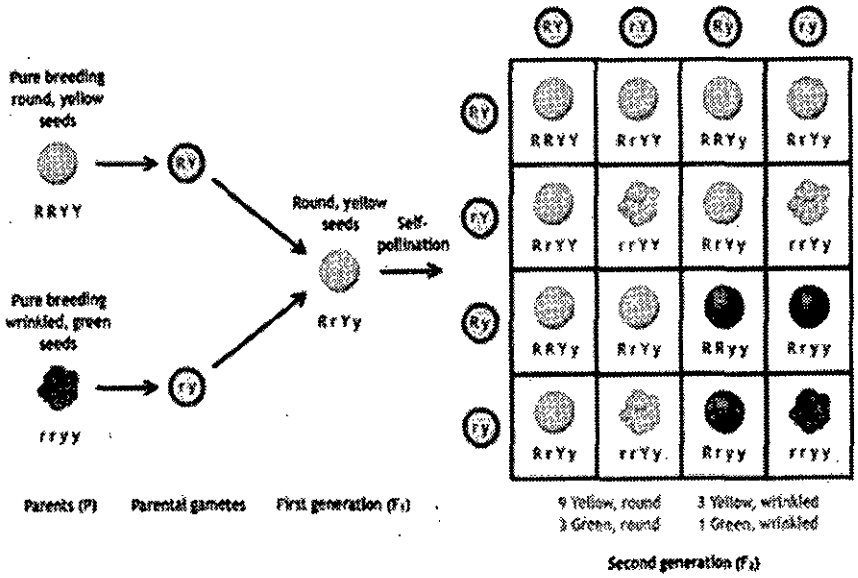


Fig. 2. Law of independent assortment. Yellow round is dominant to green wrinkled.

Test Cross

A cross between first generation (F1) hybrids with its homozygous recessive parent is described as Test Cross. It determines whether dominant phenotype is homozygous or heterozygous in nature. (See Fig.3)

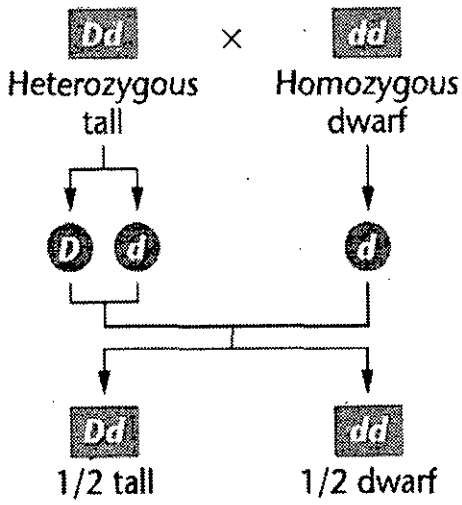


Fig. 3. Test Cross of a Monohybrid Cross

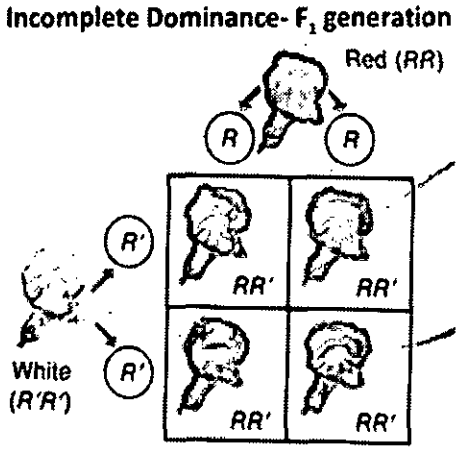


Fig.3(a). Incomplete Dominance

Incomplete Dominance

When a dominant allele is not completely dominant over recessive allele and the F1 hybrid forms after crossing is intermediate between the two parents, the phenomenon is called incomplete dominance.

"For example: Flower colour in Mirabilis Jalapa, (4'O clock plant). When homozygous red (RR) flower is crossed with white (rr) flower, the F1 offspring's form will have pink flowers (Rr). The phenotypic ratio as well as genotypic ratio in F2 generation is 1:2:1". **See Fig. 3(a)**

Multiple Allelism or Co-dominance

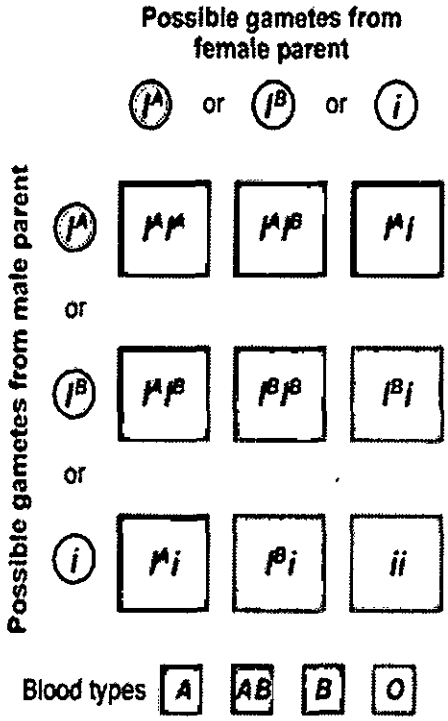
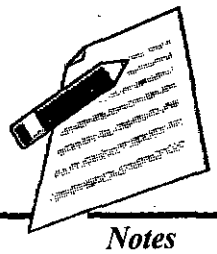


Fig.4. Multiple alleles



When a gene exists in more than two allelic forms, the phenomenon is known as multiple allelism. "For example: multiple alleles is the inheritance of A, B and O blood groups in human being". The gene for blood group occurs in three allelic forms I^A, I^B and i. An individual can possess any two of these alleles. The gene I^A codes for glycoprotein A which is responsible for A blood group and gene I^B codes for glycoprotein B which is responsible for blood group B.

The gene 'i' do not produce any glycoprotein and so the person who is homozygous for it, will have O group blood. The genes IA and IB are dominant over 'i'. IA and IB alleles are equally dominant and produce both glycoproteins A and B and the blood group is AB. Such alleles are known as co-dominant alleles See Fig. 4

Chromosome theory of Inheritance

This theory was proposed by Sutton and Boveri in1902. This theory is also known as Boveri-sutton theory after the name of the scientist who proposed the theory.

Important Characteristics of Chromosome theory of Inheritance

- Both chromosomes as well as genes exists in pairs in the diploid cells.
- Gamete contains only one chromosome of particular type and only one of the two alleles of a character.
- Fertilization restores diploid condition.
- Homologous chromosomes separate at the time of meiosis.
- Chromosomes segregates and assort independently.

Sex Determination in Different Organisms

Chromosomes that are involved in the determination of sex of an individual are called sex chromosomes or allosomes while the other chromosomes are called autosomes. There are different sex chromosomes that determine the sex of different organisms as explained below-

(1) XX – XY type

For example: Drosophila (fruit fly) and mammals including human beings. The females have 2 X chromosomes as sex chromosomes, thus **homomorphic** (morphologically identical homologous chromosomes) in nature. The males are heteromorphic, that is, they have one X and one Y chromosomes as sex chromosomes. For maleness Y chromosome is essential. Thus the presence or absence of Y chromosome decide whether the child will be male or female.

(2) ZZ – ZW type

For example: birds and reptiles. The males are represented as ZZ (homomorphic) and females are heteromorphic, that is ZW.

(3) XX – XO type

For example: roundworms and insects. The females have two sex chromosomes, XX, while the males have only one sex chromosomes X. Therefore, the males are labelled as XO.

Sex Determination in Humans

Humans have 22 pairs of autosomes and one pair of sex chromosomes or allosomes. All the eggs formed by female possess only X chromosomes as they are homogametic/homomorphic in nature. The male gametes produced by human males are of two types, that is, they either contain X chromosome or Y chromosome.

Genetic Disorders

Disorders that arise due to abnormality in individual's DNA. Below are some examples of genetic disorders

Haemophilia

It is a sex-linked recessive disease. It is a disorder in which person ability of blood clotting is lost, that is, clotting is delayed. This can prove fatal.

Sickle Cell Anaemia

It is an autosome recessive disease. This occurs due to mutant allele on chromosome 11. In this amino acid glutamine (GAG) is replaced by valine (GUG) at the sixth position of β-chain of haemoglobin. The patient RBCs becomes sickle shaped and thus reduces the oxygen supply to different parts of the body.

Phenylketonuria

It is an autosomal recessive disease caused by mutant allele on chromosome number 12. The individuals suffering from the disease lack an enzyme known as phenylalanine hydroxylase that converts the amino acid phenylalanine into amino acid tyrosine. Due to this, phenylalanine accumulates in the cerebrospinal fluid (CSF) causing brain problems.

Chromosomal Disorders

Disorders that arise due to abnormal arrangement of chromosomes. This leads to change in chromosome number. This occurs due to non-disjunction of chromosomes at the time of meiosis.

Aneuploidy

This occurs when there is loss or gain of one or more chromosomes at the time of gamete formation. "For example: Turner's syndrome (45).

Polyploidy

Polyploidy is a condition in which nucleus contain more than two sets of homologous chromosomes. "For example: Down syndrome.

Down's Syndrome

The trisomy at 21st chromosome resulting from non-disjunction of chromosomes at the time of gamete formation.

Symptoms: Short stature, mentally retarded, low muscle tone etc.

Klinefelter's Syndrome

Non-disjunction of X chromosomes at the time of egg formation. When an ovum containing 2 X chromosomes is fertilized with the sperm containing single Y chromosome. The individual will have 47 chromosomes instead of 46 chromosomes.

Symptoms: The child is male genotypically but possess features of female child. The child will have low testosterone level in the body, weaker muscles, fatter around the belly etc.

Turner's Syndrome

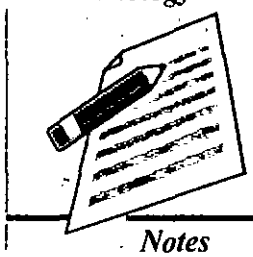
Fig.5. Girl with turner syndrome

When non-disjunction of X-chromosomes occurs at the time of ova formation. When an ovum without X-chromosome is fertilized by a sperm carrying X-chromosome, a zygote with XO, that is, with single X chromosome is formed. See Fig. 5

Symptoms: low set ears, females with rudimentary ovaries, short fingers and toes, delayed growth, swelling of hands and feet.

Summary of the chapter

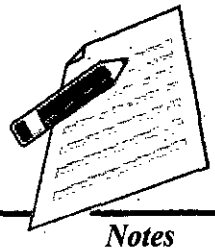
- Heredity means the transmission of characters from parents to offspring.
- Variation pertains to differences between siblings or members of same species.
- Mendel was the first to explain that heredity involves transmission of certain factors from reproductive cells of parents to offspring.
- Hugo de Vries, Correns and Tschermach rediscovered Mendel's Laws of inheritance nearly 35 years after Mendel's death. z 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 parents 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



EXERCISE

Multiple Choice Questions

1. If a hybrid expresses a character, it is called _____
   (a) Epistasis
   (b) Dominant
   (c) Co-dominant
   (d) Recessive
2. A plant having the genotype AABbCC will produce _____ kinds of gametes
   (a) 5
   (b) 4
   (c) 3
   (d) 2
3. Colour blindness is an _____ linked recessive trait
   (a) Z chromosome
   (b) Y chromosome
   (c) X chromosome
   (d) None of the above
4. In most species, mitochondrial DNA is passed down from
   (a) DNA
   (b) Mother and Father
   (c) Father
   (d) Mother
5. Where are the genes for cytoplasmic male sterility in plants located?
   (a) Chloroplast genome
   (b) Mitochondrial genome
   (c) Cytosome
   (d) None of the above
6. _____ is a type of trait whose phenotype is influenced by more than one gene
   (a) Oncogenic Trait
   (b) Monogenic trait
   (c) Polygenic trait
   (d) None of the above
7. An individual's collection of genes is called _____
   (a) Genotype
   (b) Phenotype
   (c) Trait
   (d) None of the above
8. A man marries a woman and both do not show any apparent traits of inherited disease. Five sons and two daughters are born, and three of their sons suffer from a disease. However, none of the daughters is affected. The following mode of inheritance for the disease is
   (a) Sex-linked recessive
   (b) Sex-linked dominant
   (c) Autosomal dominant
   (d) None of the above



9. A trait that "overpowers" and hide another trait is called
   (a) Overpowering trait
   (b) Complex trait
   (c) Recessive trait
   (d) Dominant Trait
10. Why is haemophilia a disease that is more commonly seen in males?
   (a) Both (b) and (c)
   (b) The disease is Y- linked
   (c) The disease is X- linked
   (d) None of the above

Answer Key

1. (b)	2. (d)	3. (c)	4. (d)	5. (b)
6. (c)	7. (a)	8. (a)	9. (d)	10. (c)

Review Questions

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 Heredity plant (tt). Work out the phenotypic and genotypic ratios of the F2 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.

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Module 4 ENVIRONMENT AND HEALTH

Module Content

Objective of the module

This module emphasizes the basic understanding of rules governing the interrelationships in a biotic community. It brings out the basic principle of conservation by pointing out that conservation of natural resources would brighten the prospect of future of humankind. This module aims to create an idea about healthy living. It also imparts knowledge regarding role of proper and balanced diet to prevent nutritional deficiency diseases. The types, causes and modes of transmission of human diseases are discussed

18 PRINCIPLES OF ECOLOGY

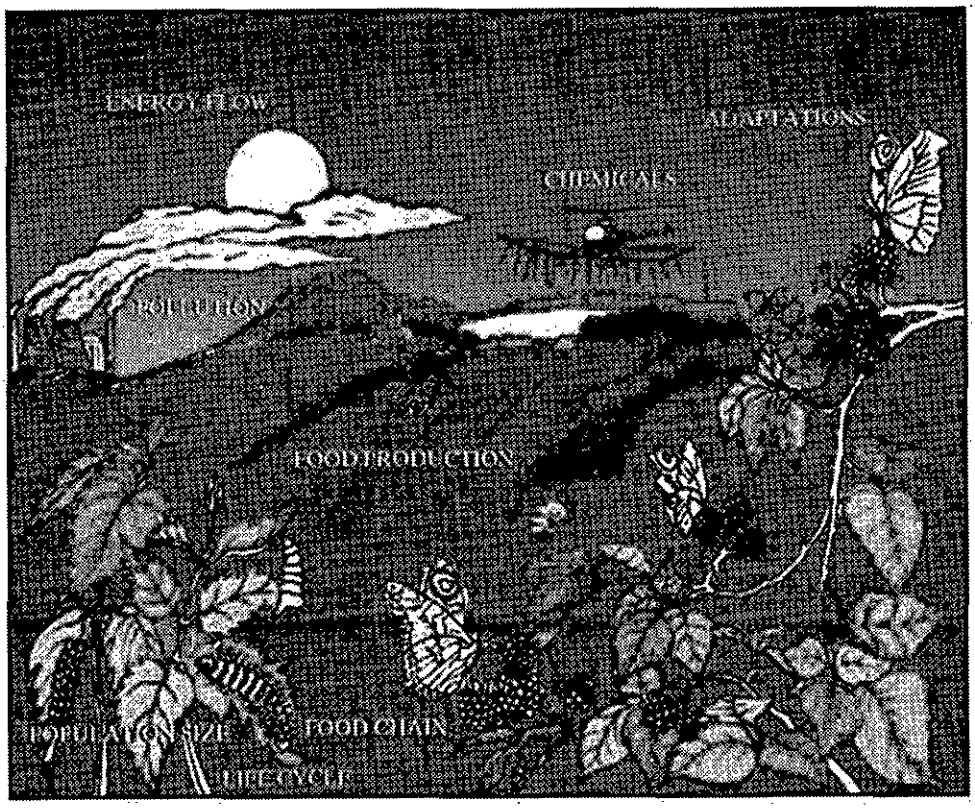
Introduction

"Ecology is the study of the relationships between Living Organisms, including humans, and their Physical Environment; it seeks to understand the vital connections between plants and animals and the world around them."

