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BIOLOGY

Standard 12

(Semester III)

PLEDGE

India is my country.
All Indians are my brothers and sisters.
I love my country and I am proud of its rich and varied heritage.
I shall always strive to be worthy of it.
I shall respect my parents, teachers and all my elders and treat everyone with courtesy.
I pledge my devotion to my country and its people.
My happiness lies in their well-being and prosperity.

રાજ્ય સરકારની વિનામૂલ્યે યોજના હેઠળનું પુસ્તક

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PREFACE

The Gujarat State Secondary and Higher Secondary Education Board has prepared new syllabi in accordance with the new national syllabi prepared by the NCERT based on NCF-2005 and core-curriculum. These syllabi are sanctioned by the Government of Gujarat.

It is a pleasure for the Gujarat State Board of School Textbooks to place before the students this textbook of **Biology, Standard 12, (Semester III)** prepared according to the new syllabus.

Before publishing the textbook, its manuscript has been fully reviewed by experts and teachers teaching at this level. Following suggestions given by teachers and experts. We have made necessary changes in the manuscript before publishing the textbook.

The board has taken special care to ensure that this textbook is interesting, useful and free from errors. However, we welcome any suggestion, from people interested in education, to improve the quality of the textbook.

Dr. Bharat Pandit
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Date : 3-3-2015

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FUNDAMENTAL DUTIES

It shall be the duty of every citizen of India

(A) **to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;**

(B) **to cherish and follow the noble ideals which inspired our national struggle for freedom;**

(C) **to uphold and protect the sovereignty, unity and integrity of India;**

(D) **to defend the country and render national service when called upon to do so;**

(E) **to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;**

(F) **to value and preserve the rich heritage of our composite culture;**

(G) **to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures;**

(H) **to develop the scientific temper, humanism and the spirit of inquiry and reform;**

(I) **to safeguard public property and to abjure violence;**

(J) **to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement;**

(K) **to provide opportunities for education by the parent or the guardian, to his child or a ward between the age of 6-14 years as the case may be.**

* Constitution of India : Section 51-A

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1

Transport in Plants

Have you ever wondered how water reaches the top of tall trees ? How substances move from one cell to the other ? Is metabolic energy required to move substances ? Water absorbed by root hairs has to reach all parts of the plant, up to the very tip of the growing stem. As same way food synthesized by the leaves has also to be moved to all parts including the root tips embedded deep inside the soil. Movement within the cell across the membranes and from cell to cell within the tissue has also to take place.

When we talk about the transport of substances we need first to define what kind of movement we are talking about, and also what substances we are looking at. In a flowering plant the substances that would need to be transported are water, mineral nutrients, organic nutrients and plant growth regulators. Over small distances substances move by diffusion and by cyto- plasmic streaming. Transport over longer distance proceeds through the vascular system which is called translocation.

The direction of transport is an important aspect. In rooted plants, transport in xylem is essentially unidirectional, from root to the stem. Organic and mineral nutrients however undergo bidirectional transport. Mostly organic food material is manufactured by leaves and is trasnlocated downward to stem and the root for consumption and storage. The mineral nutrients are taken up by the roots and transported upward in to the stem, leaves and the growing regions. Hormones are also transported, though in very small amounts, sometimes in a strictly polarized or unidirectional manner from where they are synthesized to the other parts. Hence, in a flowering plants there is a complex traffic of compounds moving in different directions, each organ receives some substances and gives out some others.

Means of Transport

(1) Diffusion : The molecules of any substance move away from a region of their higher concentration to a region of their lower concentration. Such movement is random and this process is called diffusion. This movement is passive and energy is not used. Diffusion of the gases is most rapid. Compared to it, the diffusion of liquids is slower. Diffusion rate is affected by the temperature, pressure, gradient of concentration and permeability of the membrane separating them.

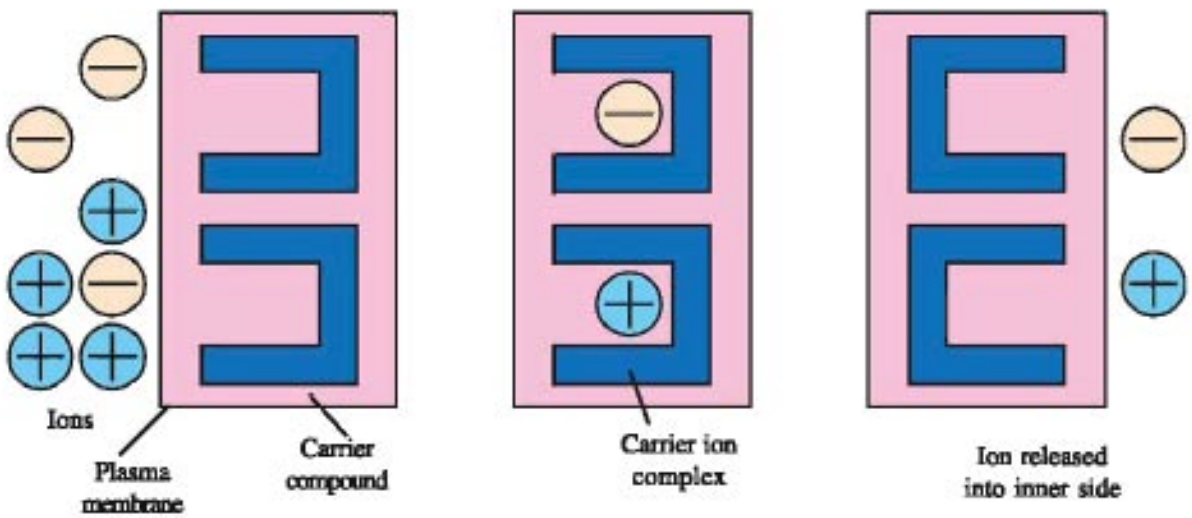
(2) Facilitated Diffusion : A gradient must be present for diffusion to occur. The diffusion rate depends on the size of molecules of the substances, obviously small size substances diffuse faster.

The diffusion of any substance across a membrane also depends on its solubility in lipids, the major constituent of the membrane. Substances soluble in lipids diffuse through the membrane faster. Substances that have a hydrophilic moiety, find it difficult to pass through the membrane. Their movement has to be facilitated. Membrane proteins provide-sites at which such molecules cross the membrane. They do not set up a concentration gradient, a concentration gradient must already be present for molecules to diffuse even if facilitated by the proteins. This process is called facilitated diffusion.

In facilitated diffusion special proteins help move substances across membranes without utilization of energy from ATP. Facilitated diffusion cannot cause net transport of molecules from a low to a high concentration. This would require input of energy. Transport rate reaches a maximum when all of the protein transporters are being used. Facilitated diffusion is very specific, it allows cell to select substances for uptake. It is sensitive to inhibitors, which react with protein side chains. The proteins form channels in the membrane for molecules to pass through. Some channels always remain open. Others can be controlled. Some are large, allowing a variety of molecules to cross. The porins are proteins that form huge pores in the outer membranes of the plastids, mitochondria and some bacteria allowing molecules up to the size of small proteins to pass through. The extracellular molecules bind to the transport protein, the transport protein then rotates and releases the molecule inside the cell.

Some transport proteins allow diffusion only if two types of molecules move together. In a symport, both molecules cross the membrane in the same direction while in an antiport, they move in opposite directions. When a molecules move across a membrane independent of other molecules, the process is called uniport.

(3) Active transport : The transport of molecules against the concentration gradient and with the help of energy is known as active transport. Active transport is carried out by membrane proteins. Hence different proteins in the membrane play a major role in both active as well as passive transport. Pumps are proteins that use energy to carry substances across the cell membrane. These molecules can transport substances from a low concentration to a high concentration. Transport rate reaches a maximum when all the protein transporters are being used. Like enzymes the carrier protein is very specific in what it carries across the membrane. These proteins are sensitive to inhibitors that react with protein side chains.



Transport of Ions by Carrier Molecules

Comparison of different transport processes :

Property	Simple diffusion	Facilitated Transport	Active Transport
1. Membrane protein	No	Yes	Yes
2. Transport saturates	No	Yes	Yes
3. Highly Selective	No	Yes	Yes
4. Requires Energy	No	No	Yes
5. Uphill transport	No	No	Yes

Plant water relations

Water plays an important role in all physiological processes in plants. The plants cannot survive in its absence for longer time. Compared to other solvents, water is a very good solvent, and usually consists most of the part of the protoplasm. Usually 75 % quantity of water is found in the cytoplasm. A watermelon has over 92 per cent water, most herbaceous plants have only 10 to 15 per cent of its fresh weight as dry matter. In several hydrophytes water quantity exceeds up to 98 %. In the some xerophytes it is usually 60 % or lesser than that. A seed may appear dry but it still has water-otherwise it would not be alive and respiring. A mature corn plant absorbs almost three liters of water in a day, while a mustard plant absorbs water equal to its own weight in about 5 hours. Because of this high demand for water it is not surprising that water is often the limiting factor for plant growth and productivity in both agriculture and natural environments.

Water Potential : All living organisms, including plants, require free energy to grow and reproduce. In thermodynamics, free energy represents the potential energy to do work. The potential energy of water is referred to as water potential. Water potential is a fundamental concept to understanding water movement.

Water molecules possess kinetic energy. In liquid and gaseous forms they are in random motion that is both rapid and constant. The gravitational pull is responsible for conversion of potential energy of water in to the form of energy which can do work. We are able to produce electricity from waterfall from stored water in reservoirs and dams because of this. Pressure is another factor which can induce water to release more free energy. The movement of water from one place to another can be explained on the basis of water potential. Three factors influence water potential: concentration, pressure and gravitation.

Water potential is denoted by greek symbol Psi or Ψ and is expressed in pressure units such as pascals (Pa). The water potential of any solution can be represented by its three compoments.

$\Psi w = \Psi s + \Psi p + \Psi g$

Ψw = Water potential.

Ψs = Solute potential. The amount of solutes dissolved in the solution.

ΨP = Potential pressure of water. As the pressure increases, water potential increases. At negative pressure it decreases. It value is zero in open pure water.

Ψg = Gravitational component. It depends on the water mass.

In case of plant cells, Ψg is generally ignored. Thus, the above equation is simplified.

$\Psi w = \Psi s + \Psi p$

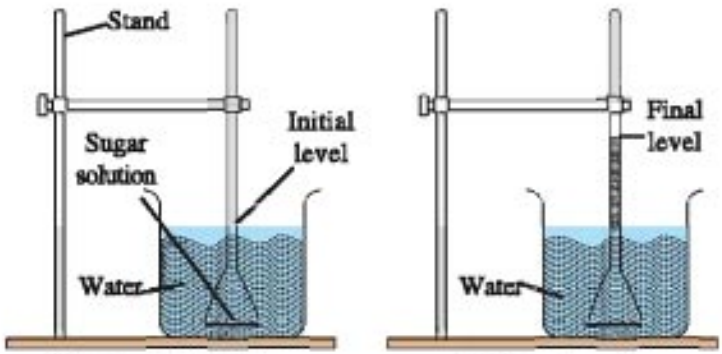
According to this equation, when water enters a cell, the value of Ψp increases. The positive value of Ψp is called turgar pressure. When this occurs, the difference between water potential of water within the cell and that of water outside the cell decreases. On the other hand, if the concentration of solutes within the cells increases, the value of Ψs decreases. As a result, water from outside, enters the cell. Generally, water moves from the region of its higher water potential to its lower water potential. In chemical context water potential is also known as chemical potential.

Osmosis : Osmosis is slightly different from diffussion , because in osmosis, some kind of barrier separating two solutions of different concentration exists; while in simple diffusion there is no barrier. The semipermeable membrane found in all the living organisms acts as barrier. The semipermeable membrane is also called as selectively permeable membrane e.g. plasma membrane. The osmosis thus, takes place between two solutions of different concentrations. We can define osmosis as "when two solutions of unequal concentrations are separated by a semi permeable membrane , the solvent (water) diffuses from dilute solution towards concentrated solution". This process of diffusion will continue till the concentrations of both the solutions become the same.

Absorption of water by root cells from the soil solution occurs mainly through osmosis. The process of osmosis can be easily explained by Thistle funnel experiment.

Thistle Funnel Experiment : A parchment paper, frog's urinary bladder or an egg membrane from hen's egg is tied at the broad end of thistle funnel as a semi permeable membrane. A sugar solution is filled in the thistle funnel. It is filled upto some region of stalk of the funnel. This position is marked out. Now the membrane bound broad end of the funnel is dipped into water filled beaker. After some time, water from beaker will enter the thistle funnel through osmosis across the membrane. By noting the level of water in the stalk, above the previous mark, osmosis can be verified. As water enters into the funnel, it is also called as endosmosis.

Now, if we apply pressure from above on the water within the thistle funnel , we can stop entery of water into it through osmosis. This pressure at which the entry of water across the semi permeable membrane stops is called osmotic pressure. The value of osmotic pressure depends upon the concentration of the solution. The higher the concentration, greater is its osmotic pressure and lower the concentration, lesser is its osmotic pressure.



(A) In the beginning (B) In the end

Thistle Funnel Experiment

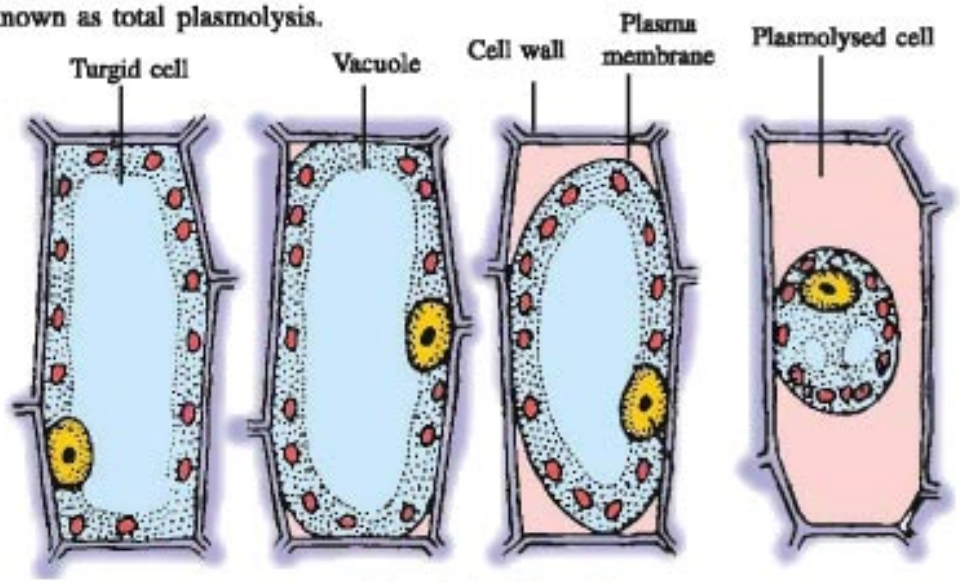
Thus, process of osmosis is affected by two aspects :

(1) Pressure gradient and (2) Concentration gradient

Both these aspects jointly determine the water potential. Water moves from its higher water potential towards its lower water potential. Water potential is also called chemical potential. It indicates the free energy in water. Free energy means potential energy which can be utilized.

Plasmolysis : The behavior of plant cells with regard to movement of water depends on the surrounding solution. If the external solution is having equal concentration than that of internal solution, it is said to be isotonic solution. If the external solution is more dilute than the cytoplasm, it is hypotonic and if the external solution is more concentrated, it is hypertonic.

When a living plant cell is placed in a concentrated solution of sugar or salt (hypertonic solution), water moves out of the cell and the cell membrane shrinks away from its cell wall. This cell is said to be plasmolysed and the phenomenon is known as plasmolysis. Normally, living cells are turgid. As the concentration of vacuolar sap in cell is lower than that of surrounding solution, water from the cell starts moving out through exosmosis. As this occurs, the cytoplasm within the cell begins to contract. This cytoplasm loses contact with the cell wall. This initial condition is called incipient plasmolysis. As exosmosis continues, the protoplasm becomes arranged as a contracted mass in some corner of the cell and the space between it and the cell wall becomes filled with the outer solution. This condition of cell is known as total plasmolysis.



Plasmolysis - Plant Cell

When a cell is placed in an isotonic solution, there is no net flow of water towards the inside or outside. However, when water flows into the cell and out of the cell and are in equilibrium, the cell is said to be flaccid.

The process of plasmolysis can be reversed if the cell is placed in the hypotonic solution. The water enters into the cell causing the cytoplasm to develop the pressure against the wall. This phenomenon is called as deplasmalysis. This pressure is called turgor pressure and the swollen condition of cell is called cell's turgidity.

Imbibition : Any colloidal system absorbs a large amount of water from its surroundings. Starch, proteins and gum do this and swell as a result. Dry wood and several seeds, whose seed coat is permeable to water, when placed in water, absorb water and swell. Thus imbibitions is a special type of diffusion when water is absorbed by solids-colloids-causing them to enormously increase in volume. Imbibition generates an imbibition pressure. The pressure that is produced by the swelling of wood had been used by prehistoric man to split rocks and boulders. Due to the same, seedlings emerge out of the seed.

Long distance transport of water

Root hairs constantly remain in touch with water. By the process of diffusion water enters into the root hairs but it can not be transported to the long distance in plant body. Diffusion is a slow process and

it can account for only short distance movement of molecules. Hence, special long distance transport systems become necessary so as to move substances across long distance and at a much faster rate. Water, minerals and food are generally moved by a mass or bulk flow system. In mass flow, the substances in bulk move from one point to the other as a result of pressure differences between the two points. Bulk flow can be achieved either through a positive hydrostatic pressure gradient (e.g. a garden hose) or a negative hydrostatic gradient (e.g. suction through a straw). The bulk movement of substances through vascular tissues of plants is known as translocation. In class XI you have already studied that in higher plants special types of vascular tissues viz. xylem and phloem are present. Xylem is associated with the conduction of water, mineral salts, some organic nitrogenous substance and hormones from root to the different parts of the body. Phloem translocates organic and inorganic solutes from leaves to different parts of the body.

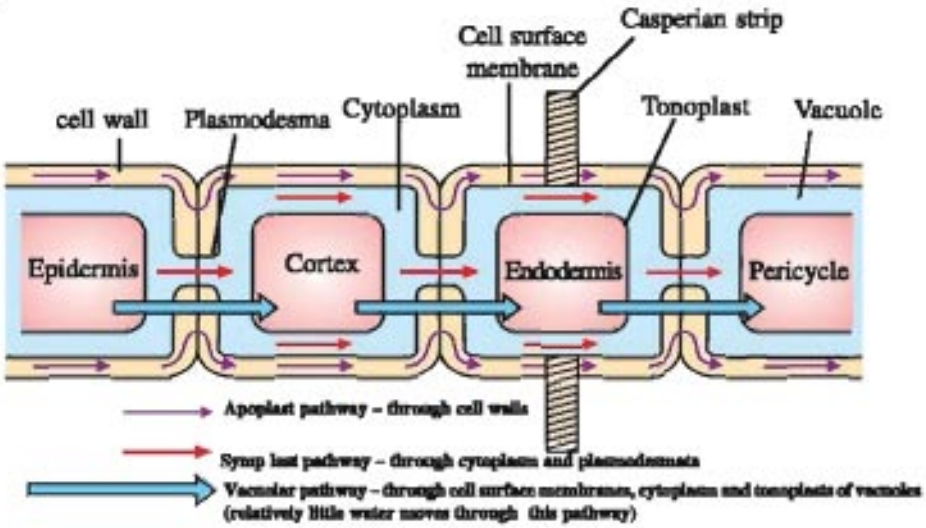
How do plants absorb water :

Although plant absorbs water through its entire surface i.e. root, stem and leaves, but major absorption takes place through the roots, especially at the tips in the region of the root hairs. The root hairs are thin walled slender extensions of root epidermal cells that greatly increase the absorptive surface. The root hairs are spread in the space between soil particles and absorb water along with mineral salts from the soil. The water absorbed by root hairs moves through cortical cells and reaches the constituents of xylem by following two distinct pathways :

(1) Apoplast pathway and (2) Symplast pathway.

The movement of water which occurs only through the intercellular spaces and walls of the cells is called as apoplastic pathway. Such water does not cross any membranous structures. The apoplast does not provide any barrier to water movement and water movement is through mass flow which occurs due to adhesive and cohesive properties of water. When water moves from one cell into the other through the plasmodesmata, the pathway is called symplast pathway.

A large amount of water moves through the root cortex along the apoplast pathway. As cells in cortex are loosely packed, there is not much resistance along apoplast pathway. A hurdle develops in the path near endodermal cells because these cells are impermeable to water. They possess thickenings of Casparian strips made up of suberin which is impermeable to water. Water in this layer pushed further forcibly pushed forward through cellular membranes. Such a transport is called transmembrane transport. In such transport, water can move across the vacuolar membrane also. Once, water reaches the elements of xylem, it rises towards stem and leaves through suction pressure generated by transpiration.



Pathway of water movement in root

In some plants root system has symbiotic association with a fungus. This association is known as mycorrhiza. The fungal filaments form a network around the young root or they penetrate the root cells. As hyphae have very large surface area, they absorb mineral ions and water from the soil in large quantity. The fungus provides minerals and water to the roots, while roots provide sugar and N-containing compounds to fungus. Some plants have an obligate association with the mycorrhizae. For example, Pinus seeds cannot germinate and establish without the presence of mycorrhizae.

Transport of water in Plants : The movement of water and minerals dissolved in it, absorbed by the root system of plants, towards the stem and the leaves is called ascent of sap. This is vital for a plant because some plants are very tall, reaching a height of up to 400 feet. The water absorbed by the roots has to be conducted upwards so as to meet the need of the tissue present there. As water moves against gravitational force, energy is required. There are two main theories proposed to explain the movement of water from root to the tip of stem. 1) Root pressure theory and 2) Transpiration pull theory.

(1) Root pressure theory : A hydrostatic pressure of water is developed inside roots due to movement of water from soil into root hairs and from there to cells of xylem, is called root pressure. This pressure pushes the water upward in the xylem vessels. Root pressure is responsible for ascent of sap. However it is useful only in very small plants. Root pressure is not enough to raise water in taller plants. If a healthily growing and adequately watered plant is cut just a little above the ground level, water exudes out from the cut end of the stem. This indicates that root pressure develops in the plants. Effects of root pressures also observable at night and early morning when evaporation is low and excess water collects in the form of liquid around special openings of veins near the tip of grass leaves and leaves of many herbaceous plants (these openings are called hydathodes). Such water loss in liquid form is known as guttation.

Root pressure does not account for the majority of water transport; most plants meet their need by transpiration pull.

(2) Transpiration pull theory : Most scientists have now agreed that the water is mainly pulled through the plant by transpiration which acts as a driving force. Transpiration mainly occurs through leaves. This is referred to as the cohesive-tension-transpiration pull model of water transport. This model explain that :

- There is a continuous network of water channel from the root hairs to the tips of the leaves.
- Water molecules are attracted towards one another and tend to stick each other (cohesion), therefore, water column has a great tensile strength.
- A strong adhesive force exists between the walls of the xylem vessels and water.
- Transpiration pull is strong enough to pull up the column of water to great height. Now question arises what generates the transpiration pull ?

When water moves out of leaves through transpiration as water vapour into the atmosphere, the water potential in the cells of leaves is lowered. As a result of this, water from the leaf veins(xylem) moves into leaf cells and xylem vessel in turn pull water from xylem vessels of the main stem. This is called transpiration pull.

Transpiration

Although plants absorb large quantity of water through their roots from the soil, yet a very little quantity of it is utilized for maintenance of their life. Rest of the absorbed water is lost from the plant

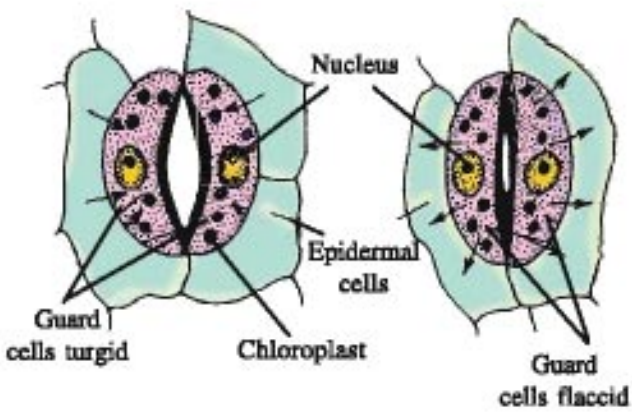
in the form of vapour or liquid. The loss of water from the plant in the form of vapour is known as transpiration. There are three main kinds of transpiration. (i) The transpiration which occurs from the surface of aerial organs of plants is known as cuticular transpiration. (ii) The transpiration which occurs through lenticels present on stem of woody plants is called lenticelar transpiration. (iii) The transpiration which occurs through stomata of leaves is called stomatal transpiration. Maximum transpiration through stomata.

Numerous stomata are located on both epidermal layers of leaf. Each stoma consists of a pore surrounded by two specialized epidermal cells called guard cells. In some cases, two more specialized cells called accessory cells also occur. The turgidity of guard cells regulate the opening and closing of stomata. The inner wall of each guard cell towards the pore or stomatal aperature is thick and elastic. When turgidity increases in the guard cells , the thin outer walls bulge out and force the inner walls into a crescent shape, thus pores get opened. The radially oriented cellulose microfibrils present in the walls of guard cells make stomata easier to open. When the guard cells lose turgidity due to water loss, the elastic inner walls regain their original shape and stoma closes.

In the dicots, (dorsiventral leaf) the lower surface of leaf possesses more number of stomata but in monocots (isobilateral leaf) both the surfaces have equal number of stomata.

The process of transpiration is affected by external factors like humidity, temperature, wind speed and light. Plant factors that affect transpiration include number and distribution of stomata, number of stomata which open, water status in plant, canopy structure etc.

Transpiration and Photosynthesis-a compromise : Transpiration is for more than one purpose as given below :



Process of Opening and Closing of Stomata

- It plays important role in the process of ascent of sap. The ascent of sap occurs as a result of suction pull developed by transpiration.
- It transports minerals from soil to the different parts of the plants.
- It causes cooling and hence, maintains the temperature of leaves.
- It supplies water to the leaves for photosynthesis.
- It maintain turgidity of cells, hence shape and structure of plants are maintained.

During photosynthesis plants require water. When water is lost in excess by transpiration it decreases rate of photosynthesis. Thus water is limiting factor for photosynthesis.

The development of the C_4 photosynthetic system is probably one of the strategies for maximizing the availability of CO_2 and minimizing water loss, Hence, C_4 plants are as twice as efficient as C_3 plants in terms of fixing CO_2 .

Uptake and transport of mineral nutrients

CO_2 and O_2 are absorbed from atmosphere by plants. Hydrogen is obtained from water. However, their other nutritional requirements are obtained from minerals in the soil.

Though water is passively absorbed by roots, minerals can not be absorbed because (1) minerals are present as charged particles which can not move across the cell membrane and (2) the concentration of minerals in the soil is always lower than that of in the roots. Therefore, minerals are always absorbed by active absorption which requires energy in the form of ATP.

Experimental observations have proved that the absorption of mineral nutrients is independent, and is in no way dependent on water absorption. Besides this mineral absorption takes place against the concentration gradient (i.e. from a lower concentration to higher concentration). Specific proteins present in the membrane of root hairs. Pump ions from soil move in to the cytoplasm of epidermal cells. The endodermal cells are also having many transport proteins in their plasma membrane which allow some nutrients (solutes) to cross the membrane, but not others. It is interesting to note that transport proteins of endodermal cells are control points, where a plant adjusts the quantity and types of solutes that reach the xylem.

Translocation of mineral ions : The mineral ions absorbed by root gradually move across the cortex, endodermis and pericycle towards constituents of xylem. Through xylem minerals are translocated to the growing regions of the plant, such as apical and lateral meristems, young leaves, developing flowers, fruits and seeds. This upward movement takes place along the transpiration route.

Within plants remobilization of mineral ions also occurs. It occurs from older dying leaves to younger leaves. In leaves , the mineral ions are assimilated into oganic compounds. These organic compounds are finally redistributed to the other parts of the plant through phloem. Elements most readily mobilized are phosphorus, sulphur, nitrogen and potassium.

Phloem transport : Flow from Source to sink

The food which is synthesized by the process of photosynthesis is transported by phloem from source to sink. Source means the site where the food is synthesized i.e. leaf and the sink means the part that needs or stores the food. The source and sink may be reversed depending upon the need of plant. Sugar stored in roots may be mobilized to become a source of food in the early spring when the buds of trees act as sink. This indicates that in phloem the direction of movement of phloem sap is bidirectional (upwards and downwards) as compared to xylem where the movement of water and minerals is unidirectional (upwards).

Mass flow hypothesis (The pressure flow hypothesis) : This hypothesis is accepted for the translocation of sugar from source to sink. During the process of photosynthesis starch is synthesized which is later on converted into sucrose. Sucrose is the principal form of carbohydrates that is translocated from leaf to the non photosynthetic plant organs. It is a non reducing sugar and hence chemically stable. This sucrose is now transported to companion cells and then into the living phloem sieve tube cells by active transport. This process of loading at the source produces a hypertonic condition in the phloem. Water in the adjacent xylem moves into the phloem by osmosis and increases turgor pressure. At the consumption end, there is low sugar concentration, which results in a low turgor and osmotic pressure. Thus a gradient of turgor pressure is created between source (leaf) and sink or consumption end (root). This causes the mas flow of substances along with water from the leaf cells (source) to the other parts of plants (sink) through the phloem tissue.

Summary

Transport over a longer distance proceeds through the vascular system is called translocation. In rooted plants, transport in xylem is essentially unidirectional, from roots to the stems. Organic and mineral nutrients howevers undergo multidirectional transport. Mostly organic food material is manufactured by leaves and is trasnlocated downward to stem and the root for consumption and storage.

The molecules of any substance move away from a region of their higher concentration to a region of their lower concentration. Such a movement is random, this process is called diffusion. In facilitated diffusion special proteins help move substances across membranes without expenditure of ATP energy while in active transport molecules move against the concentration gradient or with the help of energy.

The potential energy of water is referred to as water potential. It is designated by the Greek latter "Psi" the symbol for which is Ψ. The movement of water from one place to other can be explained on the basis of water potential.

The osmosis can be defined as "When two solutions of unequal concentrations are separated by a semi permeable membrane , the solvent (water) diffuses from dilute solution towards concentrated solution". This process of diffusion will continue till the concentrations of both the solutions become the same. Thus process of osmosis is affected by two aspects : (1) Pressure gradient and (2) Concentration gradient .

When a living plant cell is placed in a concentrated solution of sugar or salt (hypertonic solution), water moves out of the cell and the cell membrane shrinks away from its cell wall. This cell is said to be plasmolysed and the phenomenon is known as plasmolysis The process of plasmolysis can be reversed if the cell is placed in the hypotonic solution. The water enters into the cell causing the cytoplasm to develop the pressure against the wall. This pressure is called turgor pressure and the swollen condition of cell is called cell's turgidity.

The water absorbed by root hairs moves through cortical cells and reaches the constituents of xylem by following two distinct pathways : (1) Apoplast pathway and (2) Symplast pathway. The movement of water and minerals dissolved in it, absorbed by the root system of plants , towards the stem and the leaves is called ascent of sap. There are two main theories proposed to explain the movement of water from root to the tip of stem. (1) Root pressure theory and (2) Transpiration pull theory.

The loss of water from the plant in the form of vapours is known as transpiration. There are three main kinds of transpiration (1) Cuticular transpiration (2) Lenticelar transpiration and (3) Stomatal transpiration.

The food which is synthesized by the process of photosynthesis is transported by phloem from source to sink. Source means the site where the food is synthesized i.e. leaf and the sink means the part that needs or stores the food. The source and sink may be reversed depending upon the need of plant. Sugar stored in roots may be mobilized to become a source of food in the early spring when the buds of trees act as sink. This indicates that in phloem the direction of movement of phloem sap is bidirectional (upwards and downwards) as compared to xylem where the movement of water and minerals is unidirectional (upwards).

The hypothesis which is accepted for the translocation of sugar from source to sink is known as mass flow or the pressure flow hypothesis.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Plasmolysis occurs due to ...

(a) Absorption ○ (b) Imbibition ○

(c) Endosmosis ○ (d) Exosmosis ○

(2) The hypothesis accepted for the translocation of sugar from source to sink is...

(a) Cohesion hypothesis ○ (b) Mass flow hypothesi

(c) Malate hypothesis ○ (d) Donnan hypothesis

(3) Transport in xylem is always...

(a) Unidirectional ○ (b) Bidirectional ○

(c) Multidirectional ○ (d) Tridirectional ○

(4) When the molecules of any substance move away from a region of their higher concentration to a region of lower concentration, it is known as...

(a) Osmosis ○ (b) Plasmolysis ○

(c) Diffusion ○ (d) Absorption ○

(5) Three factors which influence the water potential are concentration, pressure and...

(a) Moisture ○ (b) Light ○

(c) Gravitation ○ (d) Temperature ○

(6) When water moves from one cell into the other through the plasmodesmata, the path way is called...

(a) Apoplast pathway ○ (b) Symplast pathway ○

(c) Mycoplast pathway ○ (d) Transmembrane transport pathway ○

(7) Opening and closing of stomata are regulated by...

(a) Imbibition ○ (b) Turgidity ○

(c) Diffusion ○ (d) Plasmolysis ○

(8) Which force exists between the walls of the xylem vessels and water molecules ?

(a) Cohesive force ○ (b) Adhesive force ○

(c) Turgidity force ○ (d) Osmotic force ○

(9) The direction of movement of phloem sap in the phloem is...

(a) Unidirectional ○ (b) Bidirectional ○

(c) Random ○ (d) None of them ○

(10) The process of plasmolysis can be reversed if the cell is placed in ?

(a) Hypertonic solution ○ (b) Isotonic solution ○

(c) Hypotonic solution ○ (d) Saturated solution ○

2. Answer the following questions in short :

(1) Define ascent of sap.

(2) Define diffusion and facilitated diffusion.

(3) Mention aspects by which process of osmosis is affected.

(4) Mention the external factors which affect the process of transpiration.

(5) What is the difference between osmosis and diffusion ?

3. Do as directed :

(1) Explain root pressure theory.

(2) Write a note on transpiration pull theory.

(3) Explain active transport

(4) Explain apoplast pathway of water movement

(5) Explain symplast pathway of water movement

(6) Write significance of transpiration.

4. Answer the following questions in detail :

(1) Explain the theory of mass flow.

(2) Describe the Thistle funnel experiment of osmosis.

(3) Explain the structure of stomata and also the process of opening and closing of stomata.

(4) Write a note on plasmolysis.

(5) Write a note on facilitated diffusion.

2

Mineral Nutrition

The absorption, distribution and metabolism of various mineral elements by plants is called mineral nutrition. All organisms need nutrition. Plants have the nutritional requirement of various inorganic and organic raw materials for building their structure and maintaining body functions. Plants generally derive their inorganic nutrients from soil, water and atmosphere.

We know that in plants, nutrition is mainly autotrophic. All plants which possess chlorophyll, synthesize their food with the help of energy of sun-light, H_2O and CO_2. C, H, O and N play a significant role in the constitution of energy rich organic compounds like carbohydrates, lipids and proteins. Over and above these, plants require various essential elements for their survival, growth, proper development and reproduction. These mineral elements occur mainly in their inorganic ionic forms in the soil. Plants absorb them from the soil through their root system.

The study of mineral nutrition is concerned with the absorption of essential mineral nutrients, their important role in the plant life and the effects of their imbalanced availability. If the minerals are not available to plants, specific symptoms appear due to the deficiency of a particular element.

Methods to study the requirement of Mineral in plants

Out of some methods such as Hydroponics, Aeroponics, and Organoponic to determine the requirement of minerals by plants, hydroponic method is described as below.

To understand the role of an individual mineral element and to understand the effects of its deficiency or absence, 'Hydroponic' method of growing plants is employed.

The technique of growing plants only in a nutrient medium and in complete absence of soil is known as Hydroponics. It was demonstrated for the first time by a German Botanist Julius Von Sachs in the year 1860. Minerals are absorbed by plants in solution form. So it is possible to grow plants in water containing the desired amount of mineral salts taking care that the aerial parts are exposed to air and light.

Hydroponics is soil less cultivation of plants. It is a method of growing plants using mineral nutrient solutions instead of soil. That is, soil acts as a reservoir source of nutrients for the plants but the soil itself is not required for their growth. So, the essential nutrients are introduced to the growth

Hydroponic methods

of plants artificially in a water medium. This is the principle of hydroponics. In hydroponics, plants are grown with their roots in the mineral nutrient solution only.

The root system of the plant is maintained in a solution containing various mineral nutrients dissolved in it, instead of in a soil. A large amount of such 'nutrient solution' is utilized. Essential mineral elements are dissolved in their determined amounts. Their concentrations and the pH of the medium are periodically checked and maintained at their proper levels. During growth of plants, gaseous oxygen is continuously bubbled through the solution. By doing so, the roots are constantly made O_2 available to them. Various scientists have proposed different methods of preparing such 'nutrient solutions.'

Now, we should withdraw that essential mineral nutrient, the effect of absence of which, we want to study. We can compare the growth of a plant grown in such a solution to that of the plant grown in the normal solution. Thus, we note the effect of the element which we did not provide.

Types of hydroponics

Two types of hydroponics are solution culture and medium cultures.

Solution culture : In solution culture of hydroponics, just the nutrient solution of essential plant nutrients is used for raising plants. There are three types of solution culture.

(1) **Static solution culture :** This is a method of hydroponics used for raising plants and seedlings in solution-filled containers such as glass jars, buckets, tubs and water tanks.

(2) **Continuous flow solution culture :** This is a method of hydroponics where continuous flow of nutrient-filled solution is automated by using a nutrient film technique or NFT.

(3) **Aeroponics :** This is a method of hydroponics where plants or seedlings are raised in an environment saturated with fine drops (aerosol) of nutrient solution.

Advantages of Hydroponics

- Less use of plant nutrients
- Less use of water
- Less utilization of energy and space
- Elimination of soil-borne diseases
- Complete elimination of weeds
- Balanced plant nutrition

Criteria for Essentiality of Elements

Criteria for the essentiality of elements had been given by Arnon and Stout (1939). Many elements are absorbed by the roots from the soil. To determine which one is an essential element, the following criteria are used.

(1) A plant must be unable to complete its life cycle in the absence of the mineral element.

(2) The function of the element must not be replaceable by another mineral element.

(3) The element must be directly involved in plant metabolism.

These criteria are important guidelines for plant nutrition and it is easy to understand the specific function such as the maintenance of osmotic pressure.

Essential Mineral Elements

The term essential mineral element (or mineral nutrient) was proposed by Arnon and Stout (1939).The nutrients or elements which are essential for the healthy growth of the plant are called **essential nutrients or essential elements.**

You know that 112 elements have been discovered until now. Most of the mineral elements present in soil are absorbed by roots of the plant. All minerals which are absorbed by plants are not essential minerals. Various kinds of mineral elements are considered as essential for the plants.

An essential mineral nutrient is one, in the absence of which the plant can not complete its lifecycle. Its absence cannot be compensated by another element.

According to their quantitative requirements, these are classified as - macronutrients and micronutrients. The concentration of macronutrients in the dry mass of plants is about 1 to 10 mg. per 1 gram. Such a concentration of micronutrients is 0.1 mg or less than that. Micronutrients are also called - Trace elements.

Macronutrients include - Carbon, Hydrogen, Oxygen, Nitrogen, Potassium, Phosphorus, Sulphur, Calcium, and Magnesium.

Micronutrients include - Manganese, Copper, Molybdenum, Boron, Zinc, Iron, Chlorine and Nickel. Sodium, Cobalt, Silicon and Vanadium are also seem to be important 'trace elements'.

Essential plant nutrients: their source, relative amounts, functions and classification:

Element	Chemical symbol	Source	Absorbed form	Major Functions	Relative% in plant
Macronutrients					
Non mineral Elements					
Carbon	(C)	Atmosphere	CO_2	In all organic molecules	-
Oxygen	(O)	Atmosphere	O_2	In most of organic molecules	-
Hydrogen	(H)	Soil	H_2O	In most of organic molecules	-
Nitrogen	(N)	Soil	NH_4^+ and NO_2^-, NO_3^-	In proteins, nucleic acids etc.	100
Mineral Nutrients					
Phosphorus	(P)	Soil	$H_2PO_4^-$	In nucleic acids, ATP, phospholipids etc.	6
Potassium	(K)	Soil	K^+	Enzyme activation, water balance, ion balance	25

Sulphur	(S)	Soil	SO_4^{2-}	In structure of coenzymes, ionic balances.	3
Calcium	(Ca)	Soil	Ca^{2+}	Affects the cytoskeleton, membranes and many enzymes, second messenger	12.5
Magnesium	(Mg)	Soil	Mg^{2+}	In structure of chlorophyll and many enzymes, stabilizes ribosomes	8
Micronutrients					
Iron	(Fe)	Soil	Fe^{3+}	In active site of many redox enzymes and electron carriers, In chlorophyll synthesis	0.2
Chlorine	(Cl)	Soil	Cl^-	In Photosynthesis, ion balance	0.3
Manganese	(Mn)	Soil	Mn^{2+}	Activation of many enzymes	0.1
Boron	(B)	Soil	$H_2BO_3^-$, $H_2BO_3^{2-}$	Carbohydrate transport Cell wall component	0.2
Zinc	(Zn)	Soil	Zn^{2+}	Enzyme activation, auxin synthesis	0.03
Copper	(Cu)	Soil	Cu^{2+}	In active site of many redox-enzymes and electron carriers	0.01
Molybdenum	(Mo)	Soil	MoO_4^{3-}	Various process of nitrogen fixation	0.0001
Nickel	(Ni)	Soil	Ni^{2+}	Required for iron absorption.	
Sodium	(Na)	Soil	Na^+	Involved in osmotic (water movement) and ionic balance in plants.	
Cobalt	(Co)	Soil	Co^{2+}	Required for nitrogen fixation in leguminous plants.	
Silicon	(Si)	Soil	Si^{4+}	As a component of cell walls.	
Vanadium	(V)	Soil	$V^{3+, 4+, 5+}$	Necessary for the activation of nitrogenase in the nitrogen fixing bacteria.	

Role of Macro and Micro nutrients and their deficiency symptoms or effects

The 13 mineral nutrients, which come from the soil, are dissolved in water and absorbed through plant's roots. They are not always enough in the soil for a plant to grow healthy. That is why many farmers and gardeners use fertilizers to add the nutrients to the soil.

The absence or deficiency of any of these essential elements shows deficiency symptoms or effects in plant. The symptoms can be studied by hydroponics. Under natural conditions, these effects or symptoms can be taken as indicators of the mineral deficiencies in the soil.

Carbon, Hydrogen, Oxygen and Nitrogen are Non mineral elements. The mineral nutrients are divided into two groups : macronutrients and micronutrients.

(1) Macronutrients : Macronutrients can be divided into two more groups like : **primary** and **secondary nutrients**.

(a) Primary nutrients : The primary nutrients are nitrogen (N), phosphorus (P), and potassium (K). These are usually not enough in the soil so fertilizer is always needed for the growth of the plants. Plants use these major nutrients in large amounts for their growth and survival .

(b) Secondary nutrients : The secondary nutrients are calcium (Ca), magnesium (Mg), and sulphur (S). These are usually enough in the soil so fertilizer is not always needed.

(2) Micronutrients : The micronutrients are boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo) and zinc (Zn). Micronutrients are those elements which are needed in very small (micro) quantities for plant growth. These elements are sometimes called minor elements or trace elements.

Nitrogen (N) : A very important constituent of amino acids, proteins and nucleic acids. It also occurs in the constitution of many vitamins, hormones and chlorophyll.

Source : It is absorbed as NH_4^+, NO_2^- and NO_3^- from the soil.

Deficiency Symptoms :

Deficiencies can reduce yields, cause Yellowing of leaves. (= chlorosis) and stunted growth.

Causes dormancy of lateral buds, the stem axis turns purple, flowering is delayed and cell division is hindered.

Potassium (K) : It's importance is in maintenance of 'ionic-balance' in cells. It is also essential in maintaining turgidity of cells. It plays an important role in regulation of 'stomatal-pore-size.' It is required in the process of protein synthesis and in the activity of some enzymes.

Source : It is absorbed as 'potassium ion' from the soil solution.

Deficiency Symptoms : Deficiencies result spotted or curled leaves and scorched look to leaves. Other symptoms are blackening of terminal regions of leaves, yellowing of intravenous mesophyll, removal of dominance of apical buds as a result, lateral buds develop, increase in respiratory rate, shortening of internodes, degradation of chloroplasts and reduction in cambial activity.

Phosphorous(P) : Phosphorous is a structural component of plasma membrane. It is essential in the constitution of nucleotides and nucleic acids. It is obligatory in all phosphorylation reactions. It also occurs in the structure of some proteins.

Source : It is absorbed as phosphate ion from the soil.

Deficiency Symptoms : Red or purple blots occur on leaf surfaces, induction of dormancy in seeds, premature fall of leaves and flower buds and fruits occurs.

Calcium (Ca) : It is essential in meristematic tissues and in differentiating tissues. It is required in the synthesis of middle lamella which occurs between cells. It is associated with the formation of the

bipolar spindle during cell division. It plays a role in the regulation of cellular metabolism. It is also required for the activity of some enzymes.

Source : It is absorbed as Ca^{2+} from the soil.

Deficiency Symptoms : Deficiency causes stunting of growth in newly developed branches, flowers and roots. Young root tips, shoot apices and marginal regions of young leaves begin to die.

Magnesium(Mg) : It is obligatory for the activity of enzymes involved in photosynthesis and respiration. It is also a constituent of chlorophyll. It is required for maintenance of ribosomal constitution. It is also essential for synthesis of nucleic acids.

Source : It is absorbed as Mg^{2+} ions from the soil.

Deficiency Symptoms : In deficient plants yellowing of intravenous regions of leaf - mesophyll occurs. Old leaves start to die or purple blots begin to appear on them. Premature leaf fall occurs.

Sulphur (S) : It is a constituent of some amino acids. Sulphur also occurs in constitution of vitamin thiamine and biotin. It is also required in the constitution of many co-enzymes.

Source : It is absorbed as SO_4^{2-} ion from the soil.

Deficiency Symptoms : Deficiency shows light green leaves. Yellowing of leaves and stunted growth like deficiency symptoms resemble those for Nitrogen deficiency.

- Accumulation of purple pigments.

Iron (Fe) : It is required in the constitution of electron transport - system components like cytochromes and ferredoxin. It is also needed for synthesis of chlorophyll.

Source : It is mainly absorbed as Fe^{3+} (ferric ion)

Deficiency Symptoms : Deficiency shows pale color of young leaves followed by yellowing of leaves and large veins.

- It's main effect is completely yellowing of leaves.

Manganese (Mn) : The most significant role of Mn^{2+} is to induce photolysis of water during photosynthesis. O_2 is liberated as an outcome. It is also required for activity of enzymes associated with photosythesis, respiration and nitrogen - fixation.

Source : It is mainly absorbed as Mn^{2+}.

Deficiency Symptoms : Deficiency in young leaves may show-brownish, black, or grayish spots which may appear next to the veins.

Zinc (Zn) : It is essential for the activity of carboxylase type of enzymes. It is also needed in auxin synthesis.

Source : It is absorbed as Zn^{2+}.

Deficiency Symptoms : Deficiency leads to stunted growth and yellowing of mesophyll of leaves.

Copper (Cu) : It is required for the activity of enzymes related to oxidation- reduction reactions.

Source : It is absorbed as Cu^{2+}.

Deficiency Symptoms : Deficiency causes dying of the shoot tips and leaf margin of young leaves and wilting and dropping of leaves. Bark of tree becomes rough and gets split and exudes gum-like secretion.

Boron (B) : It is required for absorption and utilization of calcium. It is essential for germination of pollen grain, cellular differentiation and translocation of sugars.

Source : It is absorbed as Boron ions.