In other words, all the organisms, irrespective of their size, species and place they live, need to interact with neighbourhood in order to survive and ecology is the scientific study of interaction of these organisms and environment.

The word Ecology is derived from two Greek words, i.e. **Oikos** meaning habitation and **logos** meaning study or discourse. Thus, ecology is the study of habitation of organisms.

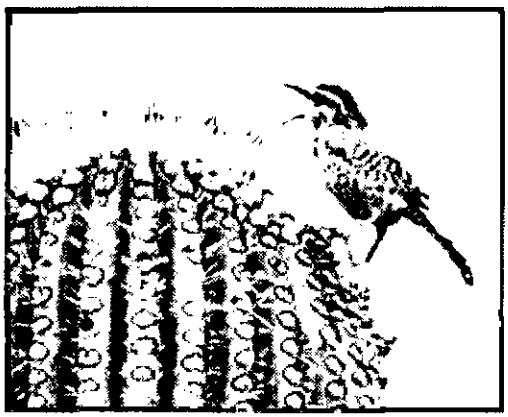
What is Ecology?



The study of Interactions between organisms and other organisms, organisms and their environment.

The word "Ecology" was coined by German scientist named Ernst Haeckel in the year 1866 and the Alexander von Humboldt, the German explorer is considered as Father of Ecology. Humboldt was the first to study the relationship between environment and organisms and exposed the existing relationships between plant species with the climate. He also explained vegetation zones via latitude and altitude and this discipline is now referred as geobotany.

Example of Ecology



A cactus in the middle of desert draws nourishment from ground and air. It depends on sunlight for energy required to grow. This cactus may be home for lizards, birds and some microscopic animals.

Here, air and water are the elements of physical environment that impacts the growth of cactus. At the same time, it releases oxygen and water-vapor into the air, thereby changing the composition of the surrounding atmosphere. The cactus also provides shelter, food and shade to several animals living nearby. Hence, it can be said that the cactus interact with different organisms and environment in different forms and this is referred as Ecology.

What does Ecology explain?

Ecology as a science seeks to explain:

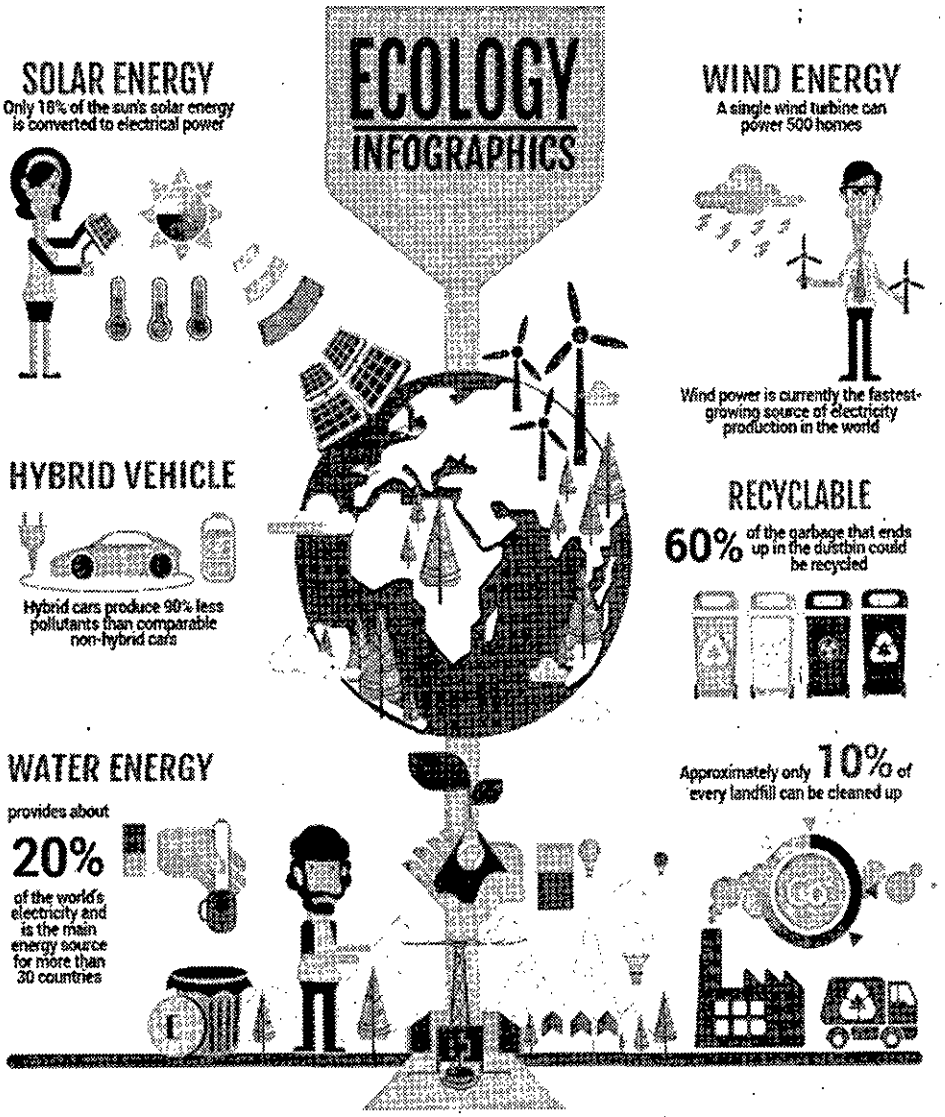
- Distribution and abundance of organisms
- Adaptations and life processes
- Movement of energy and material via different living communities
- The distribution and abundance of Biodiversity in relation to Environment
- The successional development of Ecosystems
- Several practical applications of Ecology in community health, natural resource management, basics, economics and applied science, etc.

Why studying Ecology is important?

It is important to understand Ecology because of several reasons –

- It is the science that explains the relation of species with the environment whereby people are able to preserve several types of habitats and biodiversity.

- Lack of understanding of ecology may result in degradation of environment and land which is the home of several species. The study of ecology can help in preserving and conserving endangered species like white shark, sperm whales, black rhinos, etc.



- Ecology involves the use of several laboratory experiments and scientific methodology that help in understanding different organisms as to how they grow and populate; how do they adapt to change in climate; how do they interact with other organisms, etc. This study helps in better resource allocation such as minerals, environment, space, air, etc. Thereby, preventing from deprivation.
- The study of Ecology helps in improving the energy conservation, failing which, may result in destruction of the energy resources leading to competition, scarcity and exploitation.
- It helps in establishing harmony amongst different living organisms.
- Ecological concepts when applied to forest management, helps in maintaining healthy forest ecosystems in certain types of forests.

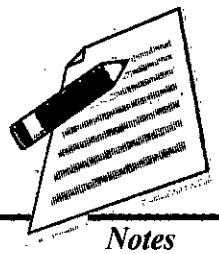
- The awareness of the concepts of ecology helps in finding the agricultural solutions. It includes the technique referred as biological control via which it is able to identify and control natural enemies and predators of pests, thus, preventing the crops from any sort of damages.

Types of Ecology

- **Organism Ecology** - It includes the study of the response of different living organisms to the changes in the physical environment. This change in environment result in changes in behaviour or physical attributes of the organisms. For instance, an animal will escape if the changes are not friendly. At this level of Ecology, the main objective is to study the adaption of organisms towards living and non-living components of the environment.
- **Population Ecology** - All the organisms, either big or small, grow and die. A population refers to the group of individuals belonging to same species living in similar environmental conditions. The manner in which they populate depends on their birth and death rate, size of colony and the population growth rate. In the environment, "**survival of the fittest**" is best implemented, whereby organisms that are able to adapt in best possible manner, are able to survive.
- **Community Ecology** - All organisms interact with each other and exist in certain flora and fauna. In Ecology, either food-chain or food-web exists that explains the role of organism in the ecosystem. Whether it is a predator, or a parasite or a food source, all play an integral role in maintaining and establishing community.
- **Ecosystem Ecology** - "An ecosystem is a community of living organism i.e., animals, plants and microbes together with abiotic components of their environment (such components include things like water, air and mineral soil)interrelating as a system." This type of ecology includes the study of certain processes that link living and non–living components. All living and non-living things interact with temperature, atmosphere, water, energy sources etc. in order to regenerate, recycle, production or consumption. This helps in ensuring the flow of energy in harmony.
- **Global Ecology** - This Ecology controls the usage and allocation of resources worldwide

Summary of the chapter

- Earth is 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 defined as the study of relationship between organism and their environment. Ecology deals with various form of interaction between the organisms and their environment.
- The levels of organisation is the living system starts 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

Review Questions

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 ecosystem?
7. What are the benefits of natural ecosystems?
8. Give two differences between energy flow and biogeochemical cycle in an ecosystem.

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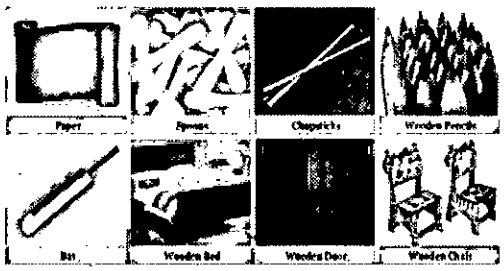
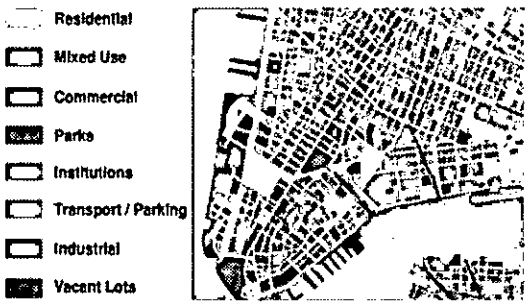
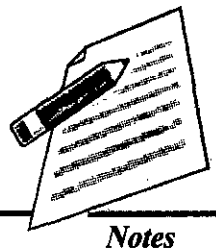
19 CONSERVATION OF PLANTS AND ANIMALS

Deforestation and Its Causes

Deforestation means clearing of forests for different purposes, such as timber and other uses of land.

Major reasons for deforestation are:

	Clearing woods to procure land for cultivation and grow more food for the ever-increasing population
	Using wood as fuel, to make furniture, and for industrial purposes (e.g., wood pulp is used to make paper)
	Using the land for building houses and factories
	Forest fires and severe droughts also lead to deforestation.



Consequences of Deforestation

Deforestation causes:

- Increase in pollution level of the Earth
- Increase in carbon dioxide in the atmosphere
- Increase in temperature or global warming
- Lowering of the level of ground water
- Disturbance in the balance of Nature
- Decrease in the rainfall
- Decrease in the fertility of soil
- Increase in the changes of natural calamities (such as droughts and floods)

Why would deforestation lead to an increase of carbon dioxide in the atmosphere and global warming?

Plants use carbon dioxide for photosynthesis and release oxygen maintaining the atmospheric balance. Fewer trees mean that less carbon dioxide will get recycled in this manner.

Carbon dioxide traps heat rays reflected by the Earth which increases in temperature on the Earth and leads to global warming.

How does deforestation cause droughts and reduction in rainfall?

When trees are cut down, the percentage of carbon dioxide in the atmosphere increases which causes global warming. Moreover, plants absorb water from the soil and release it in the air through transpiration. It is this moisture in the air which eventually turns into clouds and returns to Earth as rainfall.

Deforestation and increase in temperature on the Earth disturb the water cycle, which leads to a reduction in rainfall and droughts.

What is desertification and how is it caused?

Desertification is the process by which a fertile land turns into a desert. Deforestation is a major cause of desertification as it exposes the top layer of soil to natural forces like wind, water and sunlight. With no roots to hold the soil, it gets eroded quickly and the lower, hard and rocky layers of the soil get exposed. These layers have less humus and are less fertile. Gradually, fertile lands turn into deserts.

How does deforestation affect the quality of soil?

The forests add humus to the top layer of the soil. Their roots hold the soil together and allow the surface water to seep into the soil. Due to desertification:

- the soil erosion takes place,
- physical properties of the soil change and it becomes less fertile (its nutrient content and texture changes), and
- the water holding capacity of the soil decreases which may lead to floods.

Conservation of Forest and Wildlife

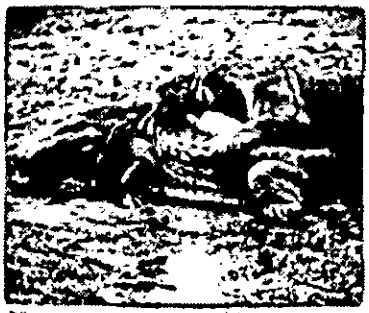
Tigers in India by region

- Karnataka - 406
- Uttarakhand - 340
- Tamil Nadu - 229
- Madhya Pradesh - 208
- Maharashtra - 190
- The Sundarbans in Bengal - 76

Tiger population rises to 2,226 from 1,411 in 2008

Rise since the 2010 estimate

There are 48 tiger reserves in India



Machali's Bellwalla : Famous long [illegible] is legendary

Machali (T-16): The royal tigress of Ranthambore

- Face of tiger conservation in India
- Most photographed tiger in the World
- Called "lady of the lake" as she dominated the waterbodies of Ranthambore

What is wildlife conservation?

Wildlife Conservation is the practice of protecting endangered plant animal species and their habitats in an effort to maintain the ecological balance.

How does the government conserve our forests and wildlife?

The government lays down rules, regulations and policies to protect our forests and wildlife. Besides, it also earmarks rich flora and fauna habitats as protected areas where the following activities are prohibited:

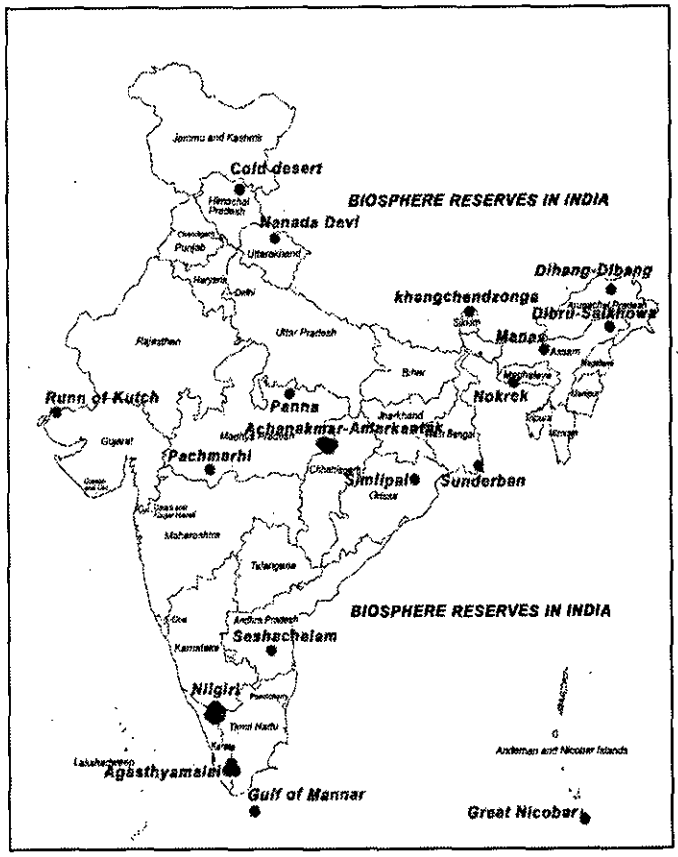
- Cutting down trees
- Grazing cattle
- Hunting
- Plantation and cultivation
- Poaching (illegally killing or capturing wild animals)

Biosphere Reserve

A **Biosphere Reserve** is an area which aims to conserve the biodiversity of the area as well as its culture. It may contain other protected areas within it. **For Example**, Pachmarhi Biosphere Reserve has a national park called the **Satpura National Park** and two wildlife sanctuaries called the **Bori Wildlife Sanctuary** and the **Pachmarhi Wildlife Sanctuary**.