Deficiency Symptoms : Deficiency kills terminal buds leaving a rosette effect on the plant. Leaves are thick brown spoted and fruits, tubers and roots are discolored. Death of root tips and shoot-apices and reduction of fruit size.

- Flowers drop off. • Fruit - size diminishes.

Molybdenum(Mo) : It is a constituent of enzymes associated with various process of nitrogen-fixation.

Source : It is absorbed as Mo^{6+} ion.

Deficiency Symptoms : Deficiency signs are pale green leaves with rolled margins.

- Deficiency of nitrogen leads to stunted growth and yellowing of leaves.

Chlorine (Cl) : It is essential for ionic-balance in cells. It is required in cell division and in splitting of H_2O during photosynthesis.

Source : It is absorbed as Cl^-

Deficiency Symptoms : Deficiency symptoms include

- Wilting of stubby roots, yellowing (chlorosis) and bronzing leaves, wilting of leaves.
- Fruit - yield decreases. Growth becomes stunted.

It can be stated that the most common effects of mineral deficiency are -chlorosis of leaves and gradual death of tips and margins of leaves.

Some Minerals Deficiencies

(1) Nitrogen (2) Potassium (3) Phosphorus (4) Calcium (5) Magnesium

(6) Sulphur (7) Iron (8) Manganese (9) Zinc

(10) Copper (11) Boron (12) Molybdenum (13) Chloride

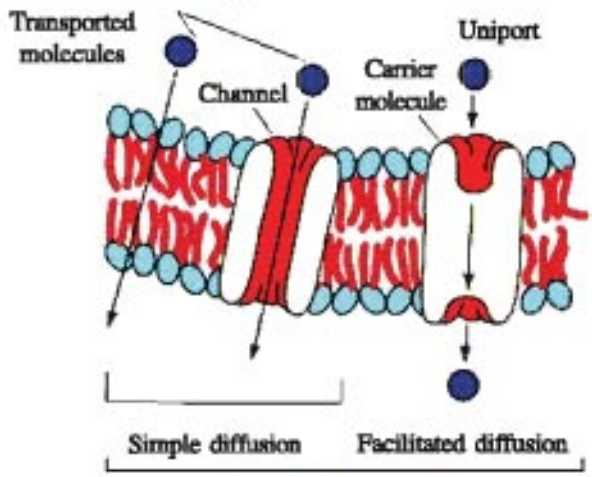
(These diagrams are only for information.)

Toxicity of Micronutrients

The requirement of micronutrients is always low while there moderate decrease causes the deficiency symptoms and a moderate increase causes toxicity. The toxicity symptoms are difficult to identify. Toxicity levels for any element may inhibit the uptake of another element. Manganese inhibits calcium translocation in shoot apex. Therefore, excess of manganese may, in fact, induce deficiencies of iron, magnesium and calcium. Thus, there is no appearing difference between the deficiency symptoms of manganese and deficiency symptoms of iron, magnesium and calcium also.

Absorption of Mineral Nutrients

It seems that there are two main stages in the process of absorption of mineral nutrients from the soil. (1) First of all, the nutrients enter the cell walls of root on the outer side of plasma membrane. Moreover, they also move into the intercellular spaces. This process is relatively more rapid. It occurs through normal diffusion and no energy is expended in it. (2) Then from this extracellular region, the mineral nutrients enter the cellular region. The cellular region means within the plasma membrane and the region within the vacuole. This process occurs in various ways.

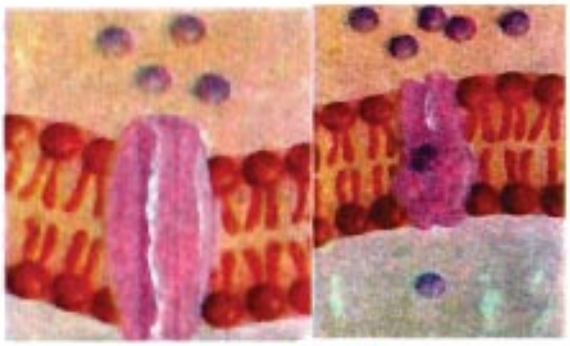


Passive transport

Plants absorb a large number of minerals from soil. The uptake of mineral ions by the roots may be **passive** or **active**.

(a) Simple or Passive Absorption : This type of absorption does not require use of any metabolic energy from the cell. It is the initial and rapid phase and ions are absorbed into the "outer space" of the cells. Absorption occurs according to normal physical principles. Examples : The diffusion, Ion Exchange, Donnan Equilibrium, Principle of Mass Flow, osmosis of water, and facilitated diffusion.

Diffusion : A substance moves from where it is in a higher concentration to where it is in a lower concentration. Thus, ions are absorbed following their concentration -gradient. For ionic absorption, various 'ionic - channels' are located in the plasma membrane. Special kinds of proteins which extend along the thickness of the plasma membrane provide pores which act as such 'ion-channels'.



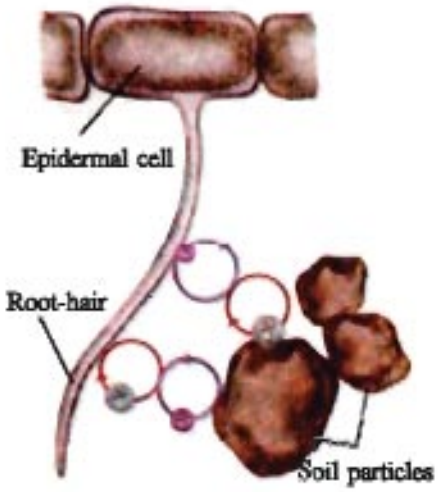
Ion-channels

Ion Exchange : Both, anions and cations are located on the surface of the cell wall through their adsorption. The soil solution also contains ions. An ion exchange occurs between them. Such an ionic-exchange occurs even against their concentration-gradient.

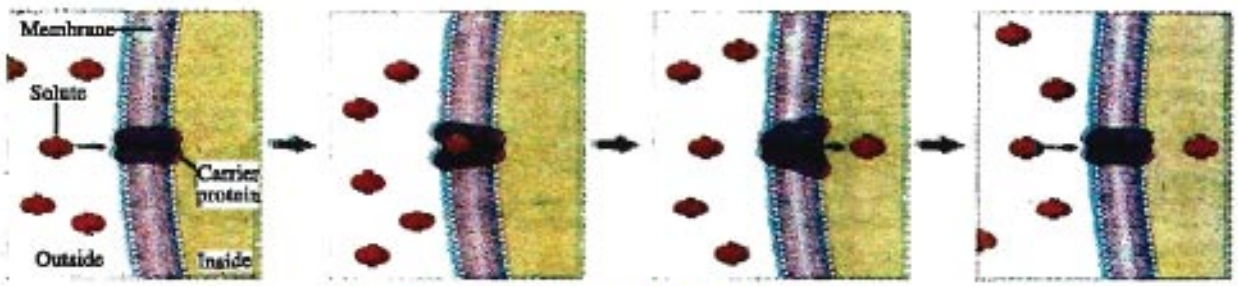
Donnan Equilibrium : Certain ions are incapable of diffusion against their concentration-gradient. The accumulation of such stable and non diffusible ions is explained through this principle. (It occurs against concentration-gradient.)

Plasma membrane possesses selective permeability. It permits exchange of some ions and does not permit that of some others. As a result, there occurs an increase in the concentration of positive ions on the inner surface of plasma membrane. As a result, the inner surface becomes positively charged. Due to this, the negatively charged ions in the soil solution, become accumulated on the outer surface of plasma membrane.

Principle of Mass Flow : According to this principle, large amounts of ions are absorbed along with the absorption of water in large amount. The suction pressure generated by transpiration causing absorption of water is responsible for this. As suction pressure increases, the absorption of water increases and along with water absorption of ions also increases.



Ion Exchange

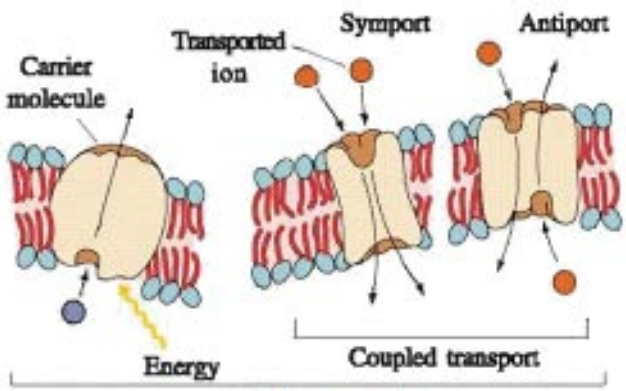


Transport of Ions through Carrier Molecules

(h) Active Absorption : This type of absorption, needs the expenditure of metabolic energy from the cell in the form of ATP. The ions are taken in slowly into the 'inner space'.

Examples : Transport of large molecules, Sodium-Potassium pump.

Such absorption of ions occurs against their concentration ingradient. Energy is consumed in it. Based on a variety of evidences, it seems that specials 'carrier molecules' are involved in this process.



Active transport

These carrier molecules are special kinds of proteins. They combine with ions on the outer side of plasma membrane and form 'ion-carrier complex.' This complex migrates across the membrane towards the inside, where the complex releases the ion. These carrier proteins do not create any pore-like passages.

Translocation of Solutes

Mineral salts are translocated through the xylem vessels to other parts of the plant along with the ascending stream of water by the root system.

The mineral nutrients absorbed by root gradually move across the cortex, endodermis and pericycle towards constituents of xylem. Translocation occurs through apoplast and symplast both. From xylem, their conduction occurs along with the ascent of sap. The rate of transport of water and minerals, also appear to be interrelated.

Soil as a nutrient reservoir

We know that substances can enter plants only in a gaseous or a liquid form. Plants obtain only carbon and oxygen from the atmosphere in the gaseous form as CO_2 and O_2. Except these two, all the minerals are absorbed by plant root system from soil. These minerals are present in soil solution. Even though, nitrogen occurs in a large amount in the atmosphere, it is not available. It occurs as its salts in the soil and is absorbed from there. C, H and O are not considered as mineral elements. Simillarly, N is also not considered a mineral as its original source is air.

All other elements enter the plants from the soil, through their absorption by their root system. These elements occur in solute forms in soil solution.

Nitrogen is absorbed as NH_4^+, NO_2^-, NO_3^-, **Potassium** as 'potassium ion', **Phosphorous** as phosphate ion, **Calcium** as Ca^{2+} ion, **Magnesium** as Mg^{2+} ions, **Sulphur** as SO_4^{2-} ion, **Iron** as Fe^{3+} (ferric ion), **Manganese** as Mn^{2+}, **Zinc** as Zn^{2+}, **Copper** as Cu^{2+}, **Boron** as Boron ions, Molybdenum as molybdenum ions and **Chlorine** as Cl^- ions etc. Macronutrients and micronutrients are absorbed from the soil and soil solution.

Soil contains particles of different sizes e.g. sand (large), silt (medium), clay (small), very small clay particles (colloids) and remain suspended particles in soil solution. Colloids are

(1) mineral (primarily aluminium silicate)

(2) organic (slowly decomposing through weather & microorganisms)

(3) have large surface area

(4) are involved in cation exchange. Therefore, soil acts as a nutrients reservoir.

Nitrogen Metabolism

We learnt earlier that C, H, O and N are amongst the most important essential elements. In living organisms, except C, H and O, N occurs in the largest amount. It occurs in the constitution of important protoplasmic substances like amino acids, proteins, nucleotides, vitamins and hormones.

We also know that the atmosphere contains a large amount of N_2 and that it cannot be directly utilized by any organism. Plants absorb salts of nitrogen like NH_4^+ , NO_2^- and NO_3^- from the soil and incorporate them into their organic constituents. Animals obtain these constituents when they consume these plants as food.

When plants and animals die, their dead bodies are decomposed. During such decomposition which is caused by bacteria, NH_3 is released. This process is called ammonification This NH_3 is immediately converted to NO_2^- and NO_3^- by a process called-nitrification. Specific bacteria are responsible for this. These salts can be absorbed by plants. Some bacteria release N_2 into atmosphere by decomposing nitrates.

Nitrogen cycle

Nitrogen Cycle is an example of gaseous type of biogeochemical cycle. Nitrogen is an essential element of protoplasm, proteins and genetically important nucleic acids such as DNA. It is also a major constituent (about 78%) of the atmosphere. Most green plants need nitrogen in the form of nitrate ions (NO_3^-) and ammonium ions (NH_4^+). Special N_2-fixing bacteria (*Rhizobium*) present in the roots of leguminous plants and certain blue green algae(*Nostoc* and *Anabena*)are capable of fixing nitrogen and converting the same into nitrates(NO_3^-). Lightning also converts gaseous N_2 into nitrates. But the denitrifying bacteria in the soil are transfer the nitrates into gaseous nitrogen and release the same to the atmosphere.

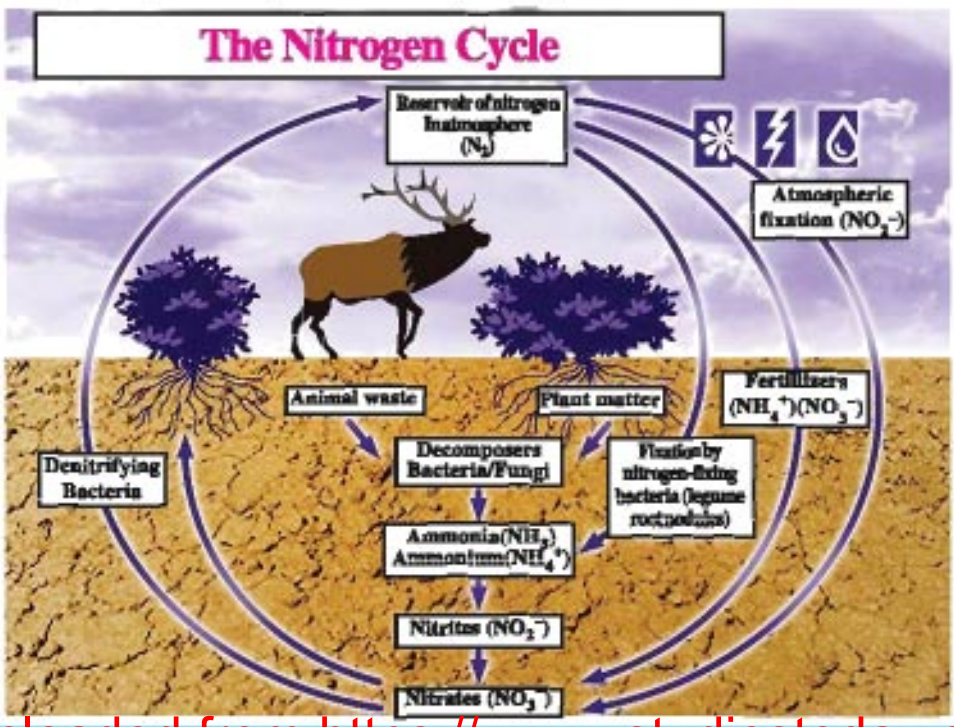
The processes involved in the cycle are fixation, ammonification, nitrification and denitrification.

Ammonification : Ammonification is the transforming process of complex organic matters into the inorganic matters. Dead animals and plant tissues and excretion matters give rise to nitrogenous wastes(complex organic matter). This nitrogenous wastes are converted into ammonia (NH_3) by heterotrophic bacteria, fungi and other decomposers in soil and water. Part of the ammonia is dissolved in water or taken up by plants. It is a one way reaction.

Nitrification : Nitrification is a biological process in which ammonia(NH_3) is converted into nitrite(NO_2^-) and nitrate(NO_3^-). Two types of microorganisms are involved in this process. NH_3 is converted into NO_2^- by *Nitrosomonas* bacteria and then NO_2^- is converted into NO_3^- by *Nitrobacter*. Thus, nitrification is a oxidation process in which nitrogen is increased.

The NO_3^- which is thus formed is once again utilized by green plants for the synthesis of proteins. And gaseous N_2 is converted into NO_3^- by lightning, N_2-fixing bacteria and blue green algae. Thus the N_2 cycle goes on continuously in nature again and again.

Denitrification : Some bacteria are capable of reducing nitrates to gaseous nitrogen, a process called denitrification. NO_3 is reconverted into gaseous N_2 by denitrifying bacteria. (*Agrobacterium* and *Pseudomonas*). e.g. $2NO_3 \rightarrow 2NO_2 \rightarrow 2NO \rightarrow N_2O \rightarrow N_2$



Nitrogen Fixation

Nitrogen fixation is the conversion process of atmospheric nitrogen to ammonia or nitrate. Ammonia is the product of biological fixation and nitrate is the product of high-energy. In biological fixation molecular nitrogen(N_2) splits into two atoms of free nitrogen:

$$N_2 \rightarrow 2N$$

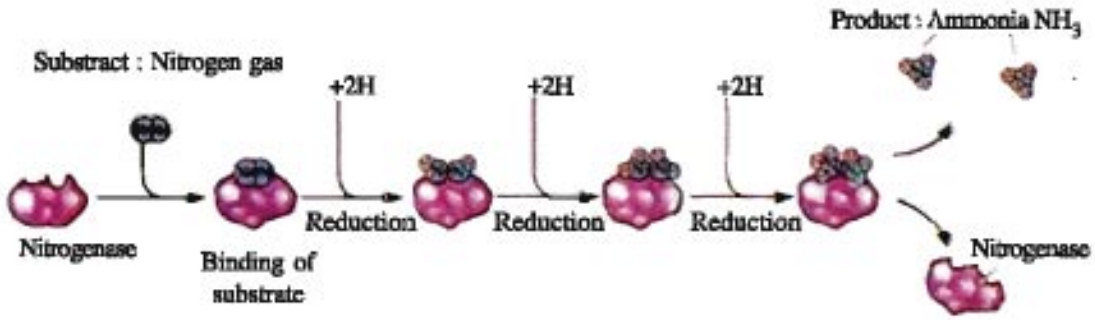
The free nitrogen atoms can combine with hydrogen to form ammonia.

$$2N + 3H_2 \rightarrow 2NH_3$$

This process is mainly carried out by living organisms i.e. specific bacteria and blue-green algae. Therefore it is called biological -nitrogen - fixation.

Symbiotic nitrogen fixation takes place by symbiotic bacteria which are association with roots of leguminous and non-leguminous plants and are known as *Rhizobium*. Non-symbiotic nitrogen fixation takes place by Blue-green algae (*Nostoc* and *Anabena*) and free-living soil bacteria (the aerobic *Azotobacter* species and the anaerobic *Clostridium* species).

Symbiotic nitrogen fixation : This type of biological fixation of nitrogen is accomplished by symbiotic bacteria.



Nitrogen Fixation

Legumes, the most conspicuous of the nitrogen - fixing plants, have a symbiotic relationship with members of the bacterial genus *Rhizobium*. They exist in the immediate surroundings of the plant roots called rhizosphere. There they multiply and increase in size, resulting in swollen infected mass of cells called root nodules, in which an oxygen carrying red pigment hemoprotein, termed as leghemoglobin, similar to hemoglobin of animal blood, is present. A nif-gene (nitrogen-fixation gene) present in *Rhizobium* is responsible for synthesis of nitrogenase enzyme. This enzyme is extremely sensitive to the presence of oxygen. Leghemoglobin accepts oxygen and thus protects the enzyme from its side effects. This process of Biological fixation possess low energy requirement regulated by two enzymes which are nitrogenase (an iron containing protein) and hydrogenase (a molybdenum containing protein).

In nitrogen fixation, nitrogen is reduced through addition of hydrogen. The three bonds (N ≡ N) between two atoms of nitrogen are opened up and three units of H_2 are introduced. In this way two molecules of NH_3 are formed.

Three components are required for this. (1) Reduction inducing unit: FAD(flavin adenine dinucleotide) acts as such a unit. FAD is synthesized during photosynthesis and respiration. (2) Energy as ATP: Energy is provided by ATP in the introduction of H_2 units in a diatomic N_2 unit. (3) Essential Enzymes.

Synthesis of Amino Acids : NH_3 is initially utilized in the synthesis of amino acids. We know that in the structure of an amino acid, there always occurs at least one amino group and one carboxyl group.

There are two main methods of amino-acid synthesis in plants.

(1) Reductive Amination : In this method, α-Keto - glutaric acid reacts with ammonia (NH_3) and forms the amino acid, named glutamic acid. The enzyme glutamate dehydrogenase is responsible for this.

(2) Transamination : In this method, an amino group is separated from one amino acid and it is transferred to a keto group in another keto kind of acid. Glutamic acid acts as a main donor of amino group. Other seventeen kinds of amino acids are synthesized in this way. The enzymes responsible for this are of transaminase types.

Synthesis of Proteins : Various kinds of amino acid units become joined with one another in various numbers and various sequences to form polypeptide chains through peptide bonds. There can be one or more polypeptide chains in the constitution of proteins.

Summary

The absorption, distribution and metabolism of various mineral elements by plants is called mineral nutrition. All organisms need nutrition. We know that in plants, nutrition is autotrophic. Mineral elements occur mainly in their inorganic ionic forms in the soil. Plants absorb them from the soil through their root systems. The study of mineral nutrition is concerned with the absorption of essential mineral nutrients, their important role in the plant life and the effects of their imbalanced availability cause specific symptoms.

Some methods to determine the requirement of minerals by plants are as Hydroponics, Aeroponics, and Organoponic. Criteria for Essentiality of Elements are

(1) A plant must be unable to complete its life cycle in the absence of the mineral element.

(2) The function of the element must not be replaceable by another mineral element.

(3) The element must be directly involved in plant metabolism.

The nutrients or elements which are essential for the healthy growth of the plant are called essential nutrients or essential elements. About 112 elements have been discovered until now. Only twenty kinds of mineral elements are considered as essential for the plants. Most of the mineral elements present in soil are absorbed by roots of the plant. All minerals which are absorbed by plants are not 'essential mineral.' Most of the **mineral nutrients**, which come from the soil, are dissolved in water and absorbed through a plant's roots.

Macronutrients include - Carbon, Hydrogen, Oxygen, Nitrogen, Potassium Phosphorus, Sulphur, Calcium, and Magnesium. Micronutrients include - Manganese, Copper, Molybdenum, Boron, Zinc, Iron, Chlorine and Nickel. Sodium, Cobalt, Silicon and Vanadium are also seem to be important - 'trace elements'. C, H, O and N are Non mineral elements.

The absence or deficiency (not present in the required amount) of any of the essential elements shows to deficiency symptoms or effects in plant. The requirement of micronutrients is always low while there moderate decrease causes the deficiency symptoms and a moderate increases causes toxicity.

Plants absorb a large number of minerals from soil. The uptake of mineral ions by the roots may be passive or active. **(a) Passive Absorption :** This type of absorption, does not require use of any

metabolic energy from the cell. **(b) Active Absorption :** This type of absorption needs the expenditure of metabolic energy from the cell in the form of ATP.

Mineral salts are translocated through the xylem vessels to other parts of the plant along with the ascending stream of water by the root system.

Most of the elements enter the plants from the soil, through their absorption by their root system. These elements occurs in solute form in soil solution. Thus the, soil acts as a nutrient reservoir.

The atmosphere contains a large amount of N_2 and that it cannot be directly utilized by any organism. It occurs in the constitution of important protoplasmic substances like amino acids, proteins, nucleotides, vitamins and hormones. Plants absorb salts of nitrogen like NH_4, NO_2 and NO_3. from the soil and incorporate them into their organic constituents. Animals obtain these constituents when they consume these plants as food.

Nitrogen Cycle is an example of gaseous type of biogeochemical cycle. The processes involved in the cycle are fixation, ammonification, nitrification and denitrification. Ammonification is the transforming process of complex organic matters into the inorganic matters. Nitrification is a biological process in which ammonia(NH_3) is converted into nitrite(NO_2) and nitrate(NO_3). *Nitrosomonas* and *Nitrobacter* are involved in this process. The NO_3 which is thus formed is once again utilized by green plants for the synthesis of proteins. NO_3 is reconverted into gaseous N_2 by *Agrobacterium* and *Pseudomonas* (denitrifying bacteria). This process is called denitrification.

The process of conversion of nitrogen into its salts is called nitrogen fixation. This process is mainly carried out by living organisms. It is called biological -nitrogen - fixation. It is carried out by specific bacteria(*Rhizobium*) and blue-green algae(*Nostoc* and *Anabena*).

In nitrogen fixation, nitrogen is reduced through addition of hydrogen and two molecules of NH_3 are formed. NH_3 is initially utilized in the synthesis of amino acids. Various kinds of amino acid units become joined to form polypeptide chains through peptide bonds and one or more polypeptide chains are presents in the constitution of proteins.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Plants absorbed the mineral nutrients by...

(a) Stem system ○ (b) Root system ○

(c) Leaf system ○ (d) None of these ○

(2) The technique of growing plants only in a nutrient medium in complete absence of soil is known as...

(a) Soil culture ○ (b) Tissue culture ○

(c) Embryo culture ○ (d) Water culture ○

(3) Which is a macronutrient element ?

(a) Manganese ○ (b) Cobalt ○

(c) Phosphorus ○ (d) Sulphur ○

(4) Trace elements is...

(a) Carbon ○ (b) Vanadium ○

(c) Phosphorus ○ (d) Magnesium ○

(5) Non mineral element is...

(a) Nitrogen ○ (b) Molybdenum ○

(c) Nickle ○ (d) Zinc ○

(6) Which element is essential in meristematic tissues and in differentiating tissues?

(a) Phosphorus ○ (b) Cobalt ○

(c) Calcium ○ (d) Nitrogen ○

(7) Yellowing of leaves is known as...

(a) Tylosis ○ (b) Necrosis ○

(c) Florosis ○ (d) Chlorosis ○

(8) Sulphur occurs in constitution of vitamin...

(a) Thiamine ○ (b) Riboflavin ○

(c) Retinol ○ (d) Calciferol ○

(9) Killing of terminal buds leaving a rosette effect on the plant is deficiencies of...

(a) Cobalt ○ (b) Boron

(c) Calcium ○ (d) Phosphorus ○

(10) An example of N_2-fixing bacteria is...

(a) Nitrosomonas ○ (b) Rhizobium ○

(c) Pseudomonas ○ (d) Nitrobacter ○

2. Answer the following questions in short :

(1) Mention the examples of micronutrients.

(2) In which form is nitrogen obtained from the soil ?

(3) Which vessels are involved in mineral salts translocation ?

(4) Give the examples of blue green algae.

(5) What is leghemoglobin ?

3. Define :

Hydroponics, Essential elements, Ammonification, Nitrification

4. Write short notes :

(1) Macronutrients (2) Passive transport (3) Active transport

(4) Nitrogen cycle (5) Diffusion (6) Donnan equilibrium

5. Give the comparative account : Passive transport and Active transport.

6. Answer the following questions in detail :

(1) Give the importance of potassium and its deficiency symptoms.

(2) Mention the toxic effects of nutrients.

(3) Describe the translocation of minerals.

(4) Soil as a reservoir of mineral elements – explain.

(5) Describe the Nitrogen metabolism.

(6) Mention the process of synthesis of Amino acids.

3

Photosynthesis

All animals including human beings depend upon plants for their food. All green plants carry out photosynthesis. Various kinds of algae, several bacteria and all higher green plants synthesize their own food through this process. During this process light energy of sun is fixed as a chemical energy in food, which is used by all other organisms. Thus the energy requirement of the entire living world is fulfilled through photosynthesis. The fossil fuel from which we obtain energy is also a product of photosynthesis in the past. During photosynthesis CO_2 from the atmosphere is consumed and at the end of this process O_2 is released into the atmosphere as a by-product. As energy is fixed during this process, it is considered as an endergonic process.

What do you know ?

Let us see what we know about photosynthesis. Some simple experiments you might have performed in earlier classes which have shown that chlorophyll, light and CO_2 are required for photosynthesis to occur.

The two leaves experiment showing formation of starch might have carried out by you in which one leaf was covered by black paper and other was exposed to light. On testing these leaves for starch it was clear that photosynthesis took place only in the green part of the leaf which was exposed to sun light.

Another experiment which you may have carried out is the half leaf experiment where a part of leaf is inserted in a test tube having KOH soaked cotton (which absorbs CO_2), while the other half is exposed to air. This setup is then placed in sunlight for some time. On testing for the starch it was found that only the exposed part of leaf gave positive test for starch. This indicates that CO_2 is required for photosynthesis.

Early Experiments

The study of the process of photosynthesis dates back to some 300 years.

Joseph Priestley (1733 – 1804) : In 1770 performed a series of experiments and showed that plants obtain CO_2 from the atmosphere and release O_2 in the atmosphere.

Jan Ingenhousz (1730 – 1799) : Performed an experiment on aquatic plant and showed that in bright sunlight, small bubbles were formed around the green parts of the plant while in the dark they

did not. He identified these bubbles to be of oxygen. He concluded that only those organs of plants which possess chlorophyll release O_2 and that too only in presence of light.

Julius Von Sachs (1854) : He showed that green substance (chlorophyll) in plants is located in special bodies (chloroplasts) of plant cell. This green substance produces glucose which is usually stored in the form of starch.

By the middle of the nineteenth century it became established that plants prepare food using CO_2 and H_2O in presence of light and release O_2 in the atmosphere. The empirical equation representing the total process of photosynthesis for oxygen evolving organisms can be explained as below :

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

Where $[CH_2O]$ represented a carbohydrate.

Cornelius van Niel (1897 – 1985) : Who, based on his studies on purple and green bacteria, demonstrated that photosynthesis is essentially a light dependent reaction in which hydrogen from a suitable oxidisable compound reduces carbon dioxide to carbohydrates. Niel put up a simple equation for plant as follow :

$$2\,H_2O + CO_2 \xrightarrow{\text{Light}} O_2 + CH_2O + H_2O$$

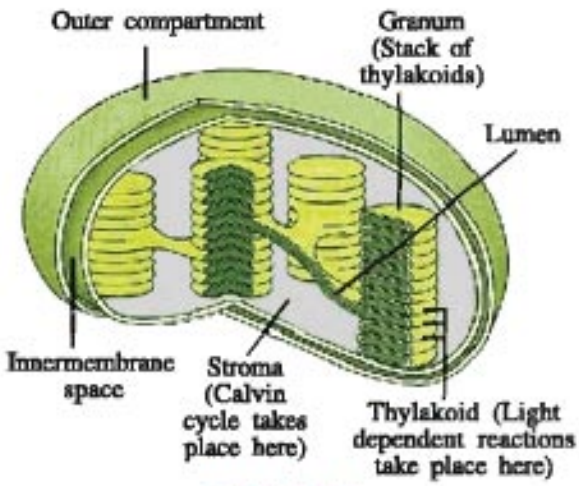
Later, another scientist **Robert Hill** demonstrated that the O_2 released into atmosphere comes from water. Thus the equation was modified as under :

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

Where does photosynthesis takes place ?

The process of photosynthesis takes place only in the green organs of the plants. Amongst these, the leaves are the main organs. Even in a leaf this process occurs in the chlorenchyma of mesophyll. The cells of this tissue possess organelles called chloroplasts. The chloroplasts are arranged in the peripheral region of the cell, which facilitates the diffusion of gases.

We have earlier studied the structure of chloroplast. Within the chloroplast, there is the membranous system consisting of grana and the fluid stroma. Each granum is made up of flat, lamellar structures called thlakoids which are arranged like a stack pile of coins. Thylakoids contain chlorophyll pigments. A clear division of labour can be seen in chloroplast. The membrane system is responsible for trapping the light energy and synthesis of ATP and NADPH. This is called light reaction. In stroma enzymatic reactions incorporate CO_2 into the plant leading to synthesis of sugar. Since it is not light driven process, it is known as dark reaction.



Chloroplast

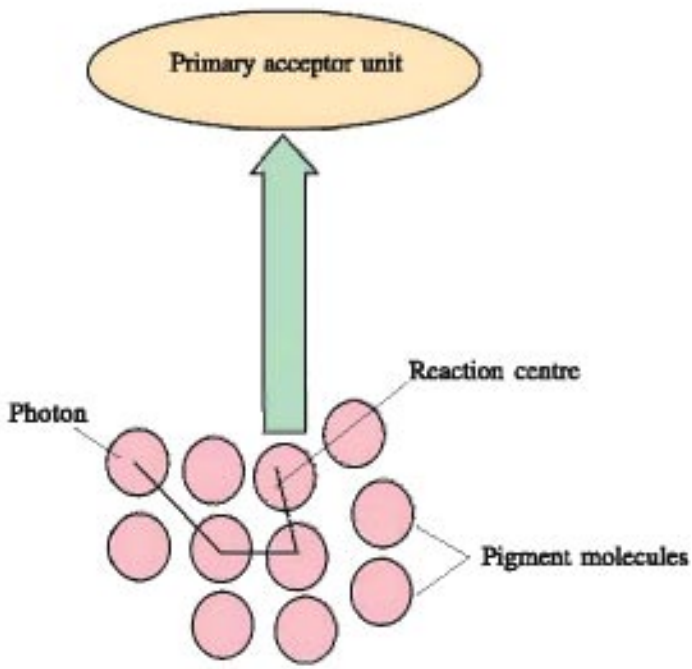
How many pigments are involved in photosynthesis

Chromatographic separation of leaf pigments shows that the color that we see in leaves is not due to a single pigment but due to four pigments; chlorophyll-a, chlorophyll-b, xanthophyll and carotenoids,

Chlorophyll-a and chlorophyll-b are green pigments, xanthophylls are yellow and carotenoids are yellow to orange pigments. These pigments are concerned with absorption of light energy. They absorb light at specific wavelength and obtain energy from them. This energy is first converted into the energy of electrons and later into chemical energy. Chlorophyll-a molecules are the main reactants in this process. The other kinds of pigments direct and focus the energy absorbed by them towards chlorophyll-a and hence, they are known as accessory pigments. Thus chlorophyll-a molecules act as reaction centres.

What is light reaction ?

Presence of light is inevitable for light reaction. Hence, this reaction is also known as photochemical phase. It takes place in the grana regions of chloroplast. This reaction involves absorption of light, photolysis of water, release of oxygen and formation of ATP and $NADPH_2$. The photosynthetic pigments, mentioned above, are organized into two photochemical Light Harvesting Complexes (LHC) like the photosystem-I (PS-I) and photosystem-II (PS-II). In the first kind of pigment system, the chlorophyll-a molecules at the reaction centre are stimulated by the wavelength of 700 nm and hence, it is also called P_{700}. In the other pigment system the chlorophyll-a molecules at the reaction centre are stimulated by the wavelength of 680 nm and hence, it is called P_{680}. Each pigment system is made up of around 250 to 400 molecules (except one molecule of chlorophyll-a) forming a light harvesting system called antennae.The single chlorophyll-a molecule forms the reaction centre.



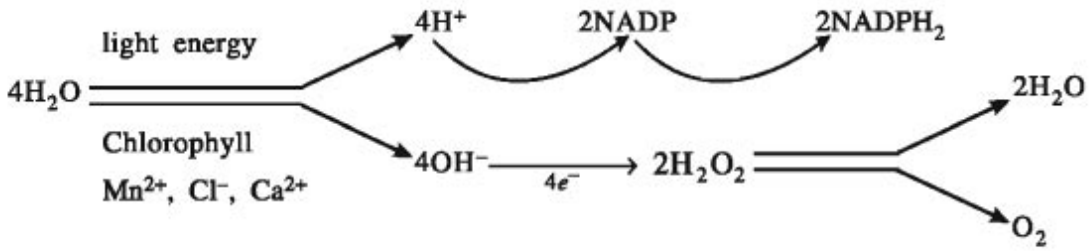
Light Harvesting Complex (LHC)

The Electron Transport System

In electron transport system, the electrons which are released from reaction centre transport in two ways : (1) Cyclic and (2) Non cyclic ways. Before going to study the transport of electrons we will see the splitting of water molecules during light reaction.

Splitting of water molecules : The splitting of water molecule using energy of light is known as photolysis of water. During this process 4 molecules of water split simultaneously. Thus $4H^+$ and

$4OH^-$ are released. These $4H^+$ are accepted by two molecules of hydrogen acceptor-NADP . Thus 2 molecules of NADP are converted into 2 molecules of $NADPH_2$. The 4 OH^- lose their 4 e^- and release 2 molecules of H_2O and 1 molecule of O_2. The entire process can be presented as under :

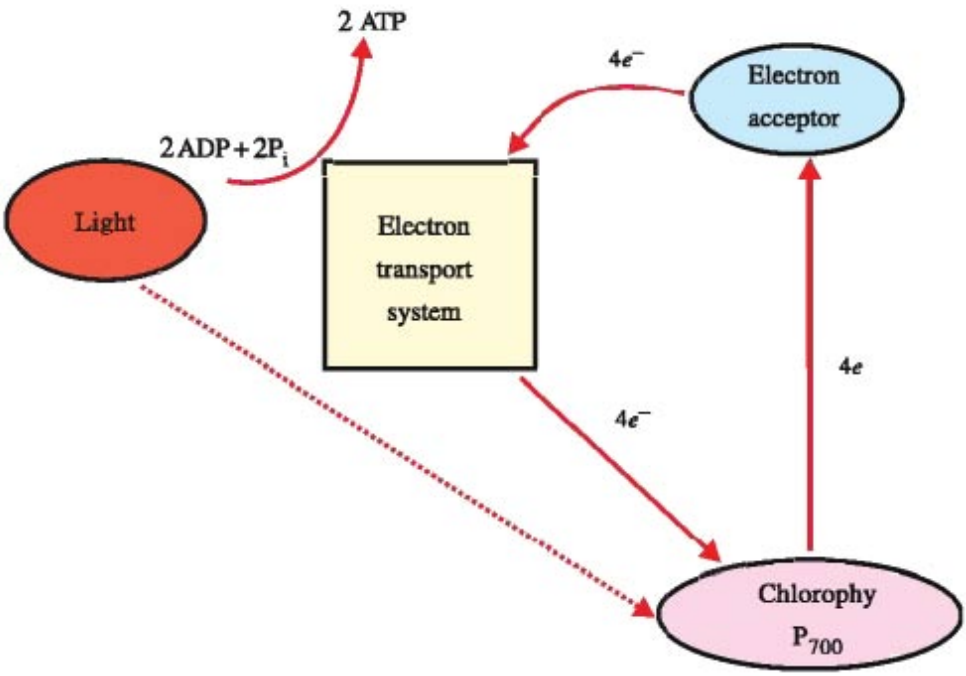


Mn^{2+}, Cl^- and Ca^{2+} play an important role in this process. The light energy required for photolysis of water is absorbed by PS-II. 2 NADP, $2H^+$ obtain $4e^-$ from PS-I and get converted into $2NADPH_2$. This $NADPH_2$ is later used in biosynthetic phase for reduction of CO_2.

Photophosphorylation : During this process ADP is phosphorylated and ATP is formed. Thus light energy gets converted into chemical energy. Photophosphorylation occurs in two ways : Cyclic Photophosphorylation and Noncyclic Photophosphorylation.

(1) Cyclic Photophosphorylation : In this process only PS-I participates. PS-I is stimulated by absorbing 4 photons from light of wavelength 700 nm. As a result 4 energy rich electrons are set free from the reaction centre of PS-I. These electrons are picked up by an electron acceptor which passes them to an electron transport system consisting of cytochromes.

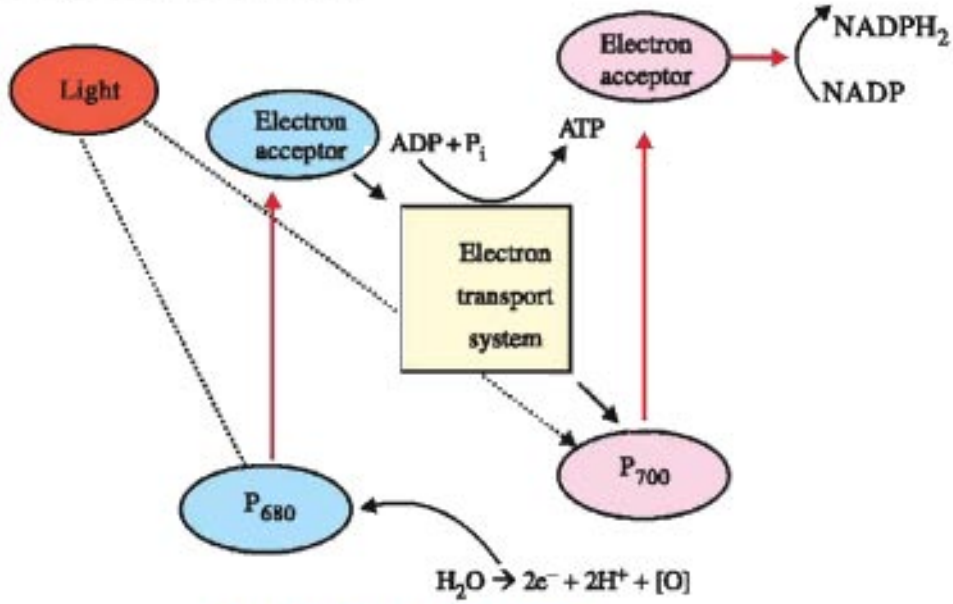
During this course of electron transport, energy is released from the electrons which is utilized for the synthesis of 2 molecules of ATP. As the electrons return to their original source, such a transport of electrons is called cyclic electron transport.



Cyclic Photophosphorylation

(2) Noncyclic photophosphorylation : In this process both PS-I and PS-II take part, in which 4 photons of sunlight of 680 nm wavelength stimulate PS-II where by $4e^-$ are released from reaction centre. The $4e^-$ released are accepted by various electron acceptors and finally enter into PS-I instead of returning to PS-II. Thus chlorophyll –a molecules at the reaction centre of PS-I receive $4e^-$ from PS-II. During this transport of electrons energy is released at various stages which is stored in phosphorylation of ADP to ATP. Simultaneously the $4e^-$ released by reaction centre of PS-I after receiving red light of wavelength 700 nm, neither go to PS-I nor to PS-II but are first accepted by electron acceptor and then utilized for the reduction of NADP.

As the electrons released in various ways do not return to their original donors, such an electron transport is called noncyclic electron transport.



Noncyclic photophosphorylation

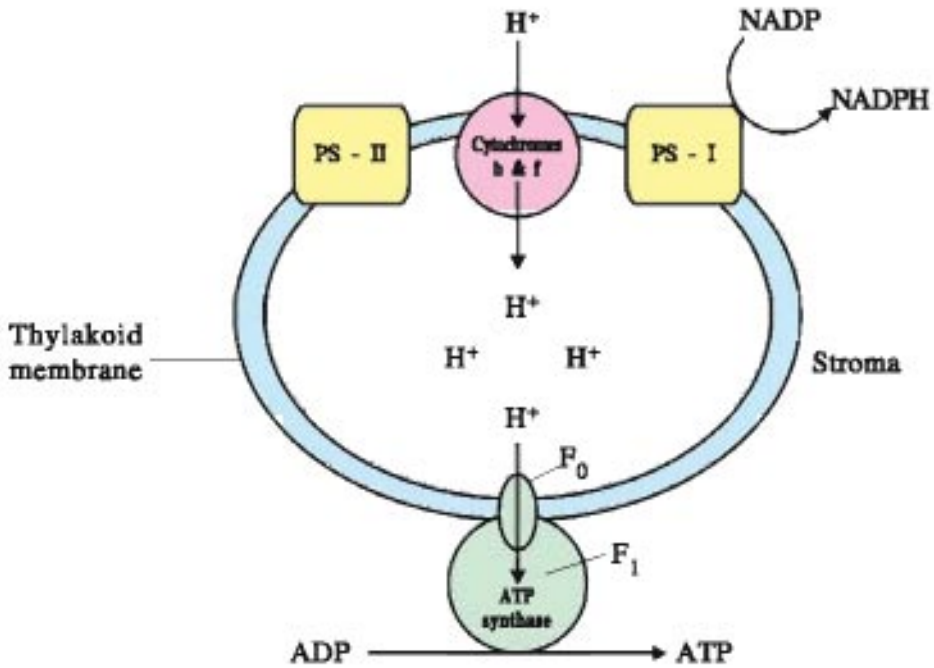
Chemiosmotic Hypothesis : The chemiosmotic hypothesis has been put forward to understand the synthesis of ATP in chloroplast. ATP synthesis is linked to development of proton gradient across the membrane of thylakoids. The proton accumulation takes place in the lumen of thylakoid. As the splitting of water molecule takes place inside the thylakoid, the protons or hydrogen ions that are produced, accumulate within the lumen of thylakoid. On the other side the reduction of NADP takes place in the stroma, outside the membrane. For this reduction protons are required and the protons which are present in the stroma are used up. Hence, within the chloroplast, protons in the stroma decreases in number, while in the lumen of thylakoid there is accumulation of protons. This creates a proton gradient across the thylakoid membrane.

What is the role of proton gradient ? Infect it is the breakdown of proton gradient which leads to release of energy. The gradient is brokendown due to the movement of protons across the membrane to the stroma through the transmembrane channel of the Fo of the ATPase. The ATPase enzyme consists of two parts :

(1) Fo - which is embedded in the membrane and forms a transmembrane channel through which diffusion of protons across the membrane takes place.

(2) F_1 - which protrudes on the outer surface of the thylakoid membrane on the side that faces stroma.

The breakdown of the gradient provides enough energy to cause a conformational change in the F_1 particle of ATPase, which makes the enzyme to synthesise several molecules of energy packed ATP. The ATP produced will be used immediately, along with NADPH, in the biosynthetic phase taking place in the stroma.



ATP synthesis through chemiosmosis

Where are the ATP and NADPH used ?

We have studied that during light reaction ATP, NADPH and O_2 are produced. O_2 diffuses out of the chloroplast while ATP and NADPH are used in the process of dark reaction or biosynthetic phase. Thus biosynthetic phase does not depend on light but it depend on the products of light reaction.

Let us now see how the ATP and NADPH are used in the biosynthetic phase. As we know that in biosynthetic phase H_2O combines with CO_2 to produce sugar. It was of interest to scientists to find out how this reaction proceeded or what is the first product formed when CO_2 is fixed. Melvin Calvin by using radioactive C^{14} in algal photosynthesis discovered that the first CO_2 fixation product was a 3-carbon organic acid i.e. 3-phosphoglyceric acid (PGA). He also studied complete biosynthetic pathway and hence it is also called as Calvin cycle.

Later on scientists also tried to know whether all plants have PGA as the first product of CO_2 fixation. Experiments conducted over a wide range of plants led to the discovery of another group of plants where the first product of CO_2 fixation was 4-carbon compound i.e. oxaloacetic acid (OAA). Since then CO_2 fixation during photosynthesis was said to be of two types:

(1) Those plants in which the first product of CO_2 fixation is a C_3 acid (PGA) i.e. C_3 pathway and

(2) Those plants in which the first product of CO_2 fixation is C_4 acid (OAA) i.e. C_4 pathway .

The primary acceptor of CO_2 : The scientists took a long time and conducted many experiments to known the primary acceptor of CO_2. Later on it was proved that the 5-carbon ketose sugar i.e ribulose biphosphate (RuBP) was the first acceptor molecule.

The Calvin cycle : Calvin and his co-workers worked out the whole pathway and showed that the pathway operated in cyclic manner. The entire Calvin cycle can be described under the following three steps :

(1) Carboxylation : Carboxylation is the fixation of CO_2 into a stable organic intermediate. First of all the CO_2 obtained from the atmosphere, combines with 5-C pentose sugar ribulose biphosphate obtained from the stroma and a 6-C unstable complex is formed which then splits into two molecules of a 3-C compound called phosphoglyceric acid (PGA). This reaction is catalysed by the enzyme RuBP carboxylase. This phase is called carboxylation phase.

(2) Reduction : A series of reactions are involved in the formation of glucose. The steps involved utilization of 2 molecules of ATP for phosphorylation and 2 molecules of NADPH for reduction per CO_2 molecule fixed. For the formation of one molecule of glucose fixation of six molecules of CO_2 and six turns of the cycle are required.