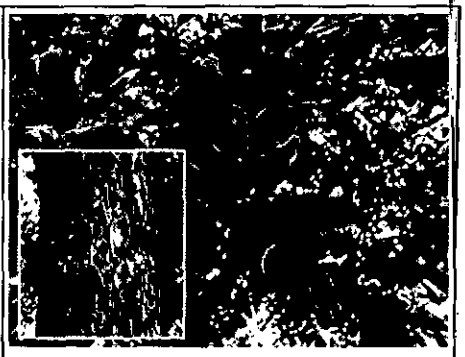
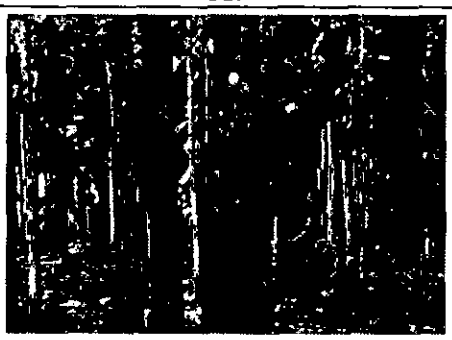
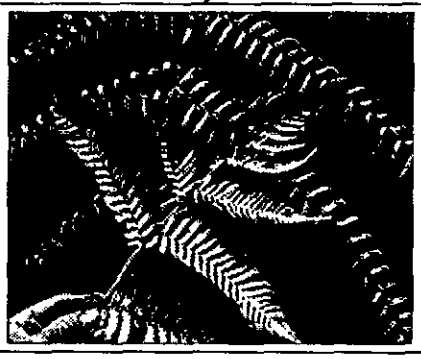
Biosphere Reserves in India

There are 18 biosphere reserves in India, which are:



Flora and Fauna

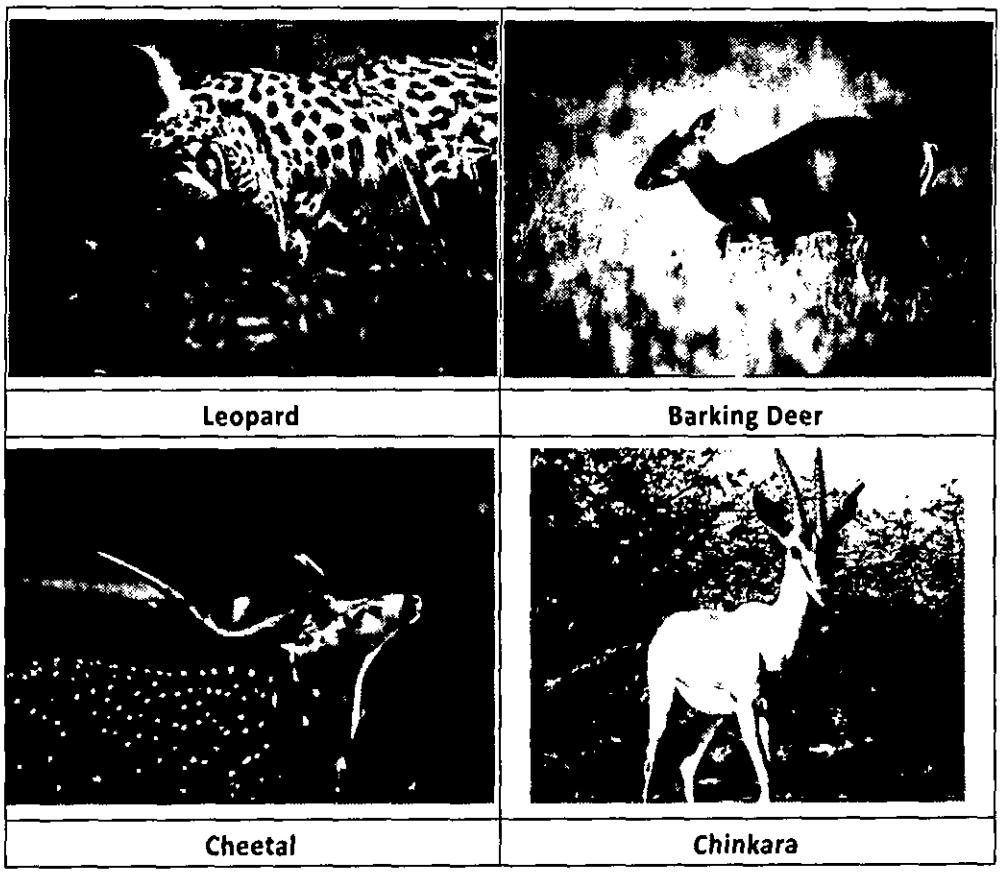
Flora: Plants found in a particular area are referred to as the flora of the area. For Example, flora in the Pachmarhi Biosphere Reserve includes:

	
Sal	Arjun
	
Teak	Silver Fern
	
Mango	Jamun

Fauna: Animals found in a particular area are referred to as the fauna of the area.

For Example, fauna in the Pachmarhi Biosphere Reserve includes:

	
Blue-bull	Wolf



Leopard	Barking Deer
Cheetal	Chinkara

Endemic Species

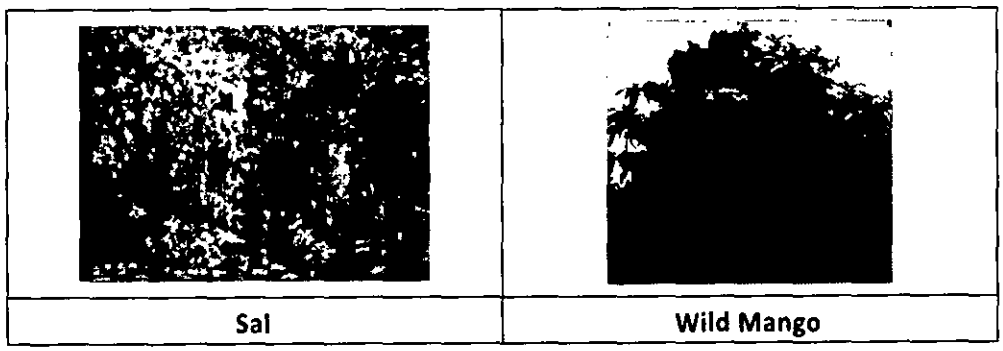
Species: A group of living organisms that can interbreed with each other are called a **Species**. It means that only members of one species can reproduce offspring that are fertile and can give birth to future generations. Members of a species look like each other and share many characteristics.

Endangered Species: Species whose number diminish so much that they might face extinction (or vanish off the face of the Earth) are known as **Endangered Species**. There can be endangered animals as endangered plants.

Endemic Species: Species of plants and animals that are exclusively found in a particular area are called **Endemic** to that zone, state or country. The endemic species are not found anywhere else naturally.

For Example:

Endemic flora of the Pachmarhi Biosphere Reserve includes sal and wild mango.



Sal	Wild Mango

Endemic fauna of the Pachmarhi Biosphere Reserve includes bison, Indian giant squirrel and flying squirrel.

Bison	Wild Mango	Flying Squirrel

Wildlife Sanctuary

Wildlife Sanctuaries are reserved forests where wild animals are protected and provided with suitable living conditions. Unlike a zoo, animals in wildlife sanctuaries live in their natural habitat and are free to roam anywhere as they like.

People living in Wildlife Sanctuaries can:

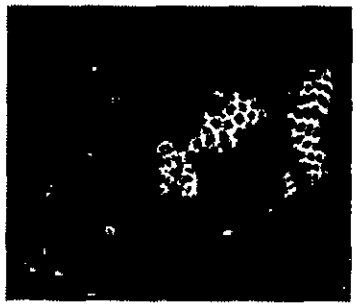
- Graze livestock, and
- Collect firewood or medicinal plants.

Activities prohibited in wildlife sanctuaries include:

- Killing (poaching) animals
- Capturing animals

These activities in wildlife sanctuaries are punishable by law.

Wildlife Sanctuaries in India



Indian wildlife sanctuaries have unique landscapes which include broad-level forests, mountain forests, and bushlands in deltas of big rivers. They protect several threatened wildlife species such as golden cat, pink-headed duck, black buck, white-eyed buck, gharial, marsh crocodile, elephant, rhinoceros, python etc.

Unfortunately, people encroach upon the land of these protected forest areas and destroy them.

There are 543 wildlife sanctuaries in India, which include as many as 50 tiger reserves which focus on the conservation of the tiger. The tiger reserves work under Project Tiger. Jim Corbett was the first tiger reserve of India. It is situated in Uttarakhand and is also the oldest national park in India.

Project Tiger is a government initiative to protect tigers. Its objective was to ensure the survival and maintenance of the population of tigers in India.

Similarly, some of these wildlife sanctuaries are called bird sanctuaries as they focus on protecting birds. **Keoladeo National Park**, for example, was a bird sanctuary before it attained the National Park status.

Some national parks focus on conserving a particular species, For Example, **Jawai leopard sanctuary** which is in Rajasthan.

National Park

National Parks are large forest reserves that attempt to preserve the entire ecosystems within the area including the landscape, flora, fauna, and historic objects of the area.

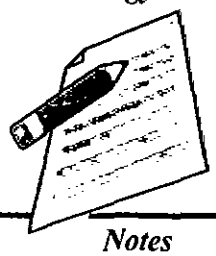
Satpura National Park is the first Reserve Forest of India. Within this forest, you can find the finest Indian teak as well as rock shelters which are evidence of the prehistoric human life in the area.

There are a total of 55 rock shelters in Pachmarhi Biosphere Reserve which also feature rock paintings depicting figures of men fighting with animals, hunting scenes, dancing, and playing musical instruments. Many tribal are still living in the area.

National Parks in India

There are 104 national parks in India. Top 10 of these national parks include:

- Jim Corbett National Park, Uttarakhand
- Kaziranga National Park, Assam
- Gir Forest National Park, Gujarat
- Sundarban National Park, West Bengal
- Satpura National Park, Madhya Pradesh
- Eravikulam National Park, Kerala
- Pench National Park, Madhya Pradesh
- Sariska National Park, Rajasthan
- Kanha National Park, Madhya Pradesh
- Ranthambore National Park, Rajasthan



Why do animals become extinct?

Disturbances in the natural habitat of animals make it difficult for them to survive and hence, become extinct. **For Example**, dinosaurs became extinct thousands of years ago.

Why do we need to conserve animals?

Animals, such as lizards, snakes, owls, and bats, play a particular role in an ecosystem and help in maintaining its balance. They form part of food chains and food webs. We need to conserve different life forms to make sure that the natural balance does not get disturbed.

What do we mean by an ecosystem?

An ecosystem refers to the living organisms and non-living components of a place, including plants, animals, microorganisms, climate, soil, river deltas etc.

Red Data Book

International Union for Conservation of Nature (IUCN) maintains a record of all the endangered animals and plants in the world and calls it **Red Data Book**. India also maintains its own Red Data Book which keeps a record of endangered plants and animals found in India.

The Golden Toad now makes the Extinct as well as the Extinct in the Wild lists of the IUCN Red List.

There is a **Red Data List** too, which is also known as **IUCN Red List of Threatened Species** or **IUCN Red List** which classified all known plant and animal species into nine groups:

- **Extinct:** No known individual of the species is alive.
- **Extinct in the Wild:** No known individual of the species in the wilderness. They exist only in captivity.
- **Critically Endangered:** Species that are at extremely high risk of being extinct in the wilderness.
- **Endangered:** Species that are at high risk of being extinct in the wilderness.
- **Vulnerable:** Species that are at high risk of being endangered in the wilderness.
- **Near Threatened:** Species that are likely to become endangered in the near future.

- **Least Concern:** Species which are found in abundance and is not at risk.
- **Data Deficient:** Species about which we do not have enough data to assess its extinction risk.
- **Not Evaluated:** Species which has not yet been evaluated on the criteria adopted by the IUCN.

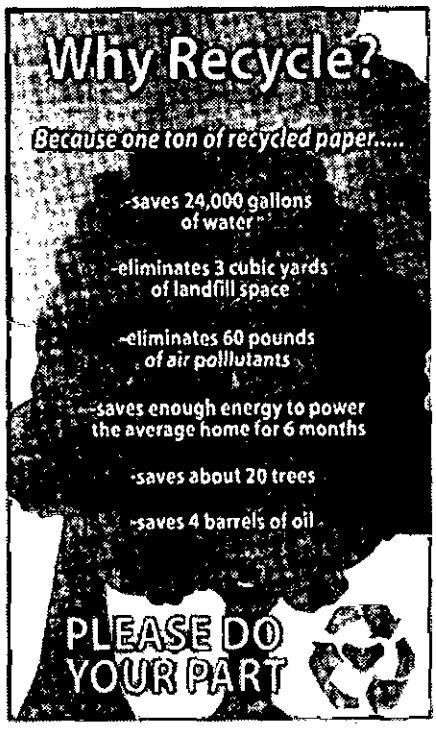
Species that fall in the Critically Endangered, Endangered and Vulnerable categories are also referred to as **Threatened Species**.

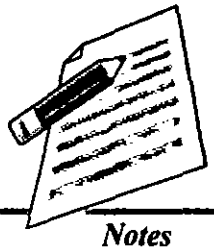
Migration

Migration is the movement of birds, animals or humans over long distances to live in a new location permanently or temporarily.

Migratory birds are birds that fly to far away areas every year to avoid harsh and inhospitable weather conditions in their natural habitat. They cover long distances to reach another land and lay their eggs.

Recycling of Paper





Why should we recycle paper?

We need to cut 17 full-grown trees to make one tonne of paper. We can easily reuse and recycle paper for five to seven trees. Reducing our consumption of paper can save trees and also save water and energy used to manufacture paper.

Besides, it can also help in reducing the use of harmful chemicals that are used to make paper.

Reforestation

Reforestation is the opposite of deforestation. Here, we plant new trees to restock forests that have been destroyed.

In India, we have the Forest (Conservation) Act which aims to preserve and conserve natural forests and meet the basic needs of the people living in or near them.

Reforestation can happen naturally or can be done artificially. If a deforested area is left undisturbed for some time, the forests grow again. However, we cut more trees than the ones that grow on their own and hence, we should plant trees to promote reforestation.

Ideally, we should plant as many trees as had been cut down and the new trees should be of the same species as the earlier ones.

Padma Shri Jadav 'Molai' Payeng, the Forest Man of India is an environmental activist and forestry worker. He is from Jorhat, India and single-handedly planted and nurtured a forest encompassing an area of 1,360 hectares across several decades along the sandbar of the River Brahmaputra.

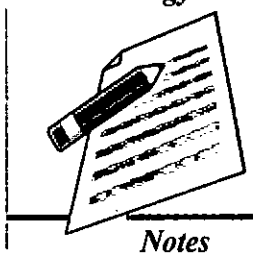
Summary of the chapter

- Wildlife sanctuary, national park and biosphere reserve are names given to the areas meant for conservation and preservation of forest and wild animals.
- Biodiversity refers to the variety of living organisms in a specific area.
- Plants and animals of a particular area are known as the flora and fauna of that area.
- Endemic species are found only in a particular area.
- Endangered species are those which are facing the danger of extinction.
- Red Data Book contains a record of endangered species.
- Migration is the phenomenon of movement of a species from its own habitat to some other habitat for a particular time period every year for a specific purpose like breeding.
- We should save, reuse and recycle paper to save trees, energy and water.
- Reforestation is the restocking of destroyed forests by planting new trees.