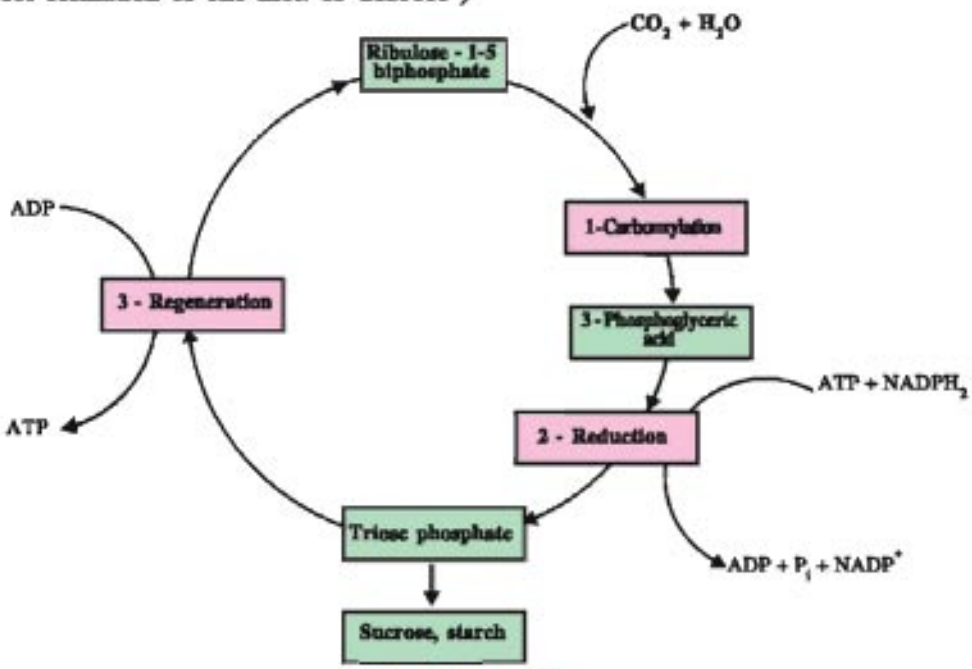
(3) Regeneration : Regeneration of RuBP is essential if the cycle is to be continued without break. Hence one ATP is also required for phosphorylation to form RuBP.

In this way for every CO_2 molecule entering the Calvin cycle, 3 molecules of ATP and 2 molecules of NADPH are required. As you know that for the formation of one molecule of glucose 6 turns of the cycle are required, how many ATP and NADPH molecules will be required to make one molecule of glucose ?

For one CO_2 molecule, 3 ATP and 2 NADPH are required so

For six CO_2 molecules, 18 ATP and 12 NADPH are required.

(i.e. for formation of one mol. of Glucose)



The Calvin cycle

The C_4 pathway

This pathway is also called Hatch-Slack pathway. C_4 pathway is generally observed in the monocot plants which grow in the tropical regions. It is very clearly observed in the leaves of sugarcane.

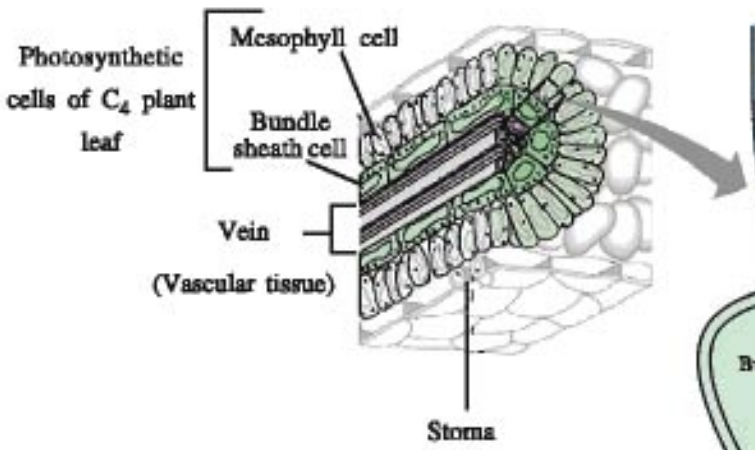
As earlier we have studied that C_3 path operates in the mesophyll cells, light phase and CO_2 fixation, both occur in the cells of mesophyll.

The C_4 pathway operates in two kinds of photosynthetic cells – mesophyll cells and bundle sheath cells. The bundle sheath cells are arranged surrounding the vascular bundles. Such an arrangement is called Kranz anatomy. The chloroplasts in mesophyll cells exhibit grana organization. The chloroplasts in bundle sheath cells do not show grana organization. They do possess thylakoids but they are not arranged into grana. These two kinds of cells perform two different types of reactions. The light reaction takes place in mesophyll cells while dark reaction occurs in bundle sheath cells. The arrangement prevents the O_2, evolved during light reaction, from entering the bundle sheath cells. Thus there is no possibility of photorespiration.

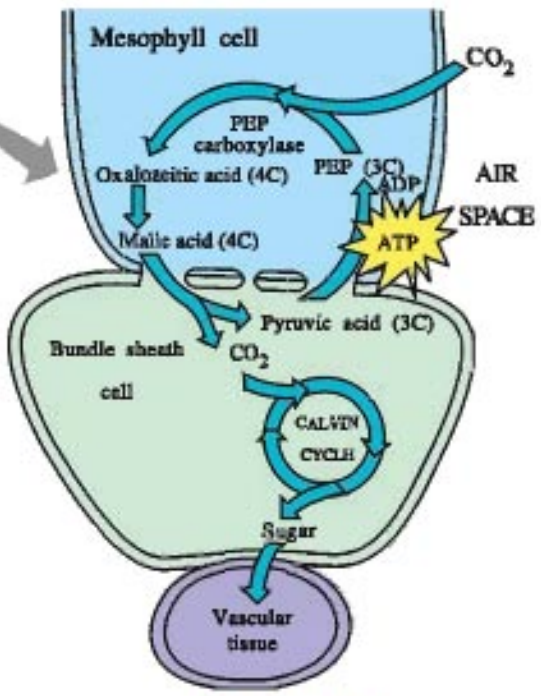
In C_4 pathway, atmospheric CO_2 first diffuses into mesophyll. This CO_2 reacts with a 3-C substance called phosphoenol pyruvic acid and forms a 4-C oxalo-acetic acid. As the first product is a 4-C molecule, this path is called C_4 path.

Now, oxalo-acetic acid is converted into malic acid which is thus formed is transported to the chloroplasts of bundle sheath cells. Here it is decarboxylated and one molecule of a 3-C pyrucic acid is formed and CO_2 is released. Pyruvic acid is transported back to chloroplast in mesophyll cells. Here it is converted to phosphoenol pyruvic acid. Thus the cycle continues.

Due to release of CO_2 in bundle sheath cells, the concentration of CO_2 goes on increasing. As the process of CO_2 fixation occurs in these cells also, more food is prepared through biosynthetic fixation. As there is no possibility of photorespiration, production of carbohydrates through C_4 path is more efficient than that through C_3 path.



C_4 Leaf anatomy



The C_4 Pathway

Table : Differences between C_3 and C_4 path

No.	Character	C_3 path	C_4 path
(1)	Type of cell	One (mesophyll)	Two (Mesophyll and Bundle sheath cells)
(2)	Kranz Anatomy	Does not occur	occurs
(3)	Chloroplast	With grana	With and without grana
(4)	First CO_2 acceptor	RuBP	PEP
(5)	First product	PGA (C_3)	Oxalo acetic acid (C_4)
(6)	Productivity	Normal	High

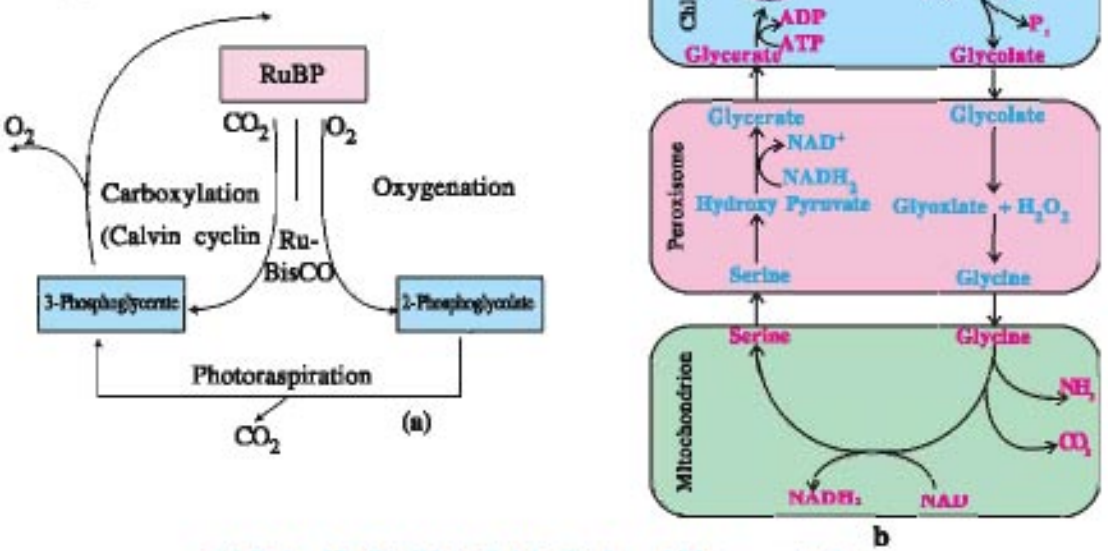
Photorespiration

We studied that in the biosynthetic phase of the photosynthesis, the atmospheric CO_2 combines with RuBP and forms two molecules of PGA. This carboxylation reaction is catalyses by an enzyme called Ribulose-bi-phosphate carboxylase (RuBisCO). This is the most abundant enzyme in the world and is characterized by the fact that its active site can bind to both CO_2 and O_2. Hence, it can also act as an oxygenase enzyme.

Photorespiration is a process of respiration which takes place in chloroplast in presence of light. In this process first of all RuBP is oxygenated in presence of O_2 forming one molecule of a 2-C phosphoglycolate and one molecule of a 3-C PGA. The PGA molecule is used in the Calvin cycle. Phosphogycolate is dephosphorylated forming glycolate. Glycolate diffuses out of chloroplast and enters the organelle called peroxisome. Here it is oxidized and becomes glyoxylate which is used in the synthesis of glycine.

Glycine now diffuses out of peroxisome and enters mitochondrion. Here 2 molecules of 2-C glycine unite and form one molecule of 3-C serine. During this one molecule of CO_2 is released.

Serine now diffuses out of mitochondrion and reenters into peroxisome. After some chemical reactions it is converted into glycerate. Glycerate diffuses out of peroxisome and enters chloroplast. Here it is phosphorylated to form PGA which enters the Calvin cycle.



(a) Role of RuBisCO in Calvin Cycle and Photorespiration
(b) Significance of Various Organelles in Photorespiration

One molecule of CO_2 which was released in the mitochondrion during formation of serine will have to be refixed. Thus, 75 % of carbon lost due to oxygenation of RuBP is recovered and 25% is wasted as one molecule of CO_2.

Under the condition of intense light and poor availability of CO_2, photorespiration plays a defensive role. With insufficient availability of CO_2 the light energy cannot be fully utilized and thus excess light can cause photooxidation and damage the plant. Photorespiration provides protection against this.

In C_3 plants some O_2 does bind to RuBisCO, and hence CO_2 fixation is decreased . In C_4 plants photorespiration does not occur. This is because they have a mechanism that increases the concentration of CO_2 at the enzyme site. This ensures that RuBisCO functions as carboxylase minimizing the oxygenase activity. This is the reason why productivity and yield are better in C_4 plants.

Factors affecting photosynthesis

The rate of photosynthesis is very important in determining the yields of plants including crop plants. Photosynthesis is under the influence of several factors, both internal and external. When several factors affect any (bio) chemical process, Blackman's (1905) Law of limiting factors comes into effect. This states the following:

"If a chemical process is affected by more than one factor, then its rate will be determined by the factor which is nearest to its minimal value : it is the factor which directly affects the process if its quantity is changed." For example, despite of presence of green leaf, optimal light and CO_2 conditions, photosynthesis may not occur if temperature is very low. This leaf, if given the optimal temperature, will start photosynthesizing.

Light : Both, the intensity and quality of light influence photosynthesis. Normally as intensity of light increases, the rate of photosynthesis increases. However, at higher intensity it is not so. At high intensity of light, oxidation of chlorophyll occurs and it is decomposed. This is called photooxidation. Because of this the rate of the process drops.

The visible spectrum of light ranges from 400 nm to 700 nm. Plants can absorbed light from this range only. The rate increases in orange and red light. It decreases in green light.

CO_2 concentration : The concentration of CO_2 is very low in the atmosphere i.e 0.036 %. Increase in the concentration upto 0.05 % can cause an increase in CO_2 fixation rates. Beyond this the levels can become damaging over longer periods. The effect of CO_2 concentration beyond this level for longer periods is damaging. At high light intensity both, C_3 and C_4 plants show increase in the rates of photosynthesis. What is important to note is that C_4 plants show saturation at about 360 $\mu l L^{-1}$ while C_3 responds to increased CO_2 concentration and saturation is seen only beyond 450 $\mu l L^{-1}$. Thus current availability of CO_2 levels is limiting to the C_3 plant.

Temperature : There are two phases in photosynthesis. There is no notable effect of temperature in the photochemical phase but as dark reaction or biosynthetic phase being enzymatic, temperature has a remarkable effect on it. The C_4 plants respond to higher temperatures and show higher rate of photosynthesis while C_3 plants have a much lower temperature optimum.

Water : The effect of water is remarkable. When availability of water is reduced, the plant experiences water stress. This has two effects – one is that the stomata are closed, as a result the amount of available CO_2 is reduced. Secondly, as water potential in leaves is lowered, they curl. Thus available leaf area is reduced for photosynthesis.

Summary

During photosynthesis light energy of sun is fixed as a chemical energy in food, which is used by all other organisms. The process of photosynthesis takes in the green organs of the plants. Amongst these, the leaves are the main organs. Even in a leaf this process occurs in the chlorenchyma of mesophyll. The cells of this tissue possess organelles called chloroplasts. The chloroplasts are arranged in the peripheral region of the cell. This facilitates the diffusion of gases. A clear division of labour can be seen in chloroplast. The membrane system is responsible for trapping the light energy and synthsis of ATP and $NADPH_2$. This is called light reaction. In stroma enzymatic reactions incorporate CO_2 into the plant leading to synthesis of sugar. Since it is not light driven process, it is known as dark reaction.

In electron transport system, the electrons which are released from reaction centre transport in two ways : (1) Cyclic and (2) Non cyclic ways. In the cyclic system electrons return to their original source and hence such a transport of electrons is called cyclic electron transport. While in non-cyclic system electrons released in various ways do not return to their original donours, such an electron transport is called non-cyclic electron transport.

The chemiosmotic hypothesis indicates that the breakdown of the proton gradient provides enough energy to cause a conformational change in the F_1 particle of ATPase, which makes the enzyme synthesise several molecules of energy packed ATP.

CO_2 fixation during photosynthesis occurs in two ways : (1) Those plants in which the first product of CO_2 fixation is a C_3 acid (PGA) i.e. C_3 pathway and (2) Those plants in which the first product of CO_2 fixation is C_4 acid (OAA) i.e. C_4 pathway.

Photorespiration is a process of respiration which takes place in chloroplast in presence of light. In this process first of all RuBP is oxygenated in presence of O_2 forming one molecule of a 2-C phosphoglycolate and one molecule of a 3-C PGA. In C_3 plants some O_2 does bind to RuBisCO, and hence CO_2 fixation is decreased. In C_4 plants photorespiration does not occur. This is because they have a mechanism that increases the concentration of CO_2 at the enzyme site. This ensures that RuBisCO functions as carboxylase minimizing the oxygenase activity. This is the reason why productivity and yield are better in C_4 plants.

The rate of photosynthesis is affected by the various factors like temperature, concentration of CO_2, light and water.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Non-cyclic photophosphorylation is performed during

(a) Dark reaction ○ (b) Photochemical Phase ○

(c) (a) and (b) both ○ (d) None of the above ○

(2) Calvin cycle occurs in

(a) Cytoplasm ○ (b) Mitochondria ○

(c) Glyoxysomes ○ (d) Chloroplast ○

(3) Element essential for splitting of water is

(a) Nitrogen (b) Oxygen

(c) Chlorine (d) Carbon

(4) C_4 plants differ from C_3 plants with respect to

(a) First product

(b) Substrate which accepts carbon dioxide

(c) Number of ATP molecules consumed

(d) All the above

(5) A specific function of light in the process of photosynthesis is

(a) Reduction of CO_2 (b) To oxidise other molecules

(b) Split water molecules (d) None of these

(6) Organelle associated with photorespiration is

(a) Ribosome (b) Peroxisome

(c) Nucleosome (d) Mesosome

(7) The wavelength of light most absorbed during photosynthesis is

(a) 700 nm (b) 660 nm

(c) 550 nm (d) 400 nm

(8) In photosynthesis, photolysis of water is used in

(a) Reduction of NADP (b) Oxidation of NADP

(e) Oxidation of FAD (d) None of the above

(9) Number of cell organelles involved in photorespiration is

(a) One (b) Two (c) Three (d) Four

(10) Maximum photosynthesis occurs in

(a) Red light (b) Green light

(b) Blue light (d) Yellow light

(11) Special feature of C_4 plant is

(a) Thin cuticle (b) Multiple epidermis

(b) Kranz anatomy (d) Both a) and b)

(12) Carbon dioxide is fixed in

(a) Light reaction (b) Dark reaction

(b) Photorespiration (d) Spliting of water

(13) Which photosynthetic cycle is performed in mesophyll cells of sugar cane ?

(a) C_4 (b) C_3 (c) C_2 (d) C_1

(14) Which one of the following is a C_4 plant

(a) Tomato (b) Sugarcane

(c) Apple (d) Mango

2. Answer the following questions in short :

(1) Define photosynthesis.

(2) Which equation was given by Scientist Niel for photosynthesis ?

(3) What is photolysis ?

(4) Give full forms of PGA, OAA, RuBP

(5) What is RuBisCO ? What is its full form ?

(6) What are the end products of photosynthesis ?

(7) In C_3 pathway, how many ATP molecules are required for the synthesis of one molecule of glucose ?

(8) What is cyclic electron transport ?

(9) Define Non-cyclic photophosphorylation.

3. Do as directed :

(1) Write short note on Kranz anatomy.

(2) Differentiate between C_3 and C_4 plants

(3) What is RuBisCO ? Explain its role in C_3 and C_4 photosynthesis

(4) Describe cyclic photophosphorylation.

(5) Write a note on non-cyclic photophosphorylation.

(6) Explain carboxylation step of Calvin cycle.

(7) Explain why light reaction is prerequisite for biosynthetic phase.

(8) Describe the structure of chloroplast.

(9) Explain splitting of water.

(10) Describe the Kranz anatomy.

(11) Explain why the productivity is more in C_4 plants as compared to C_3.

4. Answer the following questions in detail :

(1) What is Calvin cycle ? Describe in detail.

(2) Describe various factors which affect the rate of photosynthesis.

(3) Describe photorespiration.

(4) Explain the photophosphorylation.

(5) Explain light phase of photosynthesis.

(6) Describe the biosynthetic phase of photosynthesis

(7) Explain chemiosmotic hypothesis.

(8) Describe C_4 pathway.

4

Respiration

Every organism carries out various life processes. All these processes are collectively called physiological processes. A constant supply of energy is essential to carry out these processes. Living organisms derive this energy by oxidation of macromolecules that we call food. Only green plants and cyanobacteria can synthesis their own food by the process of photosynthesis. Even in green plants only those organs which possess chloroplast perform the photosynthesis but food is required for the oxidation by all the organs even, which do not possess chloroplasts. Hence, synthesized food is translocated to all non green parts. Most important part is that all the food that respired for life processes comes from photosynthesis. Thus, energy exchange takes place during biological processes. Based on the energy exchange there are two types of biological processes : (1) Endergonic processes and (2) exergonic processes.

Energy is stored during **endergonic process,** whereas energy is released during **exergonic process.** Photosynthesis is an endergonic process whereas respiration is an exergonic process. The breakdown of C-C bonds of complex compounds through oxidation within the cells releasing considerable amount of energy is called respiration. Since it takes place in cell, it is also known as cellular respiration. The substances which are oxidized during this process are known as respiratory substrates. Both plants and animals respire. Respiration is an important physiological process taking place in the mitochondria of the cells of all organisms. A part of the energy released during this process is utilized for the synthesis of ATP. The organic nutrients synthesised by the organisms or taken in as food undergo slow combustion during this process.

Do plants breathe ?

Plants require oxygen for respiration to occur and they also give out CO_2. However, plants, unlike animals, do not have specialized respiratory organs. However, stomata and lenticels are present which take part in gaseous exchange. There are several reasons why plants do not have specialized respiratory organs, such as –

- Each plant part is directly involved in the exchange of gases.
- As plant parts respire at rates far lower than the animals do, the need of gas exchange is not much.

- When cells photosynthesise, availability of O_2 is not a problem in these cells since O_2 is released within cell.

The strategy that the plant cell uses it to catabolise the glucose molecule in such a way that not all the liberated energy goes out as heat. During respiration, the stored energy in glucose is gradually released through controlled oxidation. The released energy is stored by forming ATP from ADP. The entire process of respiration can be represented by the following equation.

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

Glycolysis

The break down of glucose to pyruvic acid is called glycolysis. The term glycolysis has originated from the Greek words, 'glycos' for 'sugar' and 'lysis' for 'splitting'. The scheme of glycolysis was discoverd by Embden, Meyerhof and Parnas and is often known as EMP pathway.

Glycolysis is common to all living organisms. Both, aerobic as well as anaerobic respiration begin with glycolysis. In this phase O_2 is not utilized. Glycolysis occurs in the cytoplasm matrix of cells. During glycolysis glucose is converted into two (2) molecules of pyruvic acid. In plants, glucose is derived from sucrose which is synthesized during photosynthesis. The enzyme invertase converts sucrose into glucose and fructose, which readily enter the glycolytic pathway.

In this phase, first of all, the molecule of glucose is phosphorylated to Glucose-6 phosphate with the use of ATP. The phosphate liberated from ATP is joined to carbon number 6 of glucose. ATP becomes ADP. The enzyme, responsible is hexokinase.

Glucose-6-phosphate is converted into its isomer fructose-6-phosphate, through molecular rearrangement. Now, fructose-6 phosphate is again phosphorylated with the help of ATP forming Fructose-1-6-biphosphate. During this ATP is converted to ADP.

Fructose-1-6-diphosphate splits and two 3-C molecules – phosphoglyceraldehyde (PGAL) and dihydroxyacetone phosphate (DHAP) come into existance. Both these triose sugars are interconvertible. Normally, dihydroxyacetone phosphate is converted into phosphoglyceraladehyde. Thus two molecules of 3- phosphoglyceraldehyde are formed.

Energy will now be released in the subsequent phase. Till now, 2 molecules of ATP are consumed.

Each molecule of 3- phosphoglyceraladehyde is oxidized and $2H^+$ and $2e^-$ are released from it. The released components are accepted by NAD forming NADH + H^+. Simultaneously, a molecule of inorganic phosphate is also added. As this happen, 1,3 biphosphoglyceric acid (BPGA) is formed.

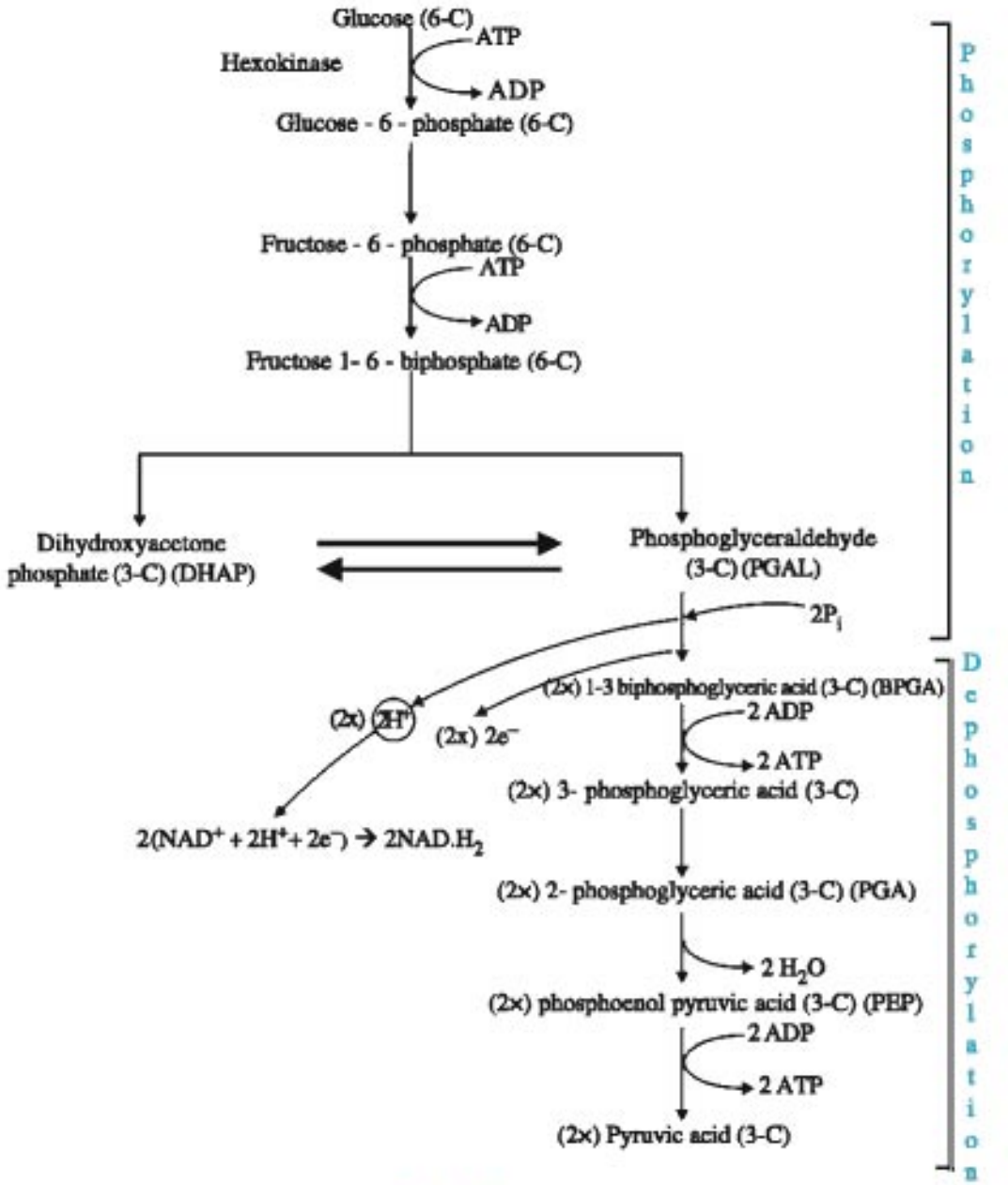
This phase of reactions constitutes phosphorylation phase. Now, the phase of dephosphorylation begins.

1,3- biphosphoglyceric acid is dephosphorylated and it is converted to 3-phosphoglyceric acid (PGA). The phosphate thus released from the substrate combines with ADP and forms ATP. This is called substrate phosphorylation.

Now, 3-phosphoglyceric acid is first converted into, 2-phosphoglyceric acid and then into phosphoenol pyruvic acid (PEP). H_2O is released during this process.

Phosphoenol pyruvic acid is dephosphorylated and converted into pyruvic acid. The phosphate released from the substrate combines with ADP and forms ATP.

Thus, at the end of entire process, two molecules of pyruvic acid are formed from one molecule of glucose. Two molecules of ATP are consumed and four molecules are formed. Thus, there is a net gain of 2 ATP. 2 molecules of $NADH_2$ are also formed. Now there are three major ways in which different cells utilize pyruvic acid produced during glycolysis. These are lactic acid fermentation, alcoholic fermentation and aerobic respiration.



Glycolysis

Fermentation

When respiration takes place in the absence of molecular oxygen, it is said to be anaerobic respiration. It results in incomplete breakdown of glucose. During this process CO_2 and organic compounds like ethyl alcohol and lactic acid are produced and some energy is released. Water molecule is not produced during anaerobic respiration. This reaction is also called fermentation. The fermentation are of two types :

Alcoholic fermentation : This fermentation occurs in Yeast. The incomplete oxidation of glucose is achieved under anaerobic conditions, where pyruvic acid is converted to CO_2 and ethanol. The enzymes pyruvic acid decarboxylase and alcohol dehydrogenase catalyse these reactions.

The pyruvic acid is first decarboxylated to acetaldehyde in the presence of enzyme pyruvic acid decarboxylase and thiamine pyro-phosphate (TPP).

$$2CH_3CO\ COOH \xrightarrow{\text{decarboxylase + TPP}} 2CH_3CHO + 2CO_2$$

Acetaldehyde

Acetaldehyde in the presence of the enzyme acetaldehyde alcohol dehydrogenase and coenzyme $NADH_2$ is reduced to ethyl alcohol. $NADH_2$ is oxidized to NAD.

$$2CH_3CHO + 2\ NADH_2 \xrightarrow{\text{alcohol dehydrogenase}} 2\ (C_2H_5OH) + 2\ NAD$$

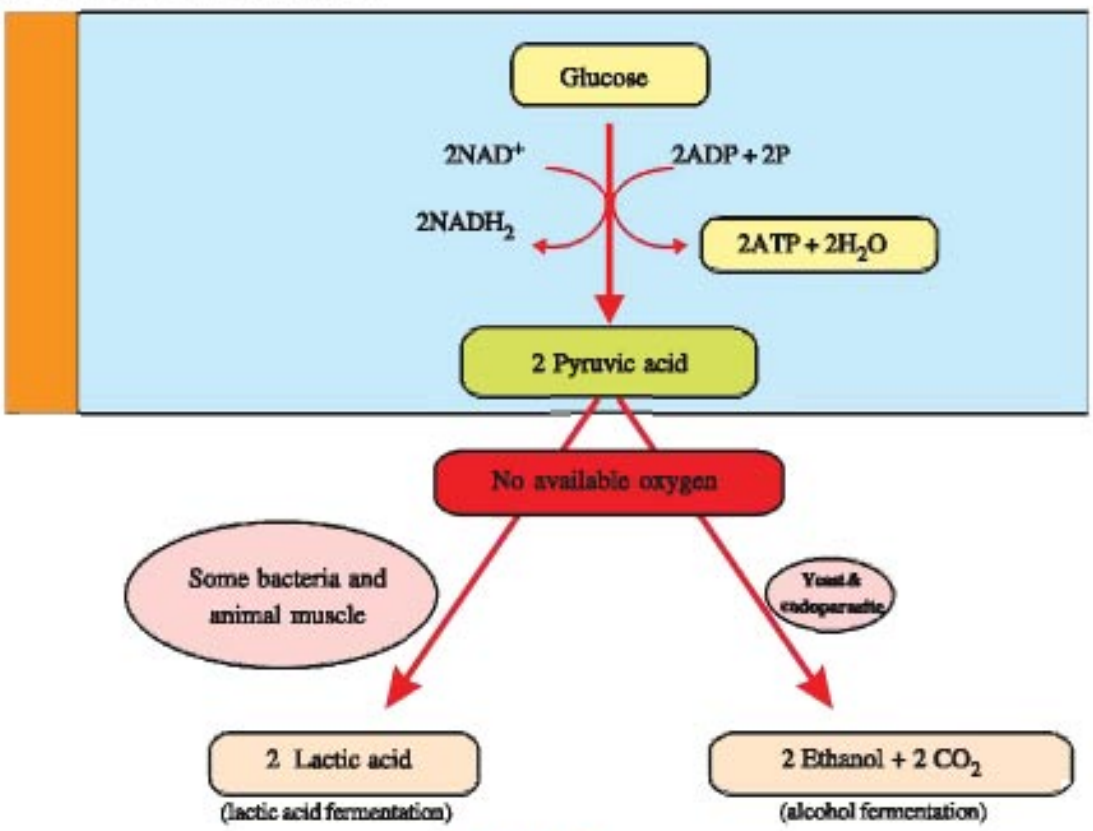
Ethyl alcohol

Lactic acid fermentation : In this type of fermentation, the pyruvic acid is converted into lactic acid by the enzyme lactate dehydrogenase and coenzyme $NADH_2$. The $NADH_2$ is oxidized to NAD.

$$2\ CH_3\ CO\ COOH + 2\ NADH_2 \longrightarrow 2\ CH_3\ CHOHCOOH + 2\ NAD$$

Lactic acid

Lactic acid fermentation takes place in the muscles of animals during exercise when oxygen is inadequate for cellular respiration.



Fermentation

In both, alcoholic and lactic acid fermentations less than seven percent of the energy in glucose is released and not all of it is trapped as high energy bonds of ATP. The end product is either lactic acid or alcohol.

Aerobic Respiration :

Aerobic respiration is the process that leads to a complete oxidation of glucose in presence of oxygen and releases CO_2, water and large amount of energy. Aerobic respiration includes Krebs cycle and oxidative phosphorylation in addition to glycolysis. At the end of glycolysis two molecules of pyruvic acid are produced, which enter the mitochondria wherein all the reactions of Krebs cycle and oxidative phosphorylation are carried out with the help of enzymes. It is interesting to note that Krebs cycle takes place in the matrix of mitochondria while oxidative phosphorylation takes place on the inner membrane of mitochondria. In mitochondria, the pyruvic acid having 3 carbon atoms undergoes complete oxidation releasing 3 molecules of CO_2. The presence of O_2 is inevitable during the entire process of Krebs cycle and oxidative phosphorylation.

Before entering into the Krebs cycle, pyruvic acid is decarboxylated and simultaneously it is also oxidized. As a result, one molecule of CO_2 is released and NAD is converted to $NADH_2$. The resulting 2C molecule is an acetate unit. Cofactor-A (CO.A) acting as a coenzyme, accepts this 2C unit and becomes acetyl co-enzyme-A. The entire reaction is catalyse by an enzyme pyruvate dehydrogenase.

$$\text{Pyruvic acid} + \text{CoA} + \text{NAD} \xrightarrow{\text{Pyruvate dehydrogenase}} \text{Acetyl Co.A} + CO_2 + NAD.H_2$$

The acetyl Co.A then enters a cyclic pathway, Tricarboxylic acid cycle, which is commonly called as Krebs cycle after the scientist Hans Krebs who first elucidated it. Acetyl Co-A is the intermediate compound linking glycolysis to Krebs' cycle.

Tricarboxylic Acid Cycle : All reactions of Krebs cycle are carried out in the matrix of mitochondrion.

Krebs cycle begins when a 4-C- organic acid molecule of oxaloacetic acid which reacts with 2C containing acetyl-co-enzyme-A. A 6-C acid called citric acid is formed as a result. Thus, as the first substance formed is citric acid, this cycle is also known as citric acid cycle.

Citric acid is converted into its isomer called - isocitric acid. Isocitric acid undergoes decarboxylation and dehydrogenation to form a 5-C α - Ketoglutaric acid. The $2H^+$ released are accepted by NAD which then becomes $NADH_2$. CO_2 is released.

α -Ketoglutaric acid undergoes decarboxylation and dehydrogenation to form a 4-C succinic acid. The $2H^+$ released are accepted by NAD which then becomes $NADH_2$. CO_2 is released.

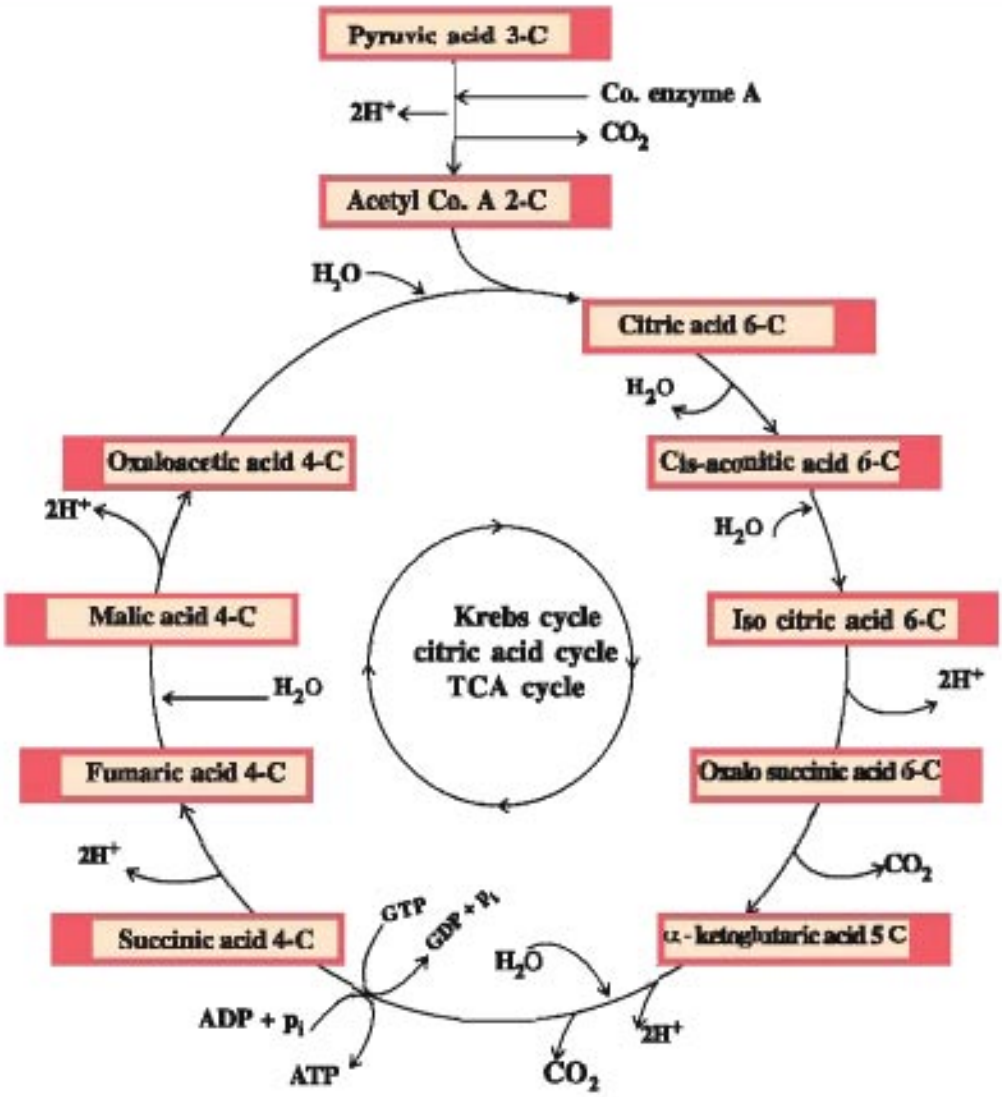
Succinic acid is dehydrogenated to form fumaric acid. The $2H^+$ released are accepted by FAD which then becomes $FADH_2$.

Fumaric acid receives one molecule of H_2O and is transformed into malic acid. Malic acid gets dehydrogenated and regenerates the oxaloacetic - acid. The released $2H^+$ are accepted by NAD which then becomes $NADH_2$.

Thus, when 1 molecule of pyruvic acid passes through the process of Krebs cycle, 3 molecules of CO_2 are released and at 5 different stages $2H^+$ and $2e^-$ are released.

When this occurs to both pyruvic acid molecules, a total of 6 CO_2 are released. Thus, the 6-C glucose molecule is completely decomposed. The summary equation for this phase of respiration may be written as follows:

$$\text{Pyruvic acid} + 4NAD^+ + FAD^+ + 3H_2O + ADP + Pi \longrightarrow 3CO_2 + 4NADH + 4H^+ + FADH_2 + ATP$$



Krebs Cycle

As, most of the organic acids, associated with this cycle, possess three carboxylic groups, this cycle is also known as TCA cycle (Tricarboxylic Acid Cycle).

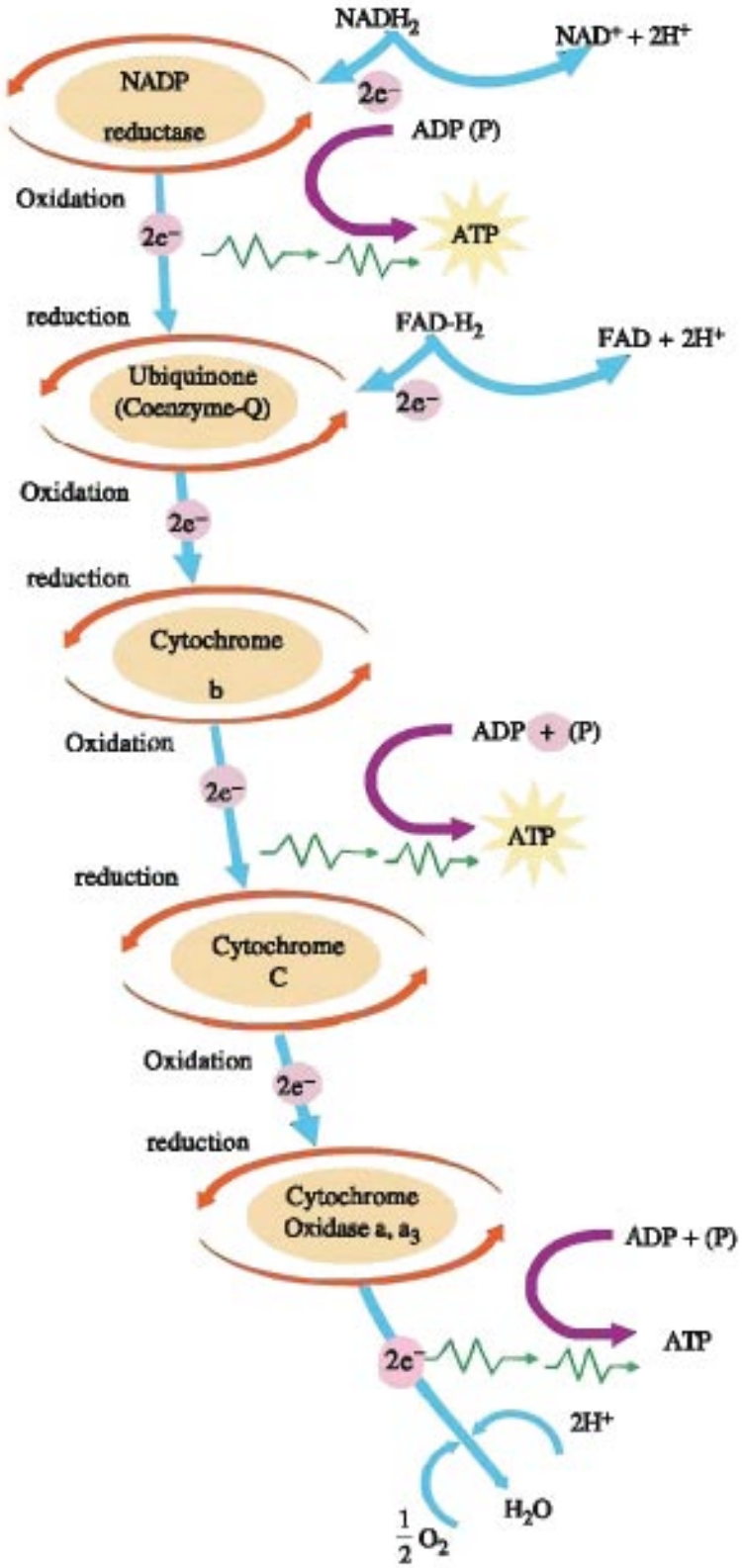
Significance of Krebs Cycle :

(1) It provides a pathway for complete breakdown of glucose.

(2) It provides the main pathway for synthesis of ATP.

(3) Various carbon - complexes formed during this cycle provide necessary components for growth and maintenance of cell. These components are utilized in the synthesis of substances like amino acids, nucleotides, fats, chlorophyll and cytochromes.

Electron Transport System (ETS) and Oxidative Phosphorylation : We observed that by the end of Krebs cycle, the molecule of glucose is completely degraded. However, unless the $NADH_2$ and $FADH_2$ formed during this process are transported to atmospheric O_2 and oxidized, no energy is released. Thus, transportation of $2H^+$ and $2e^-$ towards O_2 is essential. The metabolic pathway through which the electron passes from one carrier to another is called the electron transport system (ETS). This system is performed on inner membrane of mitochondria.



Oxidative Phosphorylation

The energy released during this process of oxidation is stored in the formation of ATP from ADP. As the phosphorylation of ADP to ATP occurs through the oxidation - energy, this phosphorylation is called oxidative-phosphorylation. This process takes place in units arranged on the cristae membranes of mitochondria.

First of all, $NADH_2$ transfers its $2H^+$ and $2e^-$ to NADP - an electron-acceptor substance. As a result NAD is released and NADP accepts $2H^+$ and $2e^-$. The $2H^+$ remain in the matrix and $2e^-$ are further transported.

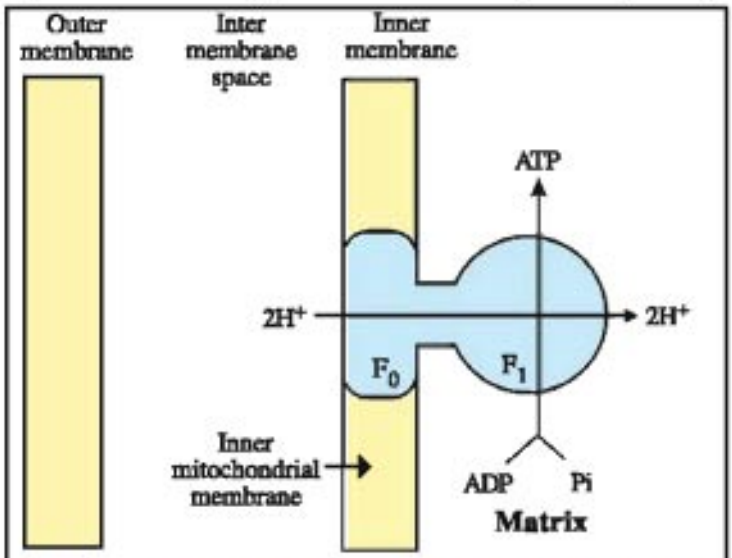
$2e^-$ from NADP enter the electron - carrier ubiquinone, from ubiquinone, they are further transported through a sequence of various cytochromes. The terminal acceptors in cytochrome chain are cytochromes *a* and a_3 *(cytochrome oxidase)*. These cytochromes collect $2H^+$ from the matrix and along with the $2e^-$ received by them combine with $\frac{1}{2}O_2$ obtained from the atmosphere and form H_2O.

The $2H^+$ and $2e^-$ from $FADH_2$ are also transported through ubiquinone (Coenzyme-a).

The energy released during transport of $2H^+$ from NAD to O_2, is stored in the synthesis of 3 ATP from ADP. Whereas during transport of $2H^+$ from FAD to O_2, energy released is stored in the synthesis of 2 ATP.

Mechanism of chemiosmotic generation of ATP :

You have already studied about the mechanism of membrane linked ATP synthesis as explained by chemiosmotic hypothesis in the chapter of photosyntheis. Since mitochondrial membrane is impermeable to protons, these cannot be diffused back into the matrix across the membrane. However, these can enter the membrane via a proton channel established by the membrane bound adenosine triphosphatase (ATPase). ATPase is a multienzyme complex containing two parts F_0 and F_1. F_0 component is embedded in the membrane forming a channel. Through this channel the protons flow to F_1. The F_1 headpiece is a peripheral membrane protein complex and contains the site for the synthesis of ATP from ADP. For each ATP produced, $2H^+$ passes through F_0 from the intermembrane space to the matrix down the electrochemical proton gradient. Thus for each pair of protons flowing back into matrix, one molecule of ATP is synthesized. So for three pairs of protons, three molecules of ATP are generated.



Diagramatic representation of ATP synthesis in mitochondria

Since $FADH_2$ transports only 2 pairs of protons outside the membrane through F_0 and F_1 complex, only two ATP molecules are produced.