EXERCISE

Multiple Choice Questions

1. Which one of the following species is not included under the 'Red List'?
   (a) Vulnerable
   (b) Endangered
   (c) Endemic
   (d) Extinct
2. Creation of wildlife reserves and endorsement of laws are conservation measures that promote increased
   (a) exploitation of species
   (b) use of biological control
   (c) preservation of species
   (d) use of biological fertilisers
3. Identify the correctly matched pair from the following.
   (a) Sunderban – Rhino
   (b) Ranthambore – Lion
   (c) Gir – Lion
   (d) Kaziranga – Sea turtle
4. What is the main reason that many species are becoming endangered?
   (a) Habitat Destruction
   (b) Disease
   (c) Natural Selection
   (d) Acid rain
5. The process of conversion of fertile lands into deserts is known as:
   (a) Famine
   (b) Acid rain
   (c) Drought
   (d) Desertification
6. A group of the population that are capable of interbreeding is known as:
   (a) Species
   (b) Flora
   (c) Sal
   (d) Fauna
7. Re-establishment of forest on a land that was cleared for commercial/personal purpose is:
   (a) Reforestation
   (b) Deforestation
   (c) Forestation
   (d) Bi-forestation



8. _____ is referred to as the variety of animals, plants and microbes generally found in an area.
   (a) Flora
   (b) Extinct species
   (c) Biodiversity
   (d) Fauna
9. Which amongst the following is not the consequence of deforestation?
   (a) Biodiversity equilibrium
   (b) Flash floods
   (c) Droughts
   (d) Soil erosion
10. Species found exclusively in a particular area are called _____ species.
   (a) Endangered
   (b) Endemic
   (c) Migrating
   (d) extinct

Answer Key

1. (C) Endemic
2. (C)
3. (C) Gir – Lion
4. (A) Habitat Destruction
5. (D) Desertification
6. (A) Species
7. (A) Reforestation
8. (C) Biodiversity
9. (A) Biodiversity equilibrium
10. (B) Endemic

Review Questions

1. In order to meet the ever-increasing demand in factories and for shelter, trees are being continually cut. Is it justified to cut trees for such projects? Discuss and prepare a brief report.
2. How can you contribute to the maintenance of green wealth of your locality? Make a list of actions to be taken by you.
3. Explain how deforestation leads to reduced rainfall.
4. Find out about national parks in your state. Identify and show their location on the outline map of India.
5. Why should paper be saved? Prepare a list of ways by which you can save paper.

Space for notes

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20 POLLUTION OF AIR AND WATER

What is air?

Air is a combination of different gases that form the atmosphere of the Earth. The constituents of air are nitrogen (78%), oxygen (21%), water vapour, carbon dioxide and other gases such as helium, ozone, argon etc (0.04%) along with dust particles, pollens and spores. This constituent of air may vary on other planets. However, some planets do not have air. Space contains no air.

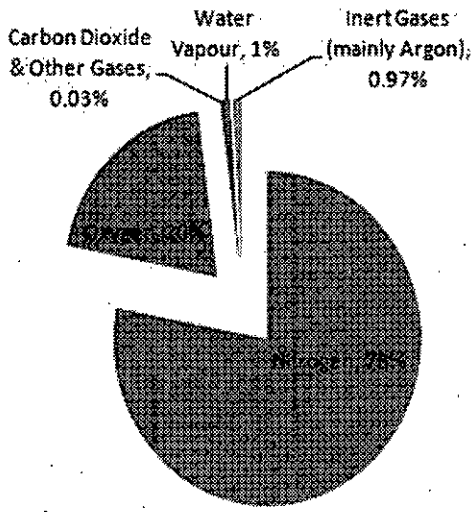


Figure 1 Constituents of air

What is Air Pollution?

According to the World Health Organization, air pollution is defined as the presence of different substances in a certain concentration in the air that causes harm to human beings and the environment.

In other words, when the air gets contaminated due to harmful and unnecessary substances that can affect the living and non-living things on the earth it is called air pollution.

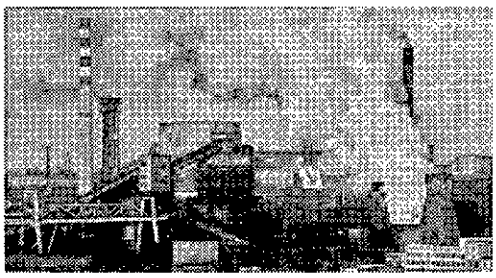


Figure 2 Pollution of Air due to industries

How does Air get polluted?

Air Pollutants: Any unwanted or harmful substance present in the air that decreases its quality and contaminates it is called air pollutants. For example, smoke is an air pollutant. Air pollutants can be classified into different categories based on their sources.

1. Indoor and Outdoor Air Pollutants

Indoor pollutants

These pollutants are generated indoors in houses, institutions, buildings or commercial facilities. Indoor air pollution may not severely impact people's health but can certainly affect them in the long run. Different indoor pollutants are:

- tobacco smoke
- biological pollutants like pet hair, fungi, bacteria, pollens etc
- building materials like lead and asbestos (asbestos can cause cancer)
- gases such as carbon monoxide

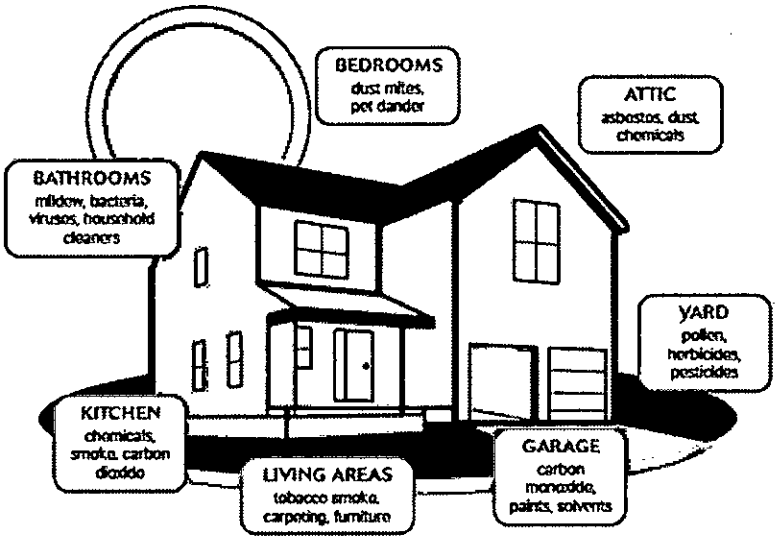


Figure 3 Indoor Air Pollutants

What is indoor air quality (IAQ)?

Indoor air quality is defined as the quality of the air within houses, buildings and commercial structures. Low indoor air quality can lead to immediate effects such as irritation in the eyes, redness of eyes, headaches or dizziness. It may also lead to adverse effects in the long run such as the problem of asthma. Air purifiers are used in many houses and offices to ensure clean air in the surroundings.

Outdoor Pollutants

Outdoor air pollution refers to the contamination of the air in the open environment. Outdoor air pollutants generally arise from the burning of fossil fuels, smoke from industries and vehicles. They adversely affect the quality of the air and hence the whole environment of the earth. Different outdoor pollutants are:

- carbon monoxide
- nitrogen oxide
- Sulphur Dioxide
- hydrocarbons

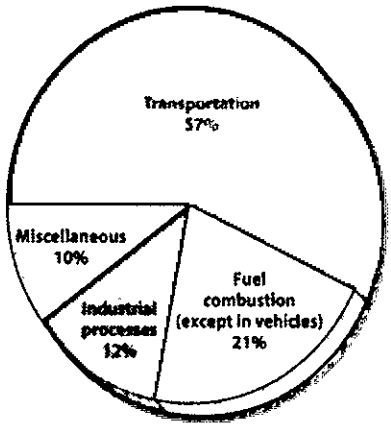


Figure 4 Outdoor Air Pollution Sources

2. Primary and Secondary Air Pollutants

Depending upon their emission into the air, the air pollutants can be categorized as primary or secondary. **Primary pollutants** are the ones that are emitted directly in the environment. For example, harmful gases such as carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen oxide etc, are emitted directly from industries and vehicles into the air.

Secondary Pollutants are the ones that get generated due to the reactions between various constituents of the year. For example, acid rain is a secondary pollutant. Nitrogen oxides react with the water vapour present in the air and form nitric acid.

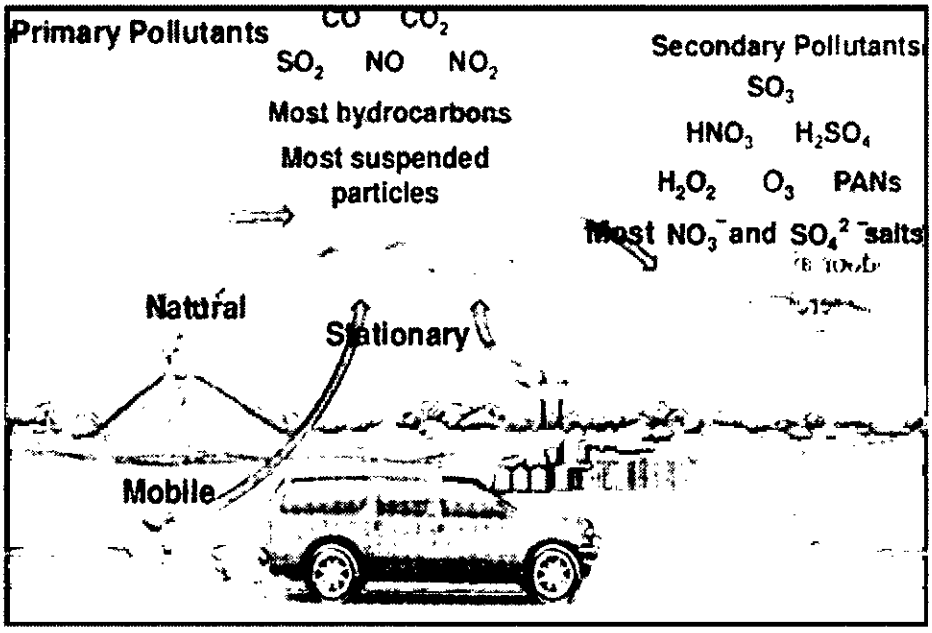


Figure 5 Primary and Secondary Air Pollutants

Causes of Air Pollution

- **Air pollution from Natural Sources:** sometimes forest fires or volcanic eruptions can lead to the release of an excess of smoke and dust in the atmosphere.
- **Burning of fossil fuels**: coal and petroleum used in industries and vehicles when burnt release harmful substances in the air such as carbon monoxide, nitrogen oxides and sulphur dioxide.
- **Exhaust from factories:** many industries release harmful substances like carbon dioxide, hydrocarbons and other harmful chemicals in the air which decrease its quality.
- **Agricultural activities:** usage of insecticides, fertilizers and pesticides lead to release of chemicals in the air. Agricultural activities also lead to the release of ammonia in the atmosphere which is extremely hazardous for us.
- **Pollution due to households:** paints, cleaning products, air conditioners, refrigerators and other appliances used in houses also contribute to air pollution. The air conditioners and refrigerators release chlorofluorocarbons that damage the ozone layer of the earth. Burning of wood and cow dung cakes in rural areas also leads to air pollution.
- **Mining activities:** mining results in the release of a large amount of dust and chemicals in the air.

Effects of Pollutants on the Environment

Pollutants	Source	Effects
Carbon monoxide	It is produced due to improper combustion of fuels	• Poisonous gas
		• Decreases blood's oxygen carrying capacity
Smog	It is a combination of fog and smoke	• Causes difficulty in breathing
		• Can cause asthma, wheezing, cough
		• Leads to decreased visibility
Sulphur dioxide	Produced mainly due to the combustion of coal	• Leads to respiratory problems
		• Can cause lung damage
Chlorofluorocarbons (CFCs)	Produced from air conditioners, refrigerators and aerosols	• Deteriorate the Ozone Layer
Suspended particulate matter (SPM)	Produced due to the burning of fuels	• Cause decrease visibility
		• Lead to problems in breathing

Air pollution and the case study of the Taj Mahal

We know that air pollution can severely affect the environment. One great example of the harmful effects of air pollution can be viewed on the Taj Mahal, the most famous and beautiful tourist attraction of India.

The air pollution in that region has led to decolourization of the white marbles of the Taj Mahal.

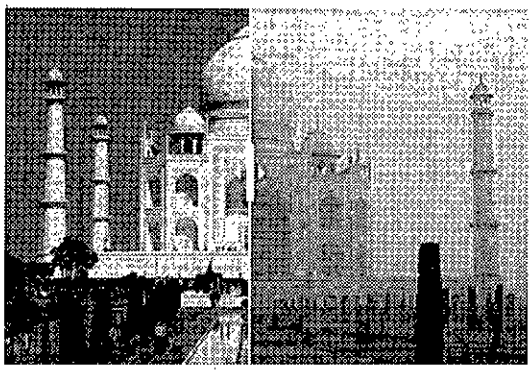


Figure 6 Effect of Air Pollution on Taj Mahal

Causes of air pollution in Agra and effects on the Taj Mahal

- The main sources of pollutants in the air around Taj Mahal are the industries around Agra.
- The Mathura oil refinery and other industries including automobiles, rubber processing and chemicals are releasing harmful substances in the air.
- The major pollutants are Nitrogen dioxide and Sulphur Dioxide. These pollutants lead to **acid rain** in the Agra region.
- When Nitrogen dioxide combines with water it forms nitric acid and when Sulphur Dioxide combines with water it forms sulphuric acid.
- The rainwater which falls on the Taj Mahal leads to decay of the marble. This is also called '**marble cancer**'.
- The Mathura oil refinery is a major source of suspended particulate matter (SPM)in the air around the Taj Mahal which is making the white marble look **yellow in colour**.

Steps were taken to reduce air pollution in the area near Taj Mahal

1. The industries are switching to clean fuels such as CNG and LPG to prevent air pollution and protect the monument.
2. Also, unleaded petrol should be used in automobiles to prevent harmful smoke from the vehicles near the Taj Mahal area.

The Greenhouse Effect

1. As the sun rays enter the earth's atmosphere, some of the radiation gets reflected back into space while some of it is trapped inside the earth's atmosphere.

2. This is possible because of certain **greenhouse gases** in the earth's atmosphere which can trap the heat of the sun. For example, carbon dioxide, methane, nitrous oxide and water vapour can trap the sun's radiation inside the earth. This phenomenon is called the **greenhouse effect**.
3. Due to this greenhouse effect, the earth has a stable temperature that can support the existence of life on it. The greenhouse effect provides the required warmth to the earth.
4. However, due to excess of carbon dioxide in the atmosphere, the greenhouse effect is becoming a serious trouble for the earth.
5. The excess of greenhouse gases leads to absorption of more heat inside the Earth which further leads to a gradual rise in the temperature of the Earth. This phenomenon of increased temperature of the earth is called **global warming**.