The respiratory balance sheet

It is possible to calculate the net gain of ATP for every glucose molecule oxidized. The details of ATP synthesis during aerobic respiration can be described as under :

Synthesis of ATP during Glycolysis

Synthesis of substrate - based ATP – 2 ATP twice. (2ATP × 2 = 4 ATP)

Utilization during phosphorylation phase of glucose – 2 ATP.

Thus, as 4 ATP are formed and 2 ATP are utilized, there is a gain of 2 ATP.

During glycolysis, 2 molecules of $NADH_2$ are formed. Their oxidative phosphorylation will result in formation of 2 x 3 ATP = 6 ATP. Thus, during glycolysis synthesis of 8 ATP will occur.

Synthesis of ATP during Krebs Cycle : At four stages during degradation of pyruvic acid, $NADH_2$ is generated and at one stage $FADH_2$ is generated. During oxidative phosphorylation of 4 $NADH_2$ = 4 x 3 ATP = 12 ATP are formed and during phosphorylation of 1 $FADH_2$ = 1 x 2 ATP = 2 ATP are formed. Thus, a total of 14 ATP are synthesized.

As two molecules of pyrivic acid pass through this process a total of 28 (14 x 2 = 28 ATP) ATP are synthesized.

Moreover, during formation of succinic acid from, α Keto - glutaric acid, 1 ATP formation occurs which is substrate based. Thus, 2 ATP are formed. Thus total 30 ATP are formed during krebs cycle.

During aerobic respiration a total of 38 ATP are formed.

During glycolysis	:	6	through oxidative - phosphorylation
		2	through, substrate - based phosphorylation
During Krebs cycle	:	28	through oxidative - phosphorylation
		2	through substrate - based phosphorylation.
	Total :	38 ATP	

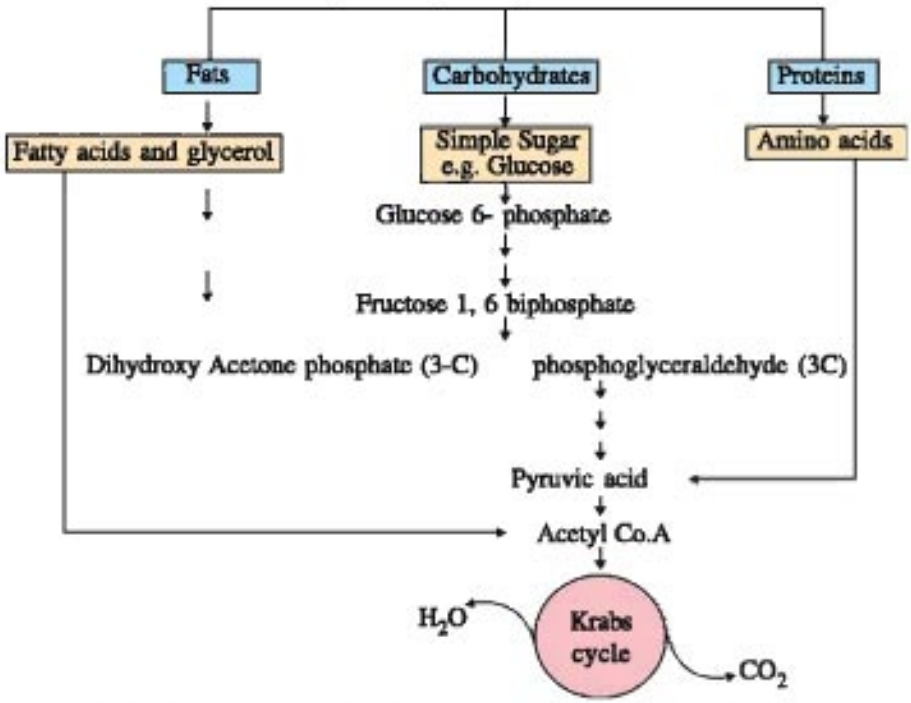
The efficiency of the process of transformation of potential chemical energy in glucose into the energy in ATP is about 45%. The remaining energy is dissipated as heat.

Moreover, as energy of two ATP is spent in transporting pyruvic acid into mitochondrion, the number of ATP is considered to be 36 in eukaryotic organisms.

Amphibolic Pathway

Carbohydrates are generally used as substrates for respiration. But before they enter respiration, they are converted into glucose. Other substrates can also be respired, but they do not enter the respiratory pathway at the first step. For example, fats need to be broken down into glycerol and fatty acids first. Now fatty acids first degraded into acetyl Co.A, which can enter into the respiratory pathway. Similarly, the glycerol is first converted into PGAL and then enter into respiratory pathway. In case of proteins, they are first broken down into amino acids which later converted in pyruvic acid and enter respiratory pathway.

The most important thing is that when fatty acids have to be respired, first they have to be broken down to acetyl Co.A which enters into respiratory pathway. But when organisms need to synthesise fatty acids, acetyl Co.A would be withdrawn from the respiratory pathway. Hence, the respiratory pathway comes into the picture both during breakdown and synthesis of fatty acids. Similarly, during breakdown and synthesis of proteins too. In this way respiratory pathway is involved in both anabolic and catabolic processes and hence it is also known as an amphibolic pathway rather than as a catabolic one.



Interrelationship among metabolic pathways showing respiration mediated breakdown of different organic molecules to CO_2 and H_2O

Respiratory Quotient

We know that during aerobic respiration O_2 is consumed and CO_2 is released. The ratio of released CO_2 to the O_2 consumed during respiration is called -Respiratory quotient - (RQ).

$$\text{Respiratory Quotient} = \frac{CO_2 \text{ released during respiration}}{O_2 \text{ consumed during respiration}}$$

The value of RQ depends on the material utilized for respiration. For example

Carbohydrates : For carbohydrats the value of RQ is 1. This would mean that the amount of O_2 utilized and the amount of CO_2 released are the same.

Equation : $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$

$$RQ = \frac{6CO_2}{6O_2} = 1$$

Fats : For fats, the value of RQ is less than 1. This would mean that there is much less oxygen in the constituion of fat as compared to that in carbohydrates. Thus, they need more O_2 for respiration.

As an example, the equation for respiration of Tripalmitin is as under :

$2\ (C_{51}\ H_{98}\ O_6) + 145\ O_2 \longrightarrow 102\ CO_2 + 98\ H_2O + \text{Energy}$

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

When proteins are respiratory substrate, the ratio would be about 0.9.

It is important to know that in living organism respiratory substances are more than one and pure proteins or fats are never used as respiratory substrates.

Summary

A constant supply of energy is essential to carry out physiological processes in living organisms. Based on the energy exchange there are two types of biological processes : (1) Endergonic processes and (2) exergonic processes. The breakdown of C-C bonds of complex compounds through oxidation within the cells releasing considerable amount of energy is called respiration. The substances which are oxidized during this process are known as respiratory substrates.

The breakdown of glucose to pyruvic acid is called glycolysis. Glycolysis occurs in the cytoplasm matrix of cells. During glycolysis glucose is converted into two molecules of pyruvic acids. There are three major ways in which different cells utilized pyruvic acid produced during glycolysis. These are lactic acid fermentation, alcoholic fermentation and aerobic respiration.

The end products of alcoholic fermentation is ethyl alcohol and CO_2 while that of lactic acid fermentation is lactic acid.

Aerobic reaspiration is the process that leads to a complete oxidation of glucose in presence of oxygen and releases CO_2, water and large amount of energy. Aerobic respiration includes Krebs cycle and oxidative phosphorylation in addition to glycolysis.

Before entering into the Krebs cycle, pyruvic acid is decarboxylated and simultaneously it is also oxidized producing Acetyl Co-A, CO_2 and $NADH_2$.

All reactions of Krebs cycle are carried out in the matrix of mitochondrion.

The metabolic pathway through which the electron passes from one carrier to another is called the electron transport system (ETS). This system is located on inner membrane of mitochondria.

During electron transport system, energy released during transport of H_2 from NAD to O_2, is stored in the synthesis of 3 ATP from ADP. Whereas during transport of H_2 from FAD to O_2, energy released is stored in the synthesis of 2 ATP from ADP.

Respiratory pathway is involved in both anabolic and catabolic processes and hence it is also known as an amphibolic pathway rather than as a catabolic one.

During aerobic respiration, O_2 is consumed and CO_2 is released. The ratio of released CO_2 to the O_2 consumed during respiration is called Respiratory quotient (RQ).

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) TCA cycle occurs in...

(a) Mitochondria ○ (b) Chloroplast ○

(c) Cytoplasm ○ (d) Peroxisome ○

(2) Anaerobic process after glycolysis is...

(a) ETS ○ (b) Calvin cycle ○

(c) Krebs cycle ○ (d) None of these ○

(3) The end products of fermentation are...

(a) O_2 and acetaldehyde ○ (b) O_2 and ethyl alcohol ○

(c) CO_2 and ethyl alcohol ○ (d) CO_2 and acetaldehyde ○

(4) Electron transport system in mitochondria is located on...

(a) Outer membrane ○ (b) Inter cristae space ○

(c) Inner membrane ○ (d) Inner membrane space ○

(5) During fermentation in Yeast cell, alcohol is fermented from...

(a) Protein ○ (b) Lipid ○

(c) Sugar ○ (d) Nucleic acids ○

(6) The key intermediate compound linking glycolysis to the Krebs cycle is...

(a) Malic acid ○ (b) Pyruvic acid ○

(c) Succinic acid ○ (d) Acetyl Co-A ○

(7) In Krebs cycle, FAD participates as electron acceptor during the conversion of...

(a) Succinyl Co.A to succinic acid ○ (b) Fumaric acid to malic acid ○

(c) Succinic acid to fumaric acid ○ (d) Malic acid to oxaloacetic acid ○

(8) Glycolysis takes place in...

(a) Mitochondria ○ (b) Cristae of mitochondria ○

(c) Cytoplasmic matrix ○ (d) Inner membrane of mitochondria ○

(9) Enzyme responsible for phosphorylation of glucose into glucose-6-phosphate is...

(a) ATPase ○ (b) Hexokinase ○

(c) Dehydrogenase ○ (d) Oxidase ○

(10) During glycolysis one molecule of glucose produces two molecules of...

(a) Acetyl Co-A ○ (b) Pyruvic acid ○

(c) Acetaldehyde ○ (d) Malic acid. ○

2. Answer the following questions in short :

(1) Why is Krebs cycle called TCA cycle ?

(2) Define cellular respiration, glycolysis.

(3) Define endergonic and exergonic processes.

(4) Mention the sites of Glycolysis, Krebs cycle and Oxidative phosphorylation

(5) Give the chemical equation of respiration

(6) Give chemical equation of Kreb's cycle.

(7) Define anaerobic respiration.

(8) What is electron transport system ?

(9) In eukaryotic organisms, how many net ATP molecules are produced from oxidation of one glucose molecule .

3. Do as directed :

(1) Differentiated between aerobic and anaerobic respiration.

(2) Describe respiratory quotient.

(3) What is significance of Krebs cycle ?

(4) Describe lactic acid fermentation ?

(5) Describe alcoholic fermentation ?

4. Answer the following questions in detail :

(1) Write, in detail, whatever you known about glycolysis.

(2) Describe Krebs cycle.

(3) Explain different steps involved in oxidative phosphorylation.

(4) Explain electron transport system.

(5) Sketch the diagram of Krebs cycle.

5

Digestion And Absorption

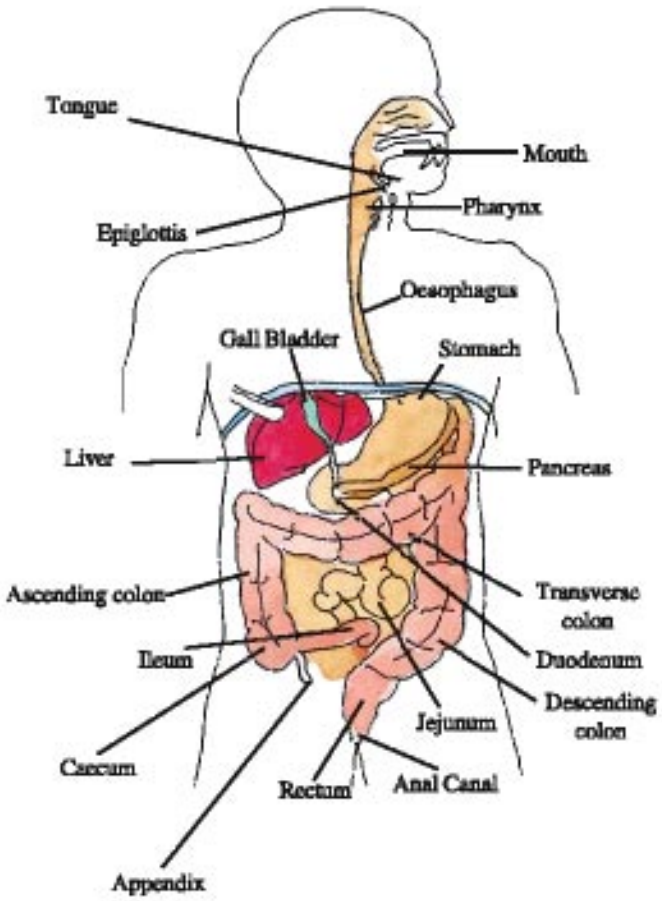
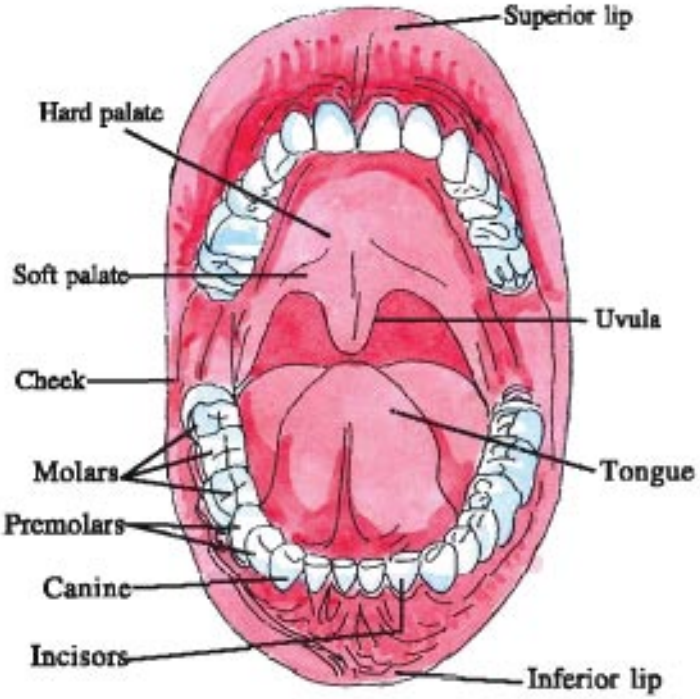


Diagram showing parts of the human digestive system

The components of the normal diet which meet various requirements of the body include carbohydrates, lipids, proteins, vitamins, minerals and water. Out of these constituents, water, minerals, vitamins can be assimilated as such. But complex substances can not be assimilated till they are structurally simplified into assimilable molecular forms. The structural simplification is brought by the action of various hydrolytic enzymes secreted by digestive tract (alimentary system). It is a long muscular, tract which is composed of different parts such as mouth, pharynx oesophagus, stomach, small intestine, large intestine, rectum and anal canal. Besides these certain accessory digestive glands and organs do also help in digestion by pouring their secretion into the tract, namely, salivary glands, pancreas, gall-bladder and liver. These organs are concerned in the mastication deglutition, digestion and absorption of food and in the elimination of the unabsorbed constituents of food.

The mouth :

The mouth leads to the buccal cavity or oral cavity. It is bounded at the sides by the maxillary bones and teeth, and communicates



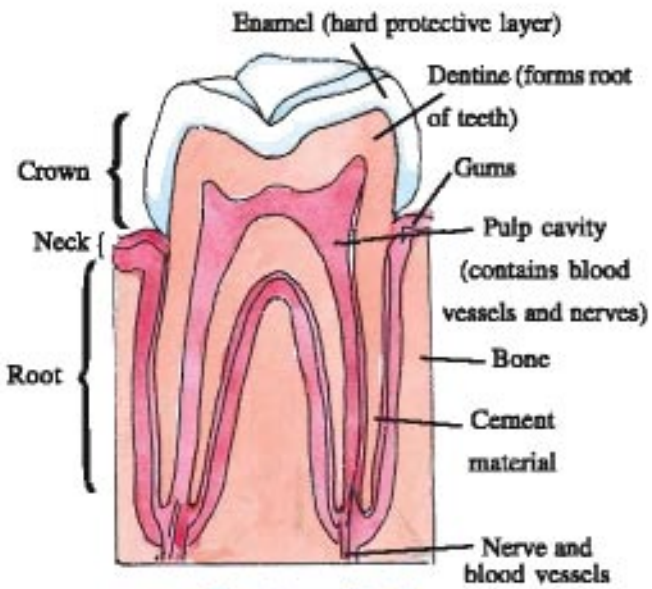
Arrangement of Human Teeth

behind with the oral pharynx. The roof of the mouth is formed by the palate. The tongue lies in the floor attached to the hyoid bone. The lips are two fleshy folds which surround the oral orifice of the mouth. They are covered on the inner surface with mucous membrane. The palate consists of two parts, the hard palate and soft palate. From the middle of the soft palate a conical process, the uvula, hangs. The cheeks form the fleshy sides of the face and are joined to the lips.

The oral cavity consists of number of teeth and a muscular tongue. Each tooth is embedded in a socket of jaw bone. This type of attachment is called thecodont. There are two sets of teeth, the temporary set and the permanent set.

There are twenty temporary or milk teeth, ten in each jaw. The permanent teeth are increased to thirty-two, sixteen in each jaw, as follows : named from the centre two incisor (I), one canine (C), two pre-molars (PM) and three molars (M). Arrangment of teeth in each half of the upper and lower jaw is in the order I, C, PM, M and it is represented by a dental formula $\frac{2123}{2123}$. Thus all tooth are not similar in human so it is called Heterodont.

The permanent teeth begins to replace the temporary ones at about the age of six years. This type of dentition is called diphyodont.



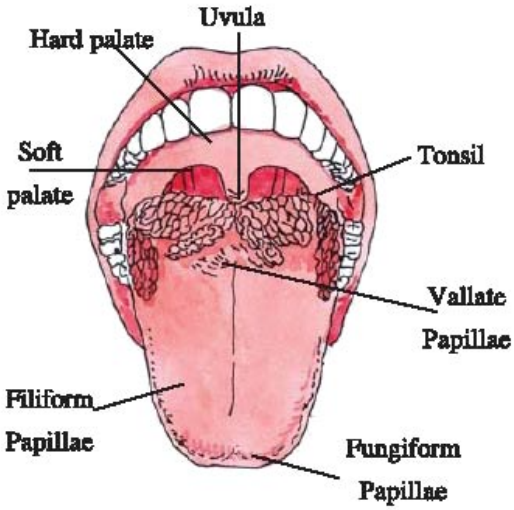
Structure of Tooth

A tooth possesses a crown, a neck and a root. The crown projects above the gum, the neck is surrounded by the gum and the root lies beneath it. The crown is composed of strong enamel. A tooth is made of a very hard material, dentine, in the centre of the structure is the pulp cavity. Tooth pulp contains connective tissue cells, blood vessels and nerves.

Mastication takes place with the help of teeth. It is the biting and grinding of food between the upper and lower jaws. Movement of the tongue and cheeks assist, by manipulating the soft foods.

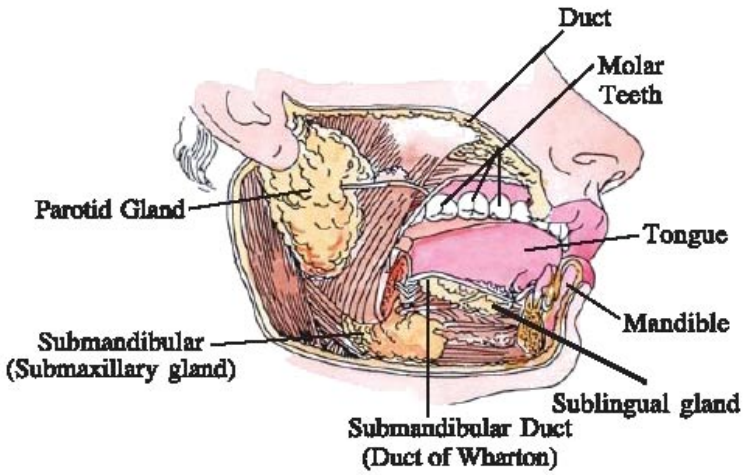
The tongue :

The human tongue lies partly in the mouth and partly in the pharynx. It is a musculo-sensory organ and is associated with the functions of swallowing, taste and speech. It is attached to the floor of the oral cavity by the frenulum, on the upper surface the tongue has small projections called papillae, some of which bears taste buds. Four types of papillae are usually found : (i) vallate papillae (ii) fungiform papillae (iii) filiform papillae, and (iv) papillae simplices. Mucus and serous glands are also present in the human tongue



Structure of the tongue

Salivary glands :



Salivary glands

Salivary glands are composed of groups of sac-like alveoli, which form small lobules. Ducts from each alveolus unite to form a larger duct which conveys the secretion towards a main duct through which the salivary secretion is poured into the mouth. The principal salivary glands are the parotid, submandibular and sublingual glands, which are in pair.

The parotid glands are the largest. They lie one on each side, below and slightly in front of the ear. The submandiburar glands lie on each side beneath the jaw-bone and the sublingual glands lie beneath the tongue.

The pharynx and oesophagus :

The pharynx lies behind the nose, mouth and larynx. It is a cone-shaped musculo-membranous passage. It is about 12.5 cm long and divided into three portions : the naso pharynx, the oral pharynx and the laryngeal pharynx.

The oesophagus is a muscular tube 23 to 25 cm long. It lies behind the trachea and in front of the vertebral column. It extends posteriorly passing though the neck, thorax and diaphragm and leads to stomach. Muscular sphincter regulates the opening of oesophagus into the stomach.

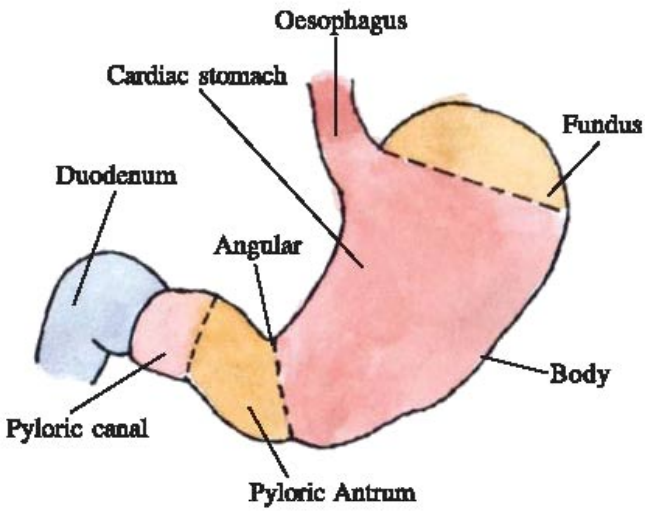


Diagram showing subsidiary parts of the stomach

The Stomach :

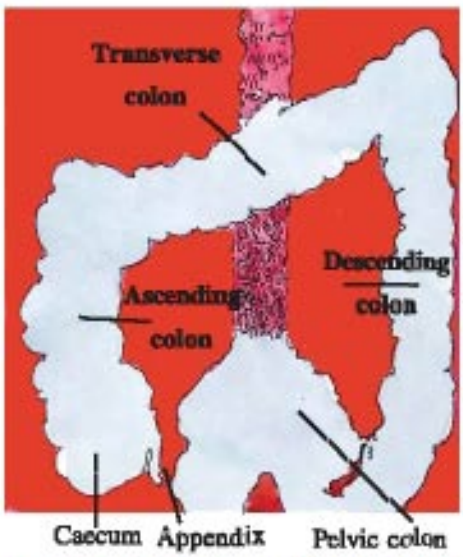
The stomach is the most dilatable portion of the alimentary canal. It lies mainly in the epigastric region below the diaphragm of the abdomen. It has three major parts - a cardiac portion, into which the oesophagus opens, fundus, the main body and the lower horizontal part, the pyloric antrum. It communicates with the oesophagus by means of the cardiac and with the duodenum by the pyloric antrum region.