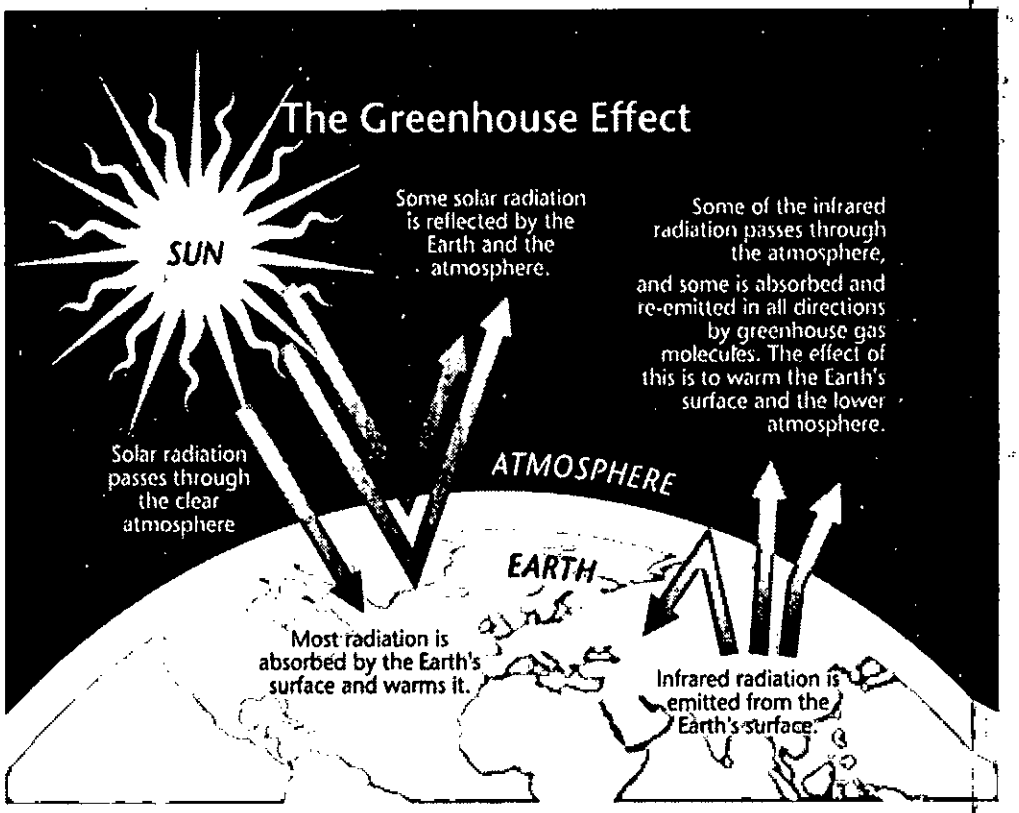


Figure 7 Greenhouse Effect

Sources of carbon dioxide on earth:

1. Human activities such as the **burning of fossil fuels and industrial activities** etc are causing a release of carbon dioxide in the atmosphere.
2. **Cutting of forests** imbalances the carbon dioxide and oxygen amounts in the air as plants take up the carbon dioxide from the environment and in return release oxygen. Therefore deforestation leads to increased presence of carbon dioxide in the atmosphere.

Effects of global warming

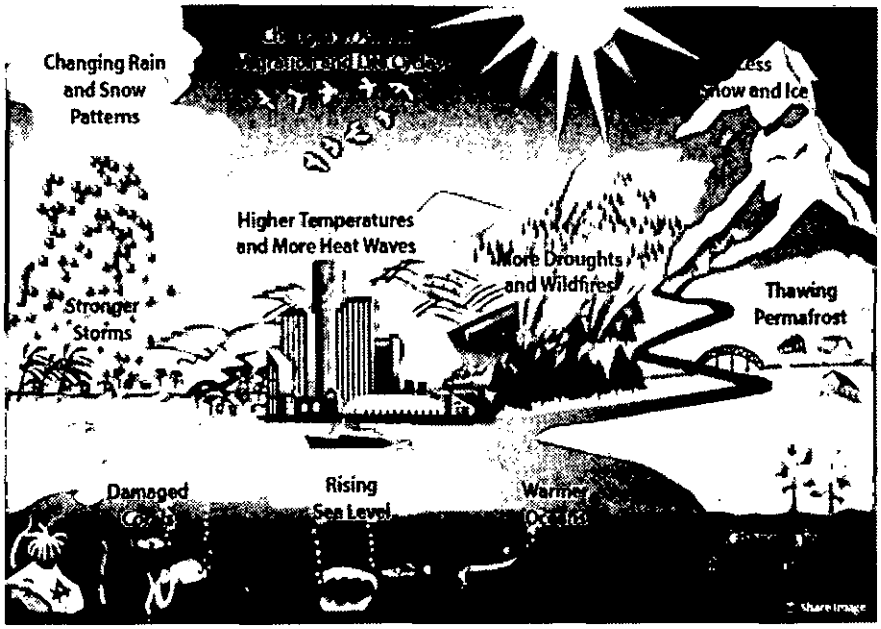


Figure 8 Effects of Global Warming

- Global warming leads to an increased temperature of the Earth which causes the melting of the glaciers and therefore increased sea levels. Hence, it results in flooding the areas around the sea.
- It also leads to extreme weather conditions in different places of the earth.
- Increased rainfall in different places has occurred due to the higher temperatures of the earth.
- Extinction of species or loss of habitats is occurring due to global warming as the animals are not able to adapt to changing climatic conditions of the earth.

What is the Ozone Layer?

- The earth's atmosphere is covered with a layer of **ozone gas** all around.
- This ozone gas prevents the dangerous ultraviolet rays of the sun from reaching the surface of the earth.
- The ultraviolet rays of the sun if reach the earth's surface can cause severe problems.
- They can affect the plants, cause cancer in human beings, skin and eye diseases and can harm all other biotic and abiotic components of the earth.
- Hence, the ozone layer has a significant role in the environment.

What is the ozone layer depletion?

Ozone layer can be termed as deterioration of the ozone layer due to the presence of harmful substances in the environment. The main cause for the depletion of the ozone layer is CFCs or Chlorofluorocarbons. They react with the ozone gas and form molecular oxygen.

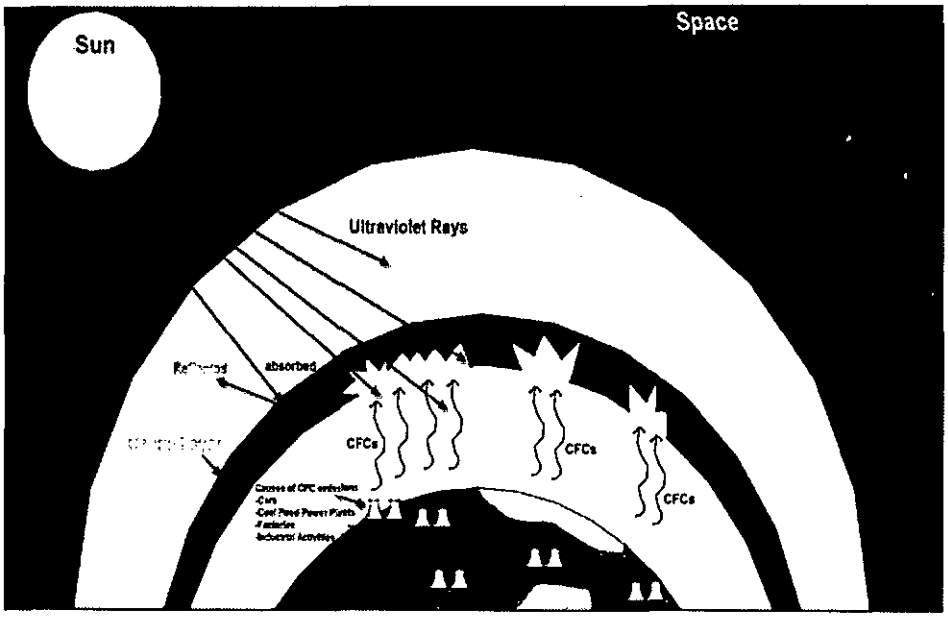


Figure 9 Ozone Layer Depletion

Prevention of Air Pollution

1. Switching to cleaner fuels like CNG and LPG can lead to decreased air pollution.
2. Generating awareness among people about air pollution and its harmful effects will encourage them to participate in preventing it.
3. Increasing the usage of solar energy, wind energy and hydropower.
4. Planting more and more trees around the cities in rural areas. India celebrates 'Van Mahotsav' in July every year where people come together and plant trees on a large scale.
5. Instead of burning dry leaves and other organic materials they should be dumped into compost.
6. Using gas stoves instead of burning coal or wood to cook food.
7. Sharing vehicles or using public transport to reduce the number of vehicles on the road and hence the air pollution.
8. Using eco-friendly paints and cleaning products for household and other buildings.

Water Pollution

- Water is not only necessary for the existence of life on the earth but it is required to perform several days to day activities like cleaning, washing clothes, bathing, cooking etc.
- Due to these activities, several substances get mixed up in water which makes it unsafe for further consumption.
- This addition of biological, chemical and physical substances in water is called water pollution.

- These substances contaminate water and make it unfit for consumption of human beings and animals are called water pollutants.

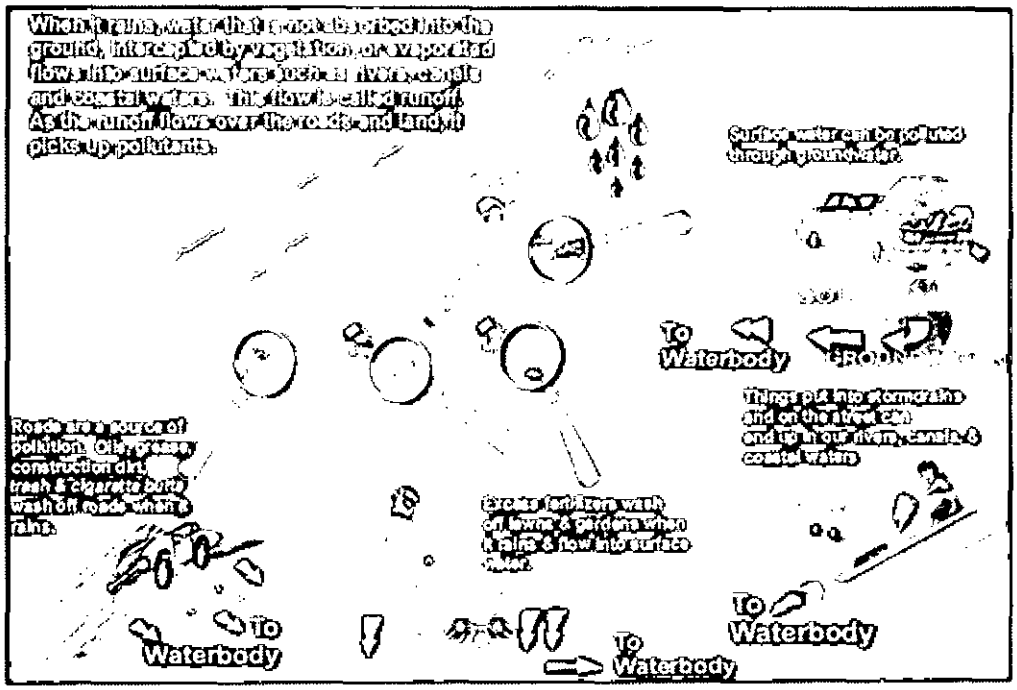


Figure 10 Sources of Water pollution

How water gets polluted?

A case study of Ganga River

- Ganga is one of the most significant rivers of India. It flows through many towns, cities and villages of the northern, eastern and central India.
- People living in these regions are dependent upon Ganga water for their livelihood as well as for their day-to-day needs.
- But it has been found that Ganga is one of the 10 endangered rivers of the world according to the (WWF)World Wide Fund for Nature. This is because of its extreme pollution. The river has been called in dead at several places as it has no aquatic life there.

Causes of water pollution of Ganga

1. Various towns, villages and cities through which the Ganga River passes release untreated sewage water, garbage, dead bodies and other harmful substances into it.
2. The Ganga River flowing through Kanpur region in Uttar Pradesh is the most polluted part of this river. This is so because of the large population of Kanpur.
3. People use river water for bathing, cleaning, washing clothes and they even defecate in the river. From polythene bags to idols of Gods, flowers and garbage, people through several things in the river. All this leads to its pollution.

4. The flow of river Ganga near Kanpur region is slow which leads to more pollution of it in still water.
5. There are more than 5000 industries in Kanpur including leather, detergent, paint and Fertilizer Industries. All of these released toxic wastes in the river which leads to its pollution.

In order to prevent the river Ganga from getting polluted the Government of India had initiated the **Ganga Action Plan** in 1985. However, increased industries and growing population of India have damaged the river to use extend. Hence the Government of India has now started another initiative called the **National Mission for Clean Ganga** in 2016.

Water pollution and its Effects		
Water Pollution Sources	**Pollutants**	**Effects**
Industries (oil refineries, textile mills, Sugar mills, paper factories, chemical factories)	• Arsenic • Lead • Chlorides o hot water	• increase toxicity in plants and animals • affect the soil and hinder the growth of plants, increase the acidity of the soil • hot water increases the temperature of water bodies • affect plants and animals living in it
Pesticides and Weedicides	Chemicals – copper, arsenic, sulphates, lead, chlorine, sulphur, nitrogen, oxygen	• cause groundwater pollution • contaminate water bodies • increased algae in ponds and lakes decrease the level of oxygen in the water • leads to the killing of aquatic animals
Untreated sewage	• food waste • detergents • microorganisms	• pollutes groundwater • causes diseases like jaundice, cholera and typhoid and viral infections

What is eutrophication?

- Eutrophication is the presence of an excess of nutrients in the water, especially stagnant water.
- Eutrophication mainly occurs due to the addition of chemicals in the water bodies.
- As a result, a large number of algae and other plants start growing in water.
- As they die, decomposers begin to rise in the water. These decomposers take up most of the oxygen of the water.
- Hence, the lack of oxygen leads to the killing of aquatic animals in the water body.

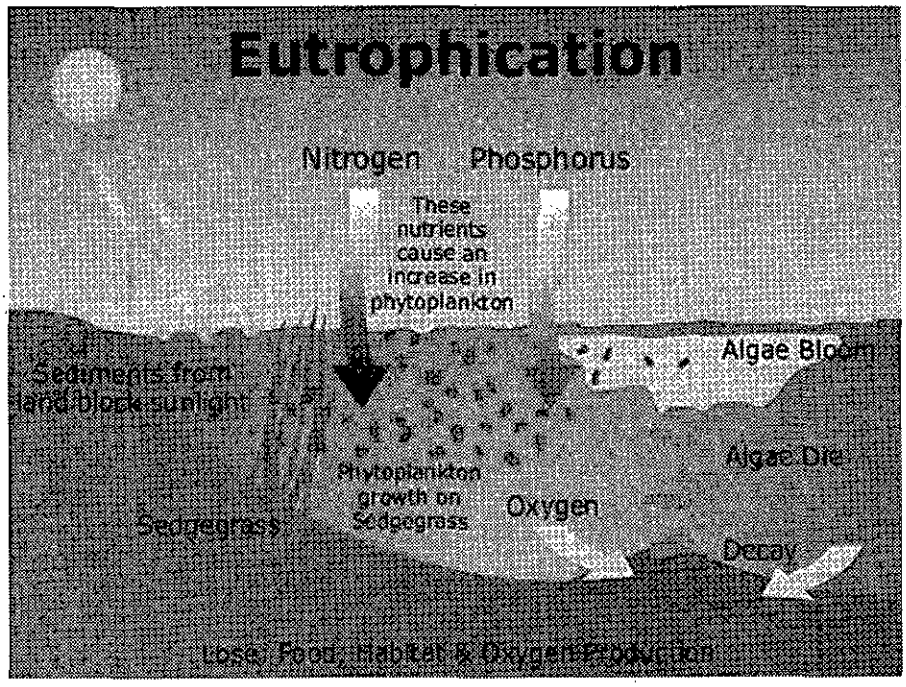


Figure 11 Eutrophication

Potable Water

Drinking water or the water that is fit for consumption and food preparation is also called Potable water.

How is water purified?

- In order to prevent water pollution, water from households, industries and other sources is treated in a sewage treatment plant and then it is released in the water bodies.
- Also, water from the water bodies is treated before passing it on to the households and other industries to ensure that it is fit for the usage.

How water is made safe for drinking?

1. **Filtration:** it is a physical method of removing impurities from water. Many households use water purifiers that can filter water and make it safe for drinking.

2. **Boiling:** it kills the germs present in the water. Many people boil water before drinking it.
3. **Chlorination:** Chlorine is a natural cleaning agent for water which makes it fit for the consumption. Often chlorine tablets are added in water to remove impurities from it.

How to prevent water pollution?

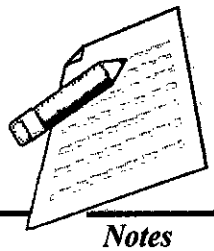
1. Industries should strictly adhere to the laws and do not dispose untreated sewage water into the rivers or any other water body directly.
2. More water treatment plants should be established near the industrial areas.
3. We should save water as much as we can, for example, we can make sure that there are no leaking taps in the houses.
4. We should reuse water if we can, for example, the water that we use for washing clothes can also be used for cleaning the house floors.

Figure 12 Steps to Prevent Water Pollution

Summary of the chapter

The Difference between Air Pollution and Water Pollution is easy to understand:

- **Air Pollution** is defined as the presence of substances in the atmosphere that have a harmful effect on human health as well as the health of other living organisms. Air pollution also has a detrimental effect of the climate of the planet, often exacerbating natural calamities such as drought and flood.
- **Water Pollution** is defined as the contamination of bodies of water usually as a result of human activities. Affected water bodies can include lakes, rivers, oceans as well as groundwater and aquifers. It can negatively impact aquatic ecosystems, which can then impact humans and other organisms that rely on the water body.



EXERCISE

Multiple Choice Questions

1. Which gas is the major pollutant of air?
   (a) Carbon monoxide
   (b) Nitrogen
   (c) Oxygen
   (d) Propane
2. The increase in concentration of which gas is not responsible for Global Warming?
   (a) Sulphur dioxide
   (b) Nitrogen
   (c) Carbon dioxide
   (d) Methane
3. In which year Ganga Action Plan was launched?
   (a) 1980
   (b) 1984
   (c) 1982
   (d) 1985
4. What radiations are absorbed by CO2?
   (a) Ultrared radiations
   (b) Infrared radiations
   (c) Ultraviolet radiations
   (d) None of these
5. Which element is present in the exhaust of automobiles?
   (a) Lead
   (b) Calcium
   (c) Chromium
   (d) Magnesium
6. The phenomenon of marble cancer is due to
   (a) soil particles
   (b) fog
   (c) CFCs
   (d) acid rain
7. The solid or liquid particles dispersed in the air are called
   (a) oxides
   (b) acids
   (c) hydrocarbons
   (d) aerosols

Answer Key

1. (a) Carbon monoxide
2. (b) Nitrogen
3. (d) 1985

4. (b) Infrared radiations
5. (a) Lead
6. (d) acid rain
7. (d) aerosols

Review Questions

1. What do CFCs stand for? Name some devices where CFCs are used. Why CFCs are considered as pollutants?
2. Why is it advised that industries should switch over to cleaner fuels such as CNG and LPG in the Taj Mahal Zone in Agra?
3. It is said, "CO2 contributes to global warming." Explain.
4. We should plant trees and nurture the ones already present in the neighbourhood. Why?
5. Explain the traditional way of purifying water to make it fit for drinking.

Space for notes

Module-IV Environment and Health

21 HUMAN HEALTH AND DISEASES

Health is affected by different factors such as:

- *Genetic disorders*
- Infection caused by any bacteria, viruses, fungi etc
- Life style of an individual such as food habits, sleeping habits, exercise etc

What are different common Human Diseases?

Disease causing organism is known as **Pathogen**. It can be bacteria, virus, fungi, nematode, etc. Examples of common human diseases:

- **Typhoid** - This disease is caused by a bacteria **Salmonella Typhi.** It is a type of fever that affect different individuals. They enter the small intestine via contaminated food and water and then reaches to the blood. The common symptoms include Stomach Pain, Headache, Loss of Appetite, Constipation. It can be fatal in severe cases. **Widal Test** is used to confirm **Typhoid fever**.
- **Pneumonia** - It is a bacterial disease which is caused by **Streptococcus Pneumoniae** and **Haemophilus Influenza**. These bacteria affect the lungs of the person. Alveoli is the smallest unit of the lungs which helps in gaseous exchange. These Alveoli are blocked by the mucus. The common symptoms include Fever, Coughs, Chills etc.
- **Common Cold** - It is caused by a group of viruses known as **Rhino Viruses**. They do not affect the lungs but affect the respiratory system including nose. The common symptoms include Cough, Headache, Congestion, Hoarseness, Sore Throat etc. This last for about 3 to 7 days.
- **Malaria** - It is caused by **Protozoan** which is a different Plasmodium species. There are different species of Plasmodium that Causes Malaria, such as **Plasmodium Falciparum, Plasmodium Ovale, Plasmodium Malariae** and **Plasmodium Vivax**.

The most severe malaria is caused by Plasmodium Falciparum.

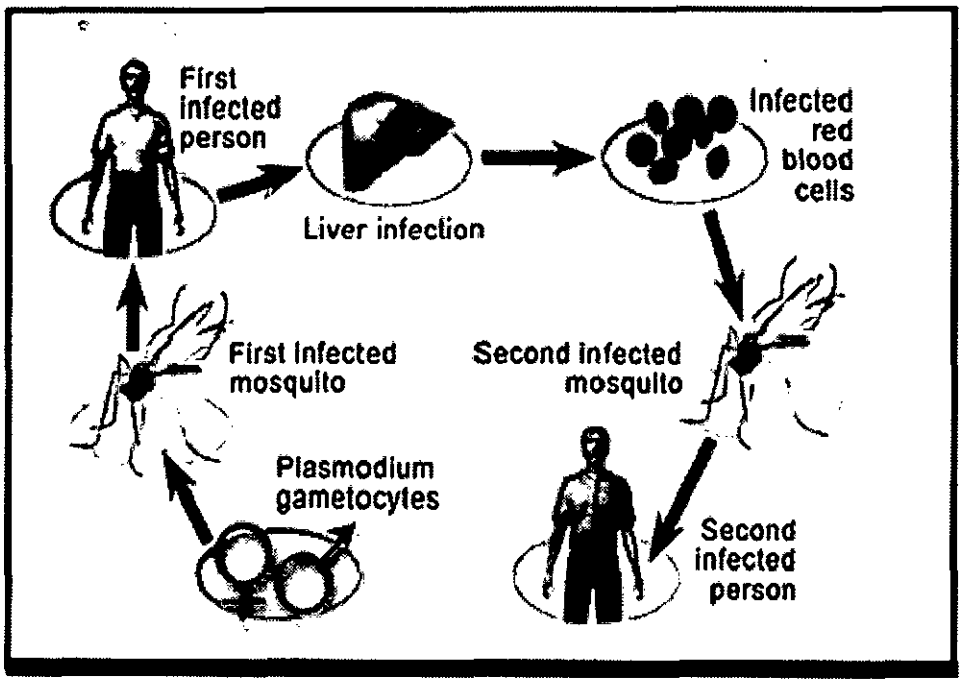


Fig.1. Life Cycle of Malaria

The Plasmodium infects the human body by sporozoites through the bite of female mosquito Anopheles.

- **Ascariasis**- Ascaris is a common roundworm that causes **Ascariasis**. It includes internal bleeding, fever, muscle pain, intestinal blockage.
- **Filariasis** - Wuchereria Bancrofti is a filarial worm that causes **Filariasis or Elephantiasis**. It causes chronic inflammation in the lower limbs. The infection is transmitted to healthy individuals via bite of the Anopheles mosquito.
- **Ringworms** - These are caused by **Fungi** such as Microsporum, Trichophyton and Epidermophyton. There is appearance of dry, scaly lesions on different parts of the body such as skin, scalp, nails etc. The symptoms include severe itching in the affected area. Personal hygiene is very important for prevention of these infections.
- **Amoebiasis** - It is caused by the **Pathogen Entamoeba Histolytica.** The parasite destroys the mucus membrane. The symptoms include pain in abdomen, nausea, fever, etc.

What is Immunity?

Immunity is defined as the ability of a body to resist an infection.

What are different types of Immunity?

There are two types of Immunity –**Innate Immunity** and **Adaptive Immunity**.

Innate Immunity refers to the non-specific defence mechanism that works

immediately when a person is encountered by an antigen. There are different barriers of innate immunity-

- Skin and mucous membranes form the physical barriers
- Hydrochloric acid in stomach and tears acts as physiological barriers
- White blood cells such as monocytes acts as cellular barrier

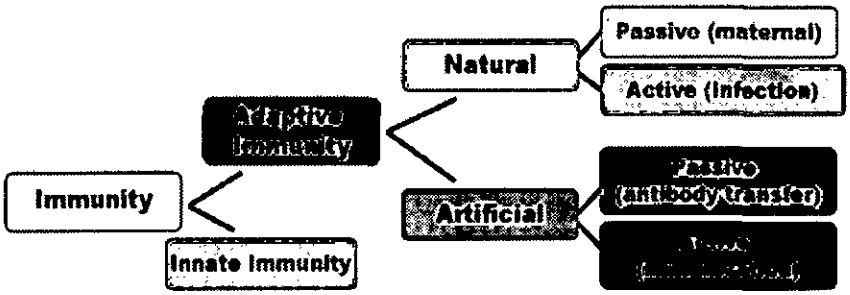


Fig.2. Different Types of Immunity

Adaptive Immunity refers to the specific defence mechanism. It involves two types of cells:

- **B cells** which are formed in bone marrow. They are involved in forming antibodies in blood. Thus this type of immune response is known as humoral immune response.
- **T cells** are formed in bone marrow but matures in thymus. They involve activation of phagocytes but do not form antibodies. This type of response is known as cell mediated immune response.

What are the differences between Innate Immunity and Adaptive Immunity?

	Innate	*Adaptive*
Self/non-self-discrimination	present, reaction is against foreign	present, reaction is against foreign
Lag phase	absent, response is immediate	present, response takes at least a few days
Specificity	limited, the same response is mounted to a wide variety of agents	high, the response is directed only to the against that initiated it.
Diversity	limited, hence limited specificity	extensive, and resulting in a wide range of antigen receptors.
Memory	absent, subsequent exposures to agent generate the same response	present, subsequent exposures to the same agent induce amplified response

There are other two types of immunity on the basis of production of antibodies:

- **Active Immunity** is the production of antibodies in response to a particular antigen.
- **Passive Immunity** is the artificial introduction of antibodies from some outside source. **For Example**: Transfer of antibodies from mother to baby during pregnancy.

Summary of the chapter

Diseases can be classified into two types:

1. **Congenital Diseases:** Genetic defects present by birth. This may be due to gene mutation, chromosomal aberration or environmental effects. Chromosomal and gene defects are transmitted to the next generation. E.g. Haemophilia, colour blindness, Down syndrome, Turner's syndrome, etc.
2. **Acquired Diseases:** Diseases acquired during a lifetime.
   a. **Infectious or communicable disease:** transmitted from one person to another
   b. **Non-communicable disease:** doesn't spread by infection
   c. **Deficiency disease:** caused due to deficiency of an important nutrient, enzyme or hormones, e.g. anaemia, kwashiorkor, beriberi, diabetes, etc.
   d. **Allergies:** hypersensitivity to foreign substances, e.g. pollen, dust, mites, etc.

EXERCISE

Multiple Choice Questions

1. Immunosuppressants such as _____ prevent transplanted organs from being rejected in recipients.
   (a) Thrombin
   (b) Cyclosporine
   (c) Aspirin
   (d) None of the above
2. Both B & T lymphocytes are produced in the bone marrow; however, only the T lymphocytes travel to the _____ and mature there.
   (a) Spleen
   (b) Thymus
   (c) Pituitary gland
   (d) Adrenal gland
3. The _____ is at its largest in children, but with the onset of puberty, it eventually shrinks and gets replaced by fat.
   (a) Thymus
   (b) Hypothalamus
   (c) Parathyroid gland
   (d) None of the above

4. Ascaris lumbricoides is a species of parasitic roundworm that lives in _____.
   (a) Humans
   (b) Grasshoppers
   (c) Pigs
   (d) None of the above
5. Which of the following diseases has been eradicated?
   (a) Smallpox
   (b) Rinderpest
   (c) Polio
   (d) All of the above

Answer Keys

1. (b) 2. (b) 3. (a) 4. (a) 5. (d)

Review Questions

1. State with examples why a few pathogens are organ/tissue-specific.
2. When the ELISA test was conducted on an immune-suppressed person, he tested positive for a pathogen.
   (a) Identify the disease the patient is suffering from.
   (b) Name the causative entity.
   (c) Mention the cells of the body that are attacked by the pathogen.
3. Mention the site in the body where the B-cells and T-cells are formed. Give one difference between them.
4. One of the following is not a matching pair of the pathogen and the disease they cause. Pick the odd one out and state why.

(a) Virus	Common cold
(b) Salmonella	Typhoid
(c) Microsporum	Filariasis
(d) Plasmodium	Malaria

5. How would a person's immune system be affected in the absence of the thymus gland?

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Module 5 EMERGING AREAS IN BIOLOGY

Module Content

30. Biotechnology
31. Immuno biology: An Introduction

Objective of the module

This module has been included in the Biology course to familiarize the learners with the importance of the new emerging areas of biology like Biotechnology and Immunology which have an impact on human lifestyles.

22 BIOTECHNOLOGY

Introduction

What is Biotechnology?

The use of biology to develop technologies and products for the welfare of human beings is known as **Biotechnology**. It has various applications in different fields such as Therapeutics, Diagnostics, Processed Food, Waste Management, Energy Production, genetically modified crops etc.

Different Branches of Biotechnology

- The use of biotechnology in medicine is known as **Medicinal Biotechnology**.

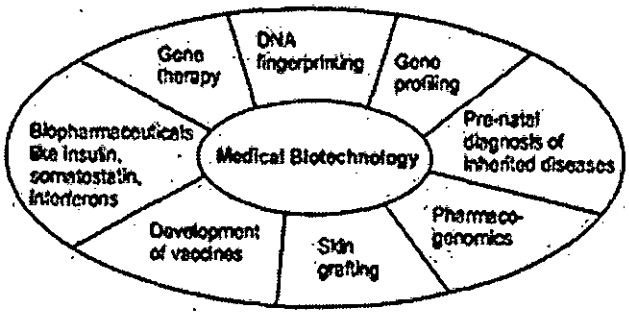


Fig.1. Application of medicinal biotechnology

For Example: This helps in formation of genetically modified insulin known as **Humulin**. This helps in treatment of large number of diabetes patients.

Human Insulin Production

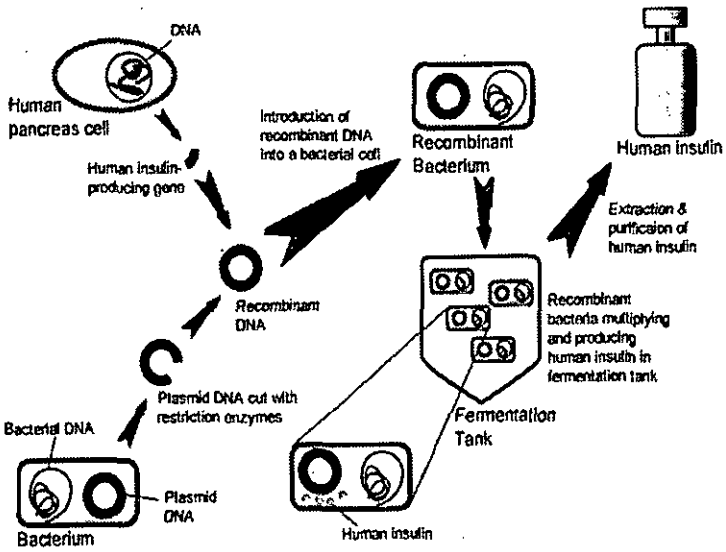


Fig. 2. Human insulin production

The use of biotechnology in agriculture is known as **green biotechnology**. Biotechnology had contributed a lot towards the upliftment of agriculture. The organisms formed after manipulation of genetic content is known as **Genetically Modified Organisms** such as Crops, Animals, Plants, Fungi, Bacteria etc. Genetically Modified crops are formed by manipulation of **DNA** to introduce new trait into the crops. These manipulations are done to introduce traits such as **Pest Resistance, Insect Resistance, Weed Resistance** etc.

Biotechnology in production of antibiotics: Plants are used to develop antibiotics for humans as well as for animal use. It helps in production of antibiotics, Vaccines and Artificial hormones for hormone therapies.

Biotechnology in diagnosis: It helps in disease diagnosis by various techniques such as **ELISA, PCR, Recombinant DNA technology**. ELISA **(Enzyme Linked Immunosorbent Assay)** is based on antigen and antibody reaction to detect different diseases. PCR **(Polymerase Chain Reaction)** is technique to amplify specific DNA segment. This helps to detect **HIV** in **AIDS** patients.

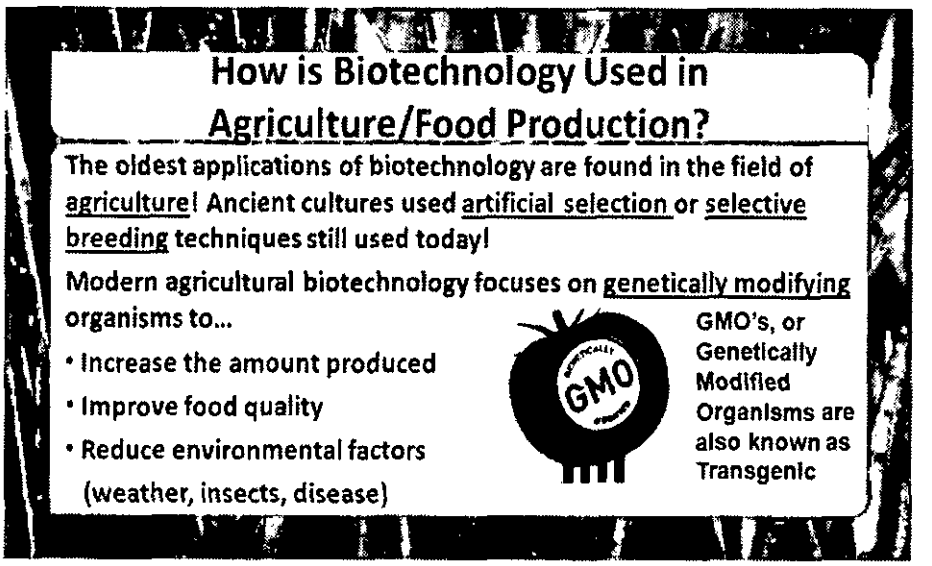


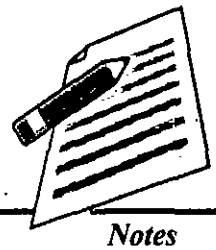
Fig.3. Applications of biotechnology in agriculture

It helps in improving the quality and quantity of fishes. Through biotechnology, fishes are induced to breed via gonadotropin releasing hormone. This is known as Blue Biotechnology.

Red Biotechnology includes designing of organisms to produce antibiotics and includes methods for genetic cure.

Genetic engineering is defined as the direct manipulation of genome of an organism. It involves the transfer of new genes to improve the function or trait. The most important technique of genetic engineering is gene cloning.

Industrial Biotechnology is the application of biotechnology for industrial purposes, including industrial fermentation. It includes the use of cells such as micro-organisms, or components of cells like enzymes, to generate industrially useful such as chemicals, food and feed, detergents, paper and pulp, textiles and biofuels.



Summary of the chapter

- 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 CO2 by yeast.
- Fermentation by the yeast Saccharomyces yields beer and that by Lactobacillus, yields butter milk. 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

EXERCISE

Short Questions

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?
   .....

Review Questions

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.

23 IMMUNITY

The ability of a host to resist a particular infection or toxins by the action of specific antibodies or sensitized white blood cells produced by them in response to natural exposure of the organism is called as immunity.

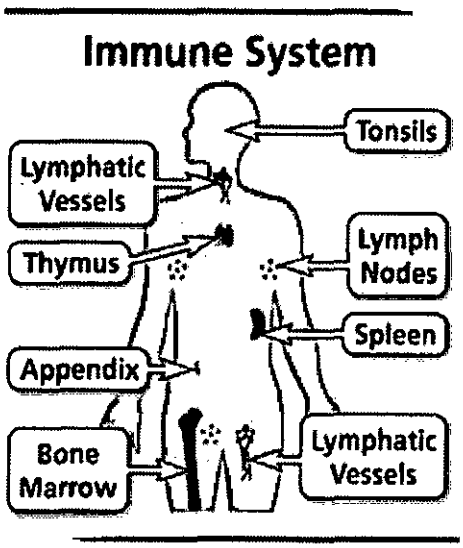
Immune System

A complex network of specialized cells, tissues, and organs that recognize and defend body from foreign substances. Primarily disease-causing microorganism such as bacteria viruses, parasites and fungi.

Lymphoid Organs:

- PRIMARY LYMPHOID ORGANS – Thymus, Bone Marrow
- SECONDARY LYMPHOID ORGANS – Lymph Node, Spleen

These organs produce immune cells or T-cells, B-cells, NK cells, macrophages, leukocytes that help to fight against pathogens



Factors Influencing the Immune Status of Individual Inherent

Species immunity

Species immunity is that in which a disease affecting one species does not affect the other species (Ex) Human do not contract cattle plague, chicken cholera, while animals are not affected by enteric fever.

Racial immunity:- is that in which various races show marked differences, in their resistance to certain infectious disease.

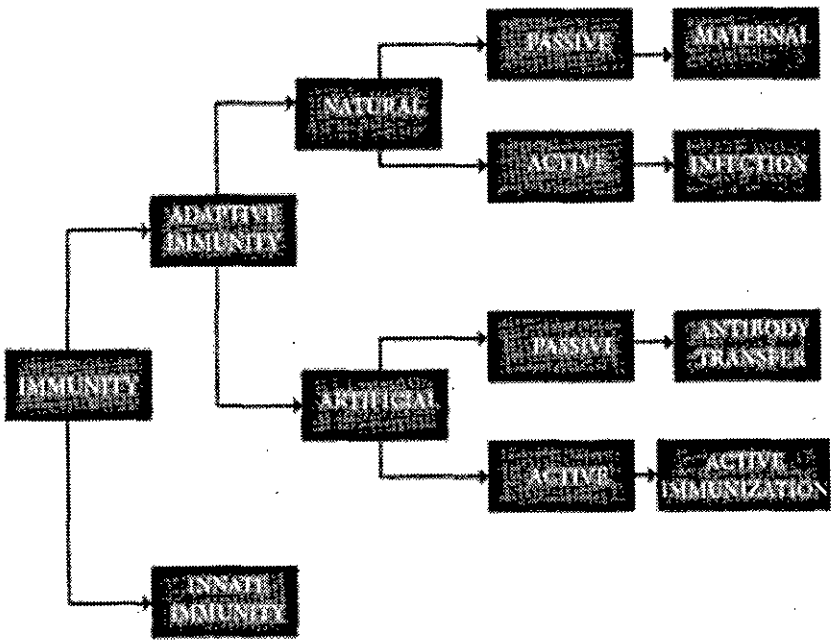
(Ex) Black Africans affected by a sickle cell anaemia (a genetic disease) are resistant to Malaria while Malaria affects other human races.

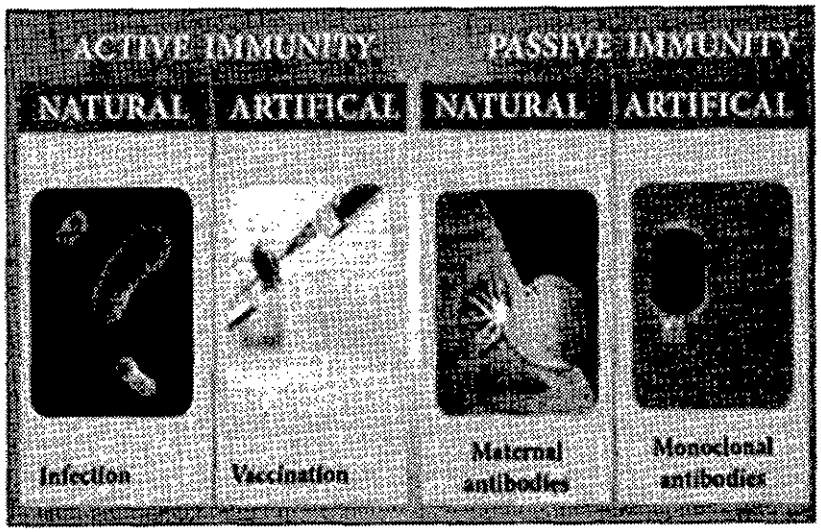
Individual immunity:-The same racial background and opportunity for exposure some individual of the race experience severe infection. (Ex) Children are more susceptible to disease such as measles, chicken pox while aged individuals are susceptible to pneumonia.

Specific antibodies or sensitized white blood cells produced by them in response to natural exposure of the organism is called as immunity.

Types of immunity: - 3 types of immunity is in human.

1. Innate immunity (natural or nonspecific)
2. Acquired (specific or adaptive) immunity
3. Active and passive immunity.





Innate (natural or Non-specific immunity: -

It refers to the inborn ability of the body to resist and is genetically transmitted from one generation to the next. The immunity offers resistance to any microorganism or foreign material encountered by the host.

Natural immunity results after acquiring certain disease Ex. Measles. This immunity lasts a life time.

Innate immunity can be divided in to species, racial, individual immunity

Acquired immunity (Specific or Adaptive):

Acquired immunity refers to an immunity that is developed by the host in its body after exposure to a suitable antigen or after transfer of antibodies.

Immunity can be described as either active or passive, depending on how it is acquired.

Active immunity: - Active immunity involves the production of antibodies by the body itself and the subsequent development of memory cells.

Passive immunity: - Results from the acquisition of antibodies from another source and hence memory cells are not developed.

Active immunity will result in long-term immunity but passive immunity will not due to the presence or absence of memory cells.

Both active and passive immunity can be induced by either natural or artificial mechanism.

Examples of active immunity: -

Natural – Producing antibodies in response to exposure to a pathogen if infection acquires. (e.g. Chicken Pox, Measles).

Artificial – Producing antibodies in response to the controlled exposure to an attenuated pathogen (e.g. vaccination)

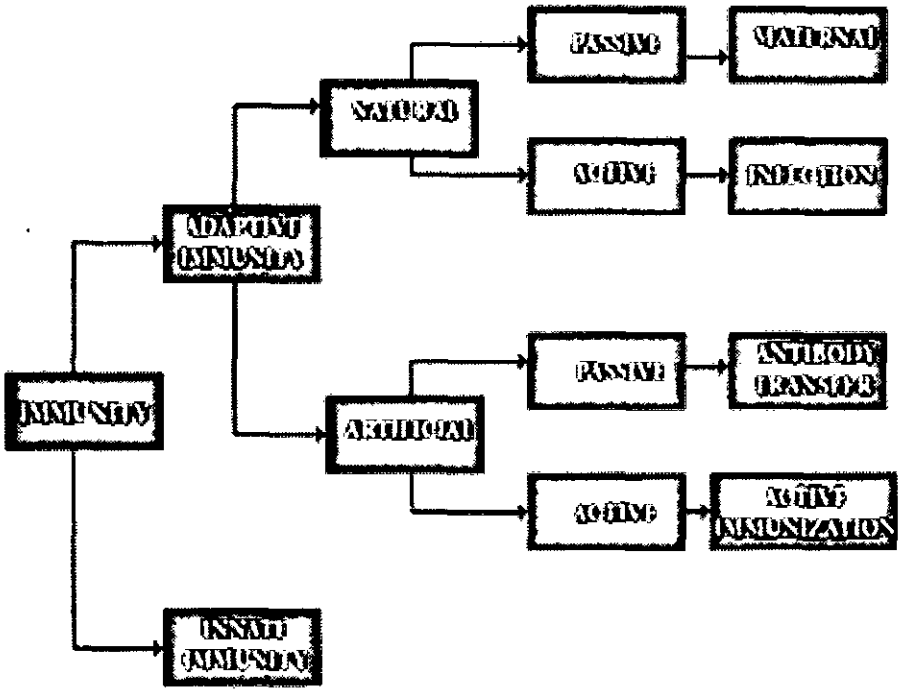
Examples of passive immunity: -

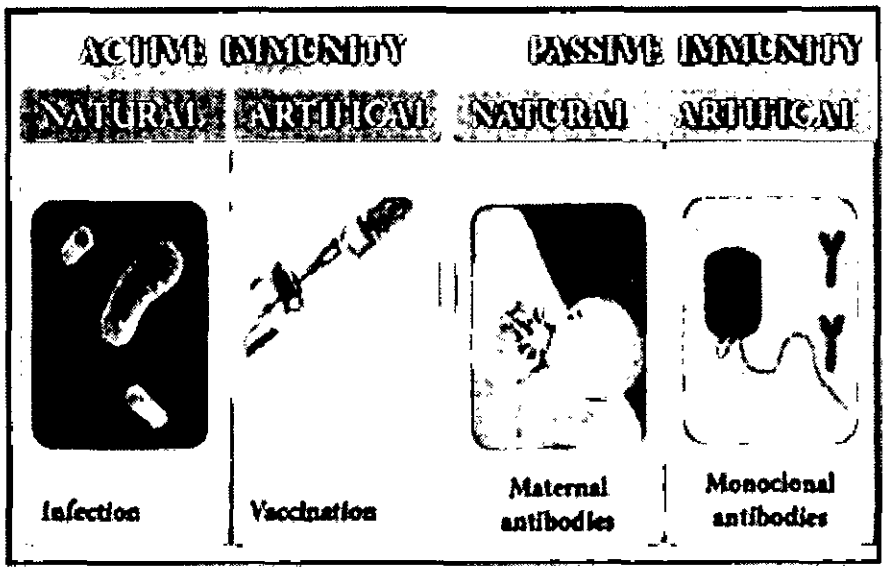
Natural: Receiving antibodies from another host. (e.g. IgG - mother to feters via the placenta; IgA - From mother to new born via breast milk (colostrum)).

Artificial: - Receiving manufactured antibodies via external delivery (Blood transfusion of monoclonal antibodies).

Types of Immunity: -

Example

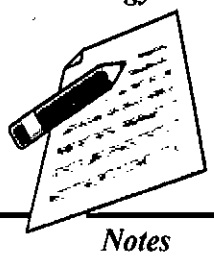




Types of immunization:

Active immunization: is the induction of immunity after exposure of an antigen. Antibodies are created by the recipient and may be stored permanently. Artificial active immunization is where the microbe is injected into the person before they are able to take it in naturally.

Passive immunization: - It can be provided when people cannot synthesize antibodies, and when they have been exposed to a particular organ that they do not develop immunity.



ANTIGENS AND ANTIBODIES

Antigens are usually exogenous substances (cells, proteins, and polysaccharides) which are recognized by receptors on lymphocytes, thereby eliciting the immune response. The receptor molecules located on the membrane of lymphocytes interact with small portions of those foreign cells or proteins, designated as antigenic determinants or epitopes. An adult human being has the capability to recognize millions of different antigens, some of microbial origin, others present in the environment, and even some artificially synthesized.

Antibodies are proteins that appear in circulation after infection or immunization and that have the ability to react specifically with epitopes of the antigen introduced in the organism. Because antibodies are soluble and are present in virtually all body fluids ("humours"), the term humoral immunity was introduced to designate the immune responses in which antibodies play the principal roles as effector mechanism. Antibodies are also generically designated as immunoglobulins. This term derives from the fact that antibody molecules structurally belong to the family of proteins known as globulins (globular proteins) and from their involvement in immunity.

The knowledge that the serum of an immunized animal contained protein molecules able to bind specifically to the antigen led to exhaustive investigations of the characteristics and consequences of the antigen-antibody reactions. At a morphological level, two types of reactions were defined:

1. If the antigen is soluble, the reaction with specific antibody under appropriate conditions results in precipitation of large antigen-antibody aggregates.
2. If the antigen is expressed on a cell membrane, the cell will be cross-linked by antibody and form visible clumps (agglutination).

Functionally, antigen-antibody reactions can be classified by their biological consequences:

Viruses and soluble toxins released by bacteria lose their infectivity or pathogenic properties after reaction with the corresponding antibodies (neutralization).

Antibodies complexed with antigens can activate the complement system. Nine major proteins or components that are sequentially activated constitute this system. Some of the complement components are able to promote ingestion of microorganisms by phagocytic cells, while others are inserted into cytoplasmic membranes and cause their disruption, leading to lysis of the offending microbial cell.

Antibodies can cause the destruction of microorganisms by promoting their ingestion by phagocytic cells or their destruction by cells mediating ADCC. Phagocytosis is particularly important for the elimination of bacteria and involves the binding of antibodies and complement components to the outer surface of

the infectious agent (opsonization) and recognition of the bound antibody and/or complement components as a signal for ingestion by the phagocytic cell.

Antigen-antibody reactions are the basis of certain pathological conditions, such as allergic reactions. Antibody-mediated allergic reactions have a very rapid on-set—a matter of minutes—and are known as immediate hypersensitivity reactions.

LYMPHOCYTES AND CELL-MEDIATED IMMUNITY

Lymphocytes play a significant role as effector cells in three main types of situations, all of them considered as expression of cell-mediated immunity, i.e., immune reactions in which T lymphocytes are the predominant effector cells.

A. Immune Elimination of Intracellular Infectious Agents

Viruses, bacteria, parasites, and fungi have developed strategies that allow them to survive inside phagocytic cells or cells of other types. Infected cells are generally not amenable to destruction by phagocytosis or complement-mediated lysis. The study of how the immune system recognizes and eliminates infected cells resulted in the definition of the biological role of the histocompatibility antigens (HLA) that had been described as responsible for graft rejection. Those membrane molecules have a peptide-binding pouch that needs to be occupied with peptides derived from either endogenous or exogenous proteins. The immune system does not recognize self-peptides associated with self-HLA molecules. In the case of infected cells, peptides split from microbial proteins synthesized by the infected cell as part of the microbial replication cycle become associated with HLA molecules. The HLA-peptide complexes are presented to the immune system and activate specific cytotoxic T lymphocytes as well as specific TH1 lymphocytes. Both cytotoxic T cells and TH1 lymphocytes can mediate killing of the infected cells against which they be-came sensitized. Cytotoxic T cells kill the infected cells directly, stopping the replication of the intracellular organism, while activated TH1 cells release cytokines, such as inter-feron-γ , which activate macrophages and increase their ability to destroy the intracellular infectious agents.

Transplant (Graft) Rejection

As stated above, the immune system does not respond (i.e., is tolerant) to self-antigens, including antigens of the major histocompatibility complex (MHC), which includes the HLA molecules. However, transplantation of tissues among genetically different individuals of the same species or across species is followed by rejection of the grafted organs or tissues. The rejection reaction is triggered by the presentation of peptides generated from nonself MHC molecules. The MHC system is highly polymorphic (hundreds of alleles have been defined and new ones are added on a regular basis to the known repertoire), and this leads to the generation of millions of peptides, which differ in structure from individual to individual.

C. Delayed Hypersensitivity

While the elimination of intracellular infectious agents can be considered as the main physiological role of cell-mediated immunity and graft rejection is an unexpected and undesired-able consequence of a medical procedure, other lymphocyte-mediated immune reactions can be considered as pathological conditions arising spontaneously in predisposed individuals. The most common example involves skin reactions, or cutaneous hypersensitivity, induced by direct skin contact or by intradermal injection of antigenic substances. These re-actions express themselves 24–48 hours after exposure to an antigen to which the patient had been previously sensitized, and because of this timing factor received the designation of delayed hypersensitivity reactions.

Vaccine:

Definition:

A vaccine is a biological preparation that provides active acquired immunity to a particular disease. A vaccine typically contains an agent that resembles a disease-causing microorganism and is often made from weakened or killed forms of the microbe, its toxin or one of its surface proteins.

The agent stimulates the body's immune and that it may encounter in the future.

The term vaccine and vaccination were derived from variola vaccine (smallpox of the cow) This term was first discovered by Edward Jenner in 1796.

Types of vaccines:

- Live Attenuated Vaccine
- Subunit Vaccine
- Conjugate Vaccine
- Recombinant Vector Vaccine
- Inactivated Vaccine
- Toxoid Vaccine
- DNA Vaccine

Live attenuated vaccine:

Live microorganism modified to be less deadly or closely related microorganism that induce immune response. The organism can be attenuated by growing it in prolonged culture. Attenuation means the loss of virulence of the pathogen.

e.g., OPV, MMR (mumps, measles, Rubella) BCG, varicella vaccine, yellow fever.

[illegible] vaccine:

Whole microorganism destroyed by heat, chemicals, radiation, antibiotics.

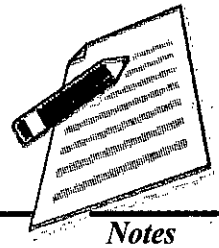
e.g. *Hepatitis A vaccine,* Hepatitis B, Pneumococcal polysaccharide, IPV, influenza, Hib, Typhoid.

Toxoid vaccine:

Inactivated toxic compounds is toxoid. [toxins can be inactivated by using formalin]

Toxin + formalin _____ toxoid

e.g., DPT, Antivenom, TT (tetanus toxoid)



Subunit vaccine:

A Protein component of the microorganism.

e.g., Surface Protein or Synthetic virus like particles lacking viral genetic material [unable to replicate] e.g. Hepatitis –B

Monovalent Vaccine:

Immunize against single strain of microorganism.

Multivalent Vaccine:

Immunize against multiple antigens strains or micro-organism

The children with malnutrition have low resistance to fight against infection. Therefore, children need timely immunization. All children have a right to get vaccines, protection against preventable disease. Extremely malnourished children may show severe reaction to certain vaccines because they have low antibodies. e.g., Measles Vaccine.

Advantages of live/killed Vaccine:

Live Vaccine:

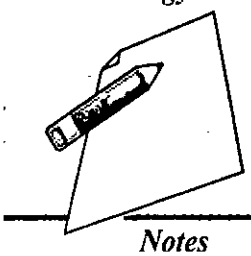
ADVANTAGES	DISADVANTAGES
Single dose	Remote chance of reactivation of virus
Induce CMI	Cannot be used in immune compromised
Long lasting immunity	Need proper cold chain
Economical	
Suitable for mass immunization	

Killed Vaccine:

ADVANTAGES	DISADVANTAGES
Safe	Multiple dose
Stable	Booster dose needed
Can be given as combined vaccines	Does not induce local immunity

Maintaining a cold chain:

It is essential to maintain the favourable temperature with cold storage, to maintain the potency of vaccines. The temperature should be around 2°C to 8°C.



The vaccine should be kept under freezing compartment. The thermometer should be placed in cold place to confirm the validity.

During transportation, the vaccines should be placed in a container maintaining the cited temperature or in a plastic bag in the ice box.

The Vaccines should be arranged according to their expiry dates for the better use.

Contraindications for the immunization:

An acute illness with fever.

When the child is on immune suppressive drug or on radiation.

A child suffering from leukaemia, lymphoma, malignancy.

NATIONAL IMMUNIZATION SCHEDULE				
National Immunization Schedule for Infants, Children and Pregnant Women				
Vaccine	When to give	Dose	Route	Site
For Pregnant Women				
TT - 1	Early in pregnancy	0.5ml	Intra-muscular	Upper Arm
TT - 2	4 weeks after TT - 1*	0.5ml	Intra-muscular	Upper Arm
TT - Booster	If received 2 TT doses in a pregnancy within last 3 years*	0.5ml	Intra-muscular	Upper Arm
For Infants				
BCG	At birth or as early as possible till one year of	0.1ml (0.05ml till 1 month age)	Intra-dermal	Left Upper Arm
Hepatitis B	At birth or as early as possible within 24 hours	0.5ml	Intra-muscular	Antero-lateral side of mid thigh
OPV - O	At birth or as early as possible within the first 15	2 drops	Oral	Oral
OPV 1, 2 & 3	At 6 weeks, 10 weeks & 14 weeks\	2 drops	Oral	Oral
DPT 1, 2 & 3	At 6 weeks, 10 weeks & 14 weeks\	0.5ml	Intra-muscular	Antero-lateral side of mid thigh
Hep B 1, 2 & 3	At 6 weeks, 10 weeks & 14 weeks\	0.5ml	Intra-muscular	Antero-lateral side of mid thigh
Measles	9 completed months - 12 months	0.5ml	Sub-cutaneous	Right upper arm
Vitamin-A (1st dose)	At 9 months with measles	1 ml (1 lakh IU)	oral	Oral
For Children				
DPT Booster	16-24 months	0.5ml	Intra-muscular	Antero-lateral side of mid thigh
Measles 2nd dose	16-24 months	0.5ml	Sub-cutaneous	Right upper arm
OPV Booster	16-24 months	2 drops	Oral	Oral
Japanese Encephalitis**	16-24 months	0.5ml	Sub-cutaneous	Left Upper Arm
Vitamin-A***				
(2nd to 9th dose)	16 months. Then one dose every 6 months upto the	2ml (2 lakh IU)	Oral	Oral
DPT Booster	5-6 years	0.5ml	Intra-muscular	Upper Arm
TT	10 years & 16 years	0.5ml	Intra-muscular	Upper Arm

* Give TT-2 or Booster doses before 36 weeks of pregnancy. However, give these even if more than 36 weeks have passed. Give TT to a woman in labour, if she has not previously received TT.

** JE Vaccine, in select endemic districts after the campaign.

*** The 2nd to 9th doses of Vitamin A can be administered to children 1 - 5 years old during biannual rounds, in collaboration with ICDS.

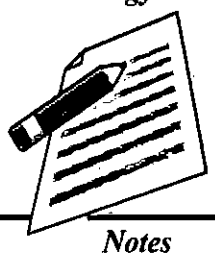
Infection & Its transmission:

1. **Entry of infection into human body:**
   - Microorganism may enter the body in
   - one of the below three ways.
   - Digestive tract – Swallowed in contaminated food or water.
   - *Respiratory tract – air contain pathogens*
   - Skin and mucous membrane – through a wound, weekend surface or injections
2. **Organism leave the body of an infected person:**
   - Excreta – Faeces and urine.
   - Coughing and sneezing and sputum Pus and wound discharges
   - Blood (Mosquito bite and injection needles)
3. **Routes of transmission:**
   - Faecal to oral route. Faces to Skin.
   - Droplet infection
4. **Prevention of infection:**
   - Hand washing before preparing or eating food.
   - Eating only clean food, kept free from flies.
   - Drinking boiled water. Avoid crowded places.
   - Immunization specially to protect children.
   - Cover the mouth and nose when coughing.

Spirilla e.g. Campylobacter jejuni

Summary of the chapter

- There are various types of defence mechanisms in our body. Immunity defends us against infections.
- Immune system is a complex network of cells, tissues and soluble factors working in close co-ordination.
- Thymus and bone marrow are the central or primary lymphoid organs.



- Lymphocytes which are the major cells performing immune functions are of two main types - B-lymphocytes and T-lymphocytes.
- B-cells are transformed into plasma cells which produce antibodies.
- Foreign molecule which triggers an immune response is called antigen.
- Antibodies (immunoglobulins) are of five types, of which IgG is found in the highest concentration.

EXERCISE

Review Questions

1. Define the term immunity.
2. What are the main defence mechanisms operating in our body?
3. 'Immune system is a complex network of cells, tissues and soluble factors. Justify this statement.
4. Describe the process of antibody production.
5. List main functions of T-cells.
6. Draw a schematic diagram of the structure of antibody.
7. What are the main physical barriers of the body?
8. Describe important features of phagocytic cells.
9. Give one main difference between passively acquired immunity and actively acquired immunity.
10. Define the process of attenuation.

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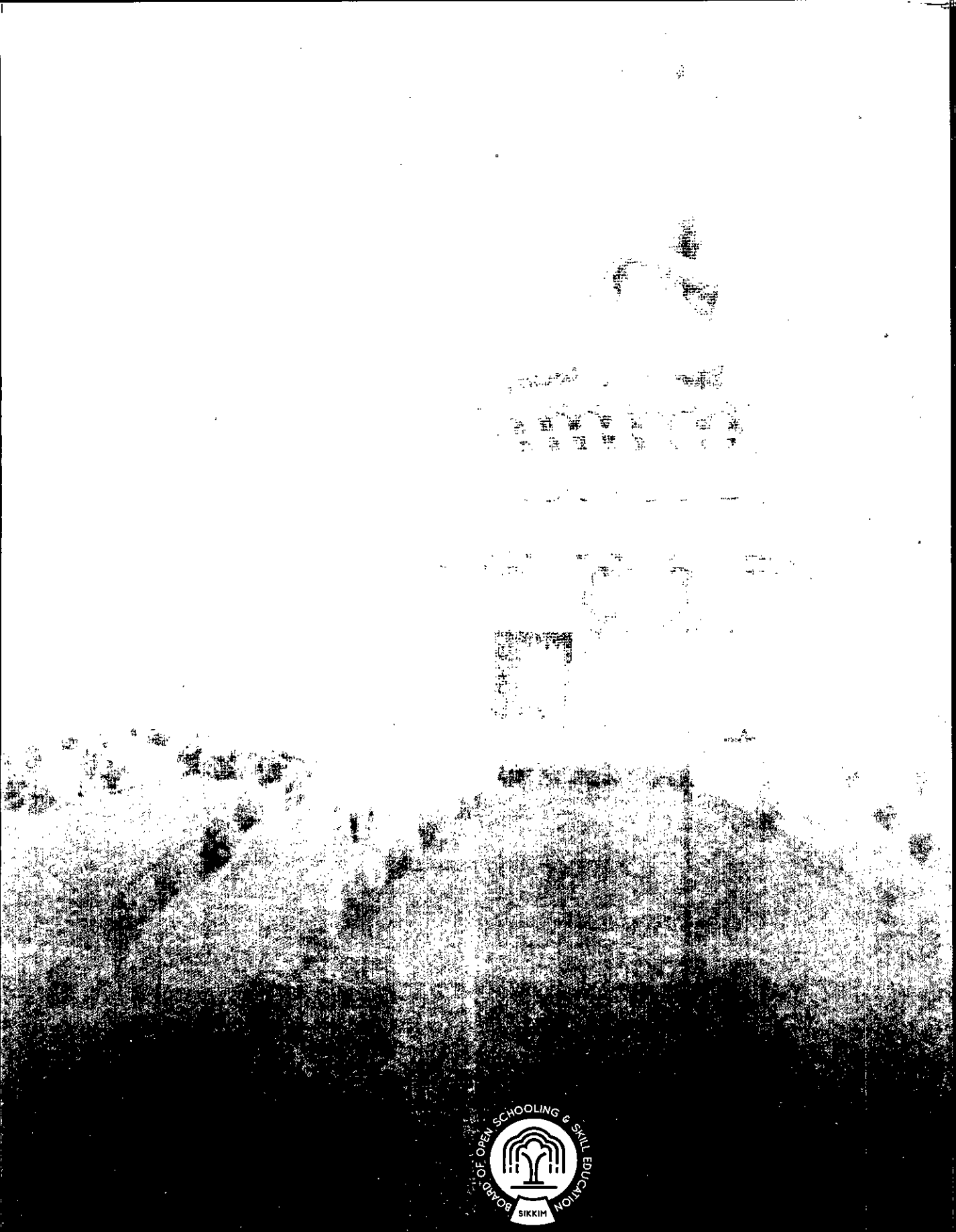

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