The small intestine :

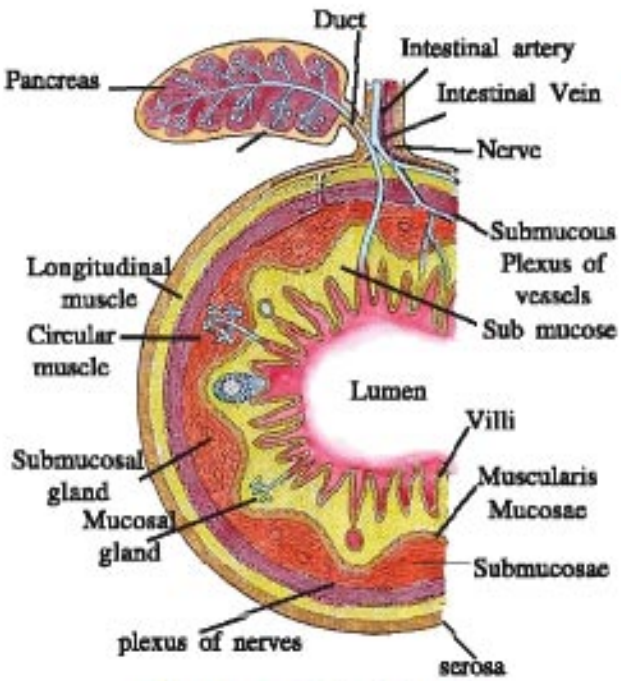
The small intestine is a tube which probably about 6.25 m long. It extends from the stomach to the ileo-caecal valve where it joins the large intestine. It lies in the umbilical region of the abdomen and is surrounded by the large intestine. It is divided into three regions, a 'U' shaped duodenum, a long coiled middle portion jejunum and a highly coiled ileum. The bile ducts and pancreatic duct open into the duodenum through common bileduct.

The large intestine :

The large intestine or colon is about 1.5 m long. The colon begins as a dilated pouch, the caecum to which the vermiform appendix is attached. The caecum opens into the colon. The colon is divided into three parts - an ascending, a transverse and a descending part. The descending part opens into the rectum which opens out through the anus. It is clearly observed, if barium milk applied for X-ray diagnosis.



The large intestine (Barium Milk Skiagram)



Transverse section of a gut

Histological structure of the wall of alimentary canal

The wall of alimentary canal possesses four layers namely serosa, muscularis, submucosa and mucosa. Serosa is the outer most layer and is made up of a thin mesothelium with some connective tissue. Muscularis is formed by smooth muscles. They are usually arranged into an inner circular and an outer longitudinal layer. The sub-mucosal layer is formed of loose connective tissues, nerves, blood vessels and lymph vessels. In duodenum, glands are also present in sub-mucosa. The inner most layer is called mucosa. This layer forms irregular folds in the stomach and small finger-like foldings called villi in the small intestine. The cells of villi produce

numerous micro villi. The villi are supplied with a network of capillaries and a large lymph vessel called the lacteal. There are goblet cells in a mucosal epithelium which secrete mucus. Gastric glands are present in a mucosa layer of stomach. All these four layers show variations on the basis of functions in different parts of the alimentary canal.

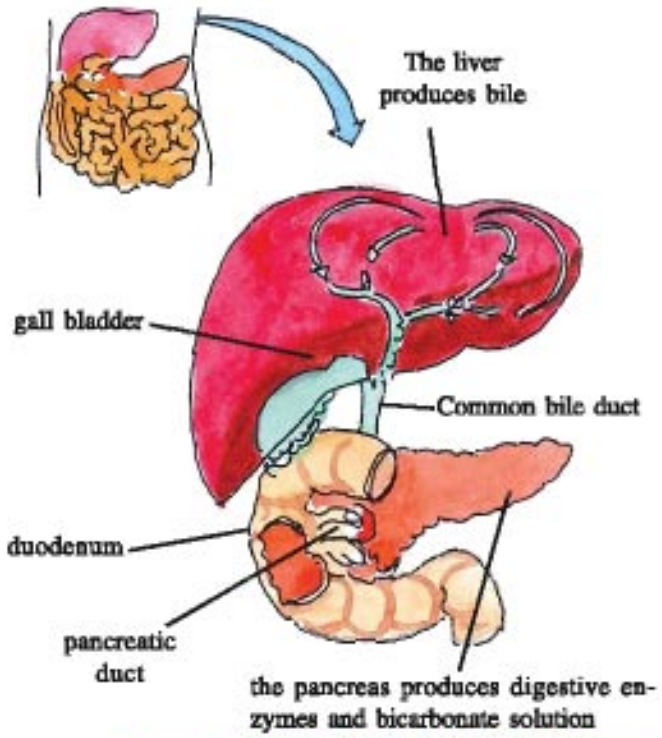
Accessory Digestive glands :

There are three major accestory digestive glands associated with the alimentary canal : salivary glands, the liver and the pancreas.

The liver :

The liver is the largest gland in the body. The human liver is wedge - shaped and is reddish brown in colour. It is weighing about 1.2 to 1.5 kg in an adult human. It is divisible into a large right and a much smaller left lobe. The thin connective tissue capsule covers the whole liver. It is situated in the abdominal cavity. The hepatic lobules are the structural and functional units of liver containing hepatic cells arranged in the form of cords. The bile secreted by the hepatic cells passes through the hepatic ducts and is stored in a gall bladder.

The duct of gall bladder (cystic duct) along with the hepatic duct forms the common bile duct. The bile duct and the pancreatic duct open together into the duodenum as the common hepato - pancreatic duct.



Accesory Digestive Glands-liver and pancreas

The Pancreas :

It is soft, lobulated gland, yellowish in colour. It is a compound racemose gland, very similar in structure to the salivary glands. It is situated between the loop of the 'U' shaped duodenum. It is an endocrine as well as exocrine gland. The Exocrine portion secretes an alkaline pancreatic juice containing enzymes and the endocrine portion secretes hormones, insulin and glucagon.

Functions of each organ of alimentary canal

Mouth (Buccal cavity)	• Mastication (biting and grinding of food) • To soften the food.
Pharynx	• It helps in the act of swallowing • Passes food to oesophagus
Oesophagus	• Passes food to stomach.
Salivary glands	• Its saliva (ptyalin) acts on sugar and cooked starches.
Stomach	• It acts as temporary storage. • Mix the food with gastric juice • All food components are liquified and mixed, in this way are prepared for intestinal digestion. • Chyme is formed in it. • Absorption - Small quantity of water, saline, glucose.
Small Intestine	• Digestion of chyme and its absorption.
Large Intestine (colon)	• The absorption of water, salt and glucose.
Rectum	• Acts as a reservoir of semi solid faeces.
Liver	• It concerns with the metabolism. • It is the largest gland and chemical factory in the body. • It modifies waste products and toxic substances to make them suitable for excretion through the bile or the urine.
Pancreas	• Its exocrine function is to secrete pancreatic juice containing enzymes and electrolytes. • Its endocrine function is to secrete Insulin and Glucagon hormones.

Functions of digestive system

- Ingestion of food.
- Digestion of food.
- Secretion of various digestive juices and absorption of products of digested food.
- Egestion of waste.

Digestive juices :

There are five digestive juices : saliva, gastric juice, pancreatic juice, succus entericus (intestinal juice) and bile. The composition and functions of each are given in the following table.

Name of the juice	Composition	Functions
• Saliva	• Water (99.5%), Solids (0.5%) • Inorganic and organic salts, - Ptyalin, mucin	• Keeps the mouth moist. • Helps in formation of bolus. • Splits starch up to maltose.
• Gastric juice	• Water (99.45%), Solids (0.55%) HCl (0.4 - 0.5%) • Inorganic and organic salts, mucin, Enzymes : pepsinogen, rennin, lipase etc.	• Protein digestion up to peptone and proteoses • Milk digestion
• Pancreatic juice	• Inorganic and organic constituents, Enzymes : trypsinogen, chymotrypsinogen, Procarboxy peptidase, nucleases, lipase	• Digestion of carbohydrates, proteins and fats, Nucleic acid
• Bile Juice	• Inorganic salts, bile salts, bile pigments (Bilirubin, Biliverdin), Cholesterol	• Helpful in digetion of lipid • Removes the acidity.
• Intestinal juice	• Water 98.5% and Solid 1.5%. Activator : Enterokinase Enzymes : Erepsin, nucleotidases, sucrase, maltase, lactase, lipase.	• Digestion of all type of food.

Digestion :

It is the process of biochemical transformation of complex food into a simple form suitable for absorption with the help of digestive enzymes.

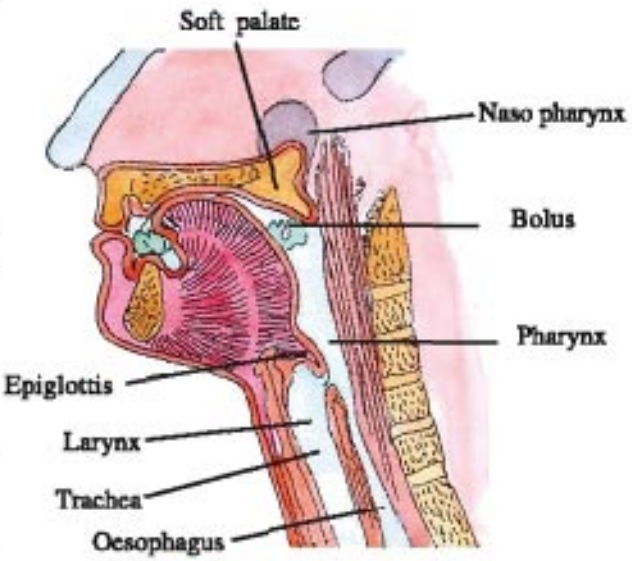
Digestion in Mouth :

The buccal cavity performs two major functions–mastication of food and facilitation of swallowing.

The most important enzyme of saliva is ptyalin or salivary amylase. The chemical process of digestion is initiated in the oral cavity by the hydrolytic action of the carbohydrate splitting enzyme, the salivary amylase. Starch is hydrolysed in a maltose. Lysozyme present in the saliva acts as an antibacterial agent that prevents infections.

Gastric Digestion :

The semi-solid food after salivary digestion reaches the stomach where it comes in contact of gastric juice, secreted by the mucosal layer of stomach wall. The pyloric part secretes gastrin which is released in the blood when food material comes in the gastric lumen. It stimulates gastric glands to secrete gastric juice. The most important enzyme of gastric juice is pepsin (greek word meaning digestion) other enzymes present in the gastric juice are rennin and lipase.



Process of Swallowing

Hydrochloric acid is one of the most important constituent of gastric juice. HCl has to perform several functions in the stomach. It lowers the pH of gastric contents and brings favorable acidic medium for the action of pepsinogen and other proteolytic enzymes of gastric juice. It converts inactive pepsinogen into active pepsin. It kills harmful bacteria and other parasites entering the body through mouth.

Pepsinogen
↓ HCl
Pepsin
↓
Proteins ⟶ Proteoses + peptones

Rennin is found in the gastric juice of human beings during infancy. This enzyme hydrolyses casein (a milk- protein) into soluble paracasein. Lipase catalyses hydrolysis of fats.

The stomach stores the food for 4 - 5 hours. The food mixes thoroughly with the acidic gastric juice of stomach by the churning movements of its muscular wall and is called the chyme.

Digestion in the small intestine :

The partially digested food material, chyme, passes through pylorus into the intestine. In the small intestine, chyme comes in contact of three different secretions : Pancreatic juice, Bile juice, Intestinal juice.

Pancreatic juice contains inactive enzymes - trypsinogen, chymotrypsinogen, procarboxypeptidases, amylases, lipases and nuclease. Trypsinogen is activated by co-enzyme, enterokinase, secreted by the intestinal mucosa into active trypsin which in turn activates the other enzymes. Trypsin digests proteoses and peptones very actively.

Trypsinogen
↓ Enterokinase

Proteins ⟶ **Trypsin** ⟶ Polypeptides, amino acids
Proteoses + Peptones

Chymotrypsins are secreted in their inactive forms, known as chymotrypsinogens. In the presence of trypsin, chymotrypsinogen is converted into chymotrypsins.

Chymotrypsinogen
↓ Trypsin

Proteoses + Peptones + Polypeptides ⟶ **Chymotrypsin** ⟶ Smaller polypeptides, A few free amino acids.

In presence of trypsin, procarboxy peptidase is converted into carboxypeptidase which acts on polypeptides

Procarboxy peptidase
↓ Trypsin

Polypeptides ⟶ **Carboxypeptidase** ⟶ Peptides and amino acids.

Carbohydrates in the chyme are hydrolysed into disacchrides by pancreatic amylase.

Polysaccharides ⟶ **Amylase** ⟶ Disaccharides

Fats are broken down by lipases with the help of bile into di and monoglycerides.

Fats $\xrightarrow{\text{Lipases}}$ Diglycerides $\longrightarrow$ Monoglycerides

Nucleases act on nucleicacids to form nucleotides and nucleosides.

Nucleic acids $\xrightarrow{\text{Nucleases}}$ Nucleotides $\longrightarrow$ Nucleosides

The enzymes act on the end products of the above reactions to form the respective absorable forms.

Dipeptides $\xrightarrow{\text{Erepsin}}$ amino acids

Maltose $\xrightarrow{\text{Maltase}}$ glucose + glucose

Lactose $\xrightarrow{\text{Lactase}}$ glucose + galactose

Sucrose $\xrightarrow{\text{Sucrase}}$ glucose + fructose

Nucleotides $\xrightarrow{\text{Nucleotidases}}$ Nucleosides $\xrightarrow{\text{Nucleosidases}}$ sugars + bases

Di and monoglycerides $\xrightarrow{\text{Lipases}}$ Fatty acids + glycerol.

The undigested and unabsorbed substances are passed on to the large intestine. The contents contain a large proportion of water. Much of this water is absorbed in the large intestine, and the residue left is known as stool (faeces). It is temporarily stored in the rectum till defaecation of faeces. Significant digestive activity does not occur in the large intestine.

Role of Hormones in Digestion

No.	Hormons	Secreatory Part	Function
(1)	Gastrin	Wall of Stomach	Stimulates gastric gland to release gastric juice.
(2)	Pancreozymin	Wall of Duodenum	Stimulates pancreas to release pancreatic juice and also helps in secretion of intestinal juice.
(3)	Secretin	Wall of Duodenum	With co-effect of pancreozymin stimulates secretion of Pancreatic juice and intestinal juice.
(4)	Cholecystokinin	Wall of Duodenum	Stimulates gall bladder to release bile juice.
(5)	Enterogastrone OR Gastric Inhibitory Peptide (GIP)	Wall of Duodenum	Inhibits gastric juice secretion and stops stomach churning.

Absorption

The complex dietary substances such as polysaccharide, lipids and proteins having very high molecular weight and large molecular size can not be absorbed. They are hydrolysed into low molecular size substances under the influence of the digestive enzymes in the digestive tract. These simpler substances do not require further structural simplification and can be absorbed as such. Thus absorption is the process by which the end products of digestion pass through the intestinal mucosa into the blood or lymph. It is carried out by passive, active or facilitated transport mechanisms. Small amounts of mono sachrides like glucose and amino acids are generally absorbed by simple diffusion. However, some of the substances like fructose and some amino acids are absorbed with the help of the carrier like Na^+. Transport of water depends upon the osmotic gradient.

Glycerol is fairly water - soluble, and hence, no difficulty is encountered in its absorption. But fatty acids can not be absorbed into the blood. They are first incorporated into small droplets called micelles. They are reformed into very small fat globules called the chylomicrons which are transported into the lymph vessels (lacteals) in the villi. These lymph vessels ultimatly release the absorbed substances into the blood stream.

Absorption of substances takes place in different parts of alimentary canal but maximum absorption occurs in the small intestine.

Disorders of Digestive System

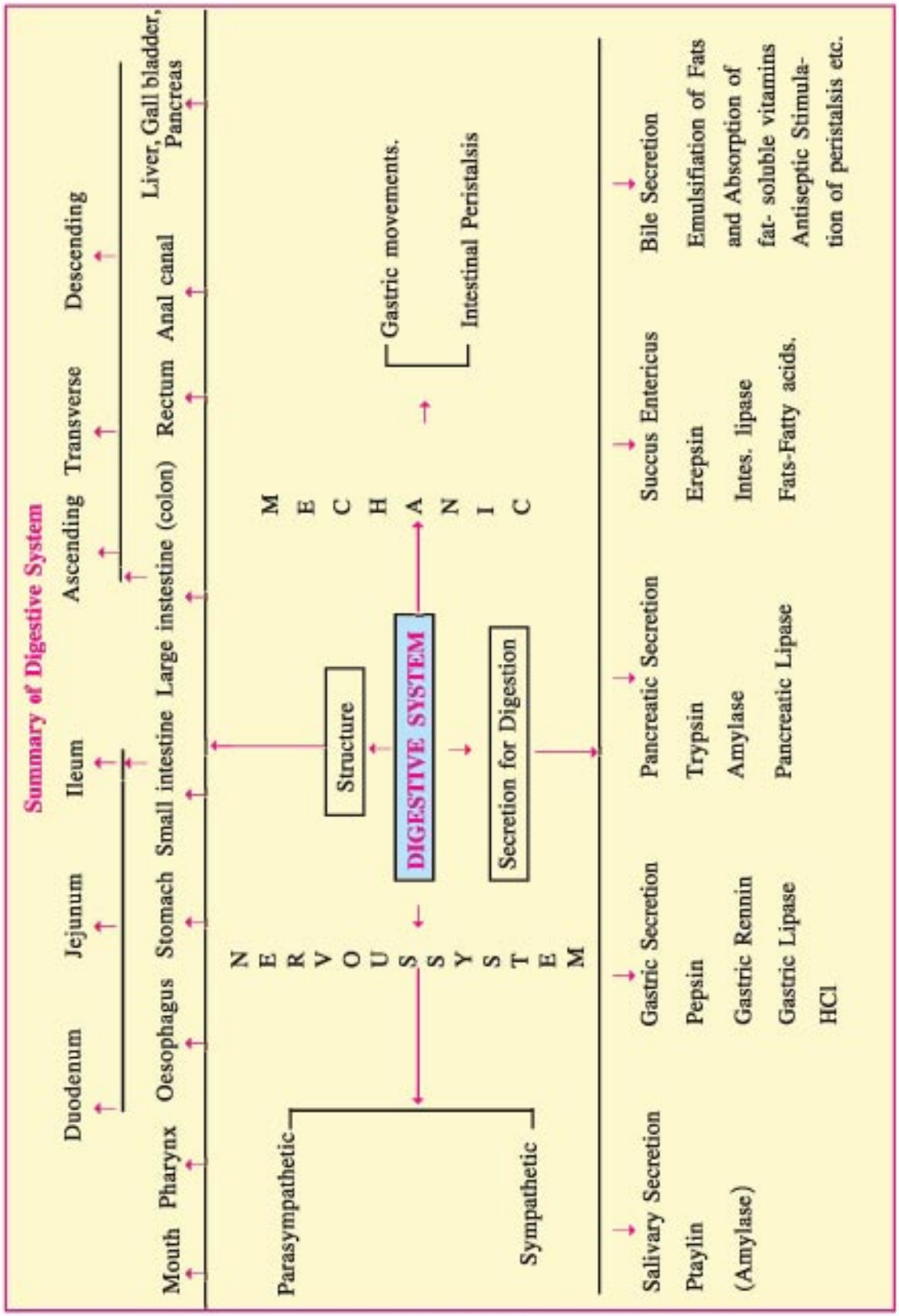
Some diseases are related to nutrition. As an example the starving peoples in famine countries are the examples of severe malnutrition called Kwashiorkor.

There are many reasons why a patient may be unable to take enough food by mouth. It is due to nausea, loss of appetite and vomiting due to disease of stomach. Pain renders swallowing difficult, as in tonsillitis. Weakness of the muscles of mastication may arise in facial paralysis. Gastritis is inflamation of the stomach. Acute gastritis is generally due to an irritant, as in food poisoning and infection. Peptic ulcer occurs on parts of the stomach and duodenum exposed to the action of gastric juice. There are many causes, including irregular meals, tension, anxiety, emotional stresses and colitis or inflamation of the colon. Ulcerative colitis is characterized by marked ulceration and dilation of the colons with the passes of watery stools containing blood and mucus. Vomiting may occur as the result of disorder of any part of the alimentary tract, in poisoning and due to motion, as in travel sickness.

Constipation has many causes. The diet may be deficient of fat, water, fruit or vegetables, faulty training in bowel habit in children. It may also be associated with indigestion. The faeces are retained within the rectum.

Jaundice : The liver is affected, skin and eyes turn yellow due to the deposit of bile pigments. It may be due to the production of too much bile pigment, or due to failure of the liver cells to modify or excrete the bile (infective hepatitis) or due to obstruction of the common bile duct.

Diarrhoea : The abnormal frequency of bowl movement and increased liquidity of the faecal discharge is known as diarrhoea. It reduces the absorption of food.



Summary

In our diet complex food-stuff can not be directly absorbed, hence it should be structurally simplified. It is possible through digestion in a digestive tract. Digestive tract consisting of mouth, pharynx, oesophagus, stomach, small intestine, large intestine and anal canal. Beside these accessory

digestive glands-salivary glands, liver and pancreas do also help in digestion. Different processes take place in a digestive tract such as mastication, deglutition, digestion, absorption and egestion. Teeth and tongue also take part in it. Pharynx and oesophagus pass the food material. Small intestine is present between stomach and large intestine or colon. It is divided into three parts : an ascending, a transverse and a descending part. The wall of the alimentary canal possesses four layers namely serosa, muscularis, submucosa and mucosa. There are five digestive juices : Saliva, Gastric juice, Pancreatic juice, Saccus entericus and Bile. Saliva splits starch up to maltose. Gastric juice digests protein up to peptones. Pancreatic juice digests carbohydrates, proteins and fats. Intestinal juice digests of all types of food. Absorption takes place through intestinal mucosa in to the blood or lymph. It is carried out by passive, active or facilitated transport mechanisms. Some disorders take place within a digestive system. They are nausea, loss of appetite, vomiting, gastritis, peptic ulcer, colitis, constipation, jaundice, diarrhoea etc.

Exercise

1. Put a dark colour in a given circle for correct answers :

(1) Which nutrients can be absorbed as such in a digestive tract ?

(a) Carbohydrates, Vitamins, Lipids ○ (b) Lipids, Water, Vitamins ○

(c) Water, Minerals, Vitamins ○ (d) Vitamins, Water, Proteins ○

(2) By which process complex food stuffs become simplified ?

(a) Assimilation ○ (b) Digestion ○

(c) Excretion ○ (d) Metabolism ○

(3) Which types of enzymes take part in digestion ?

(a) Hydrolases ○ (b) Oxido - reductases ○

(c) Synthetases ○ (d) Isomerases ○

(4) X- is a statement and Y- is a reason. Give your opinion of the following.
X- Absorption takes place only in a small intestine.
Y- It is due to intestinal juice.

(a) X - is false, Y- is also false ○ (b) X - is true, Y - is true ○

(c) X - is false, Y- is true ○ (d) X - is true, Y - is false ○

(5) Match the following :

Coloum I	**Coloum II**
(A) Salivary gland	(i) Trypsinogen
(B) Stomach	(ii) Bile pigments
(C) Pancreas	(iii) Saliva
(D) Intestine	(iv) Erepsin
(E) Gall bladder	(v) Gastric juice

(a) A-v, B-iii, C-i, D-ii, E-iv ○ (b) A-iii, B-v, C-i, D-iv, E-ii ○

(c) A-iv, B-iii, C-ii, D-i, E-v ○ (d) A-ii, B-v, C-i, D-ii, E-iv ○

(6) The type of attachment of teeth in a socket of jaw bone is called...

(a) Heterodont ○ (b) Diphyodont ○

(c) Homodont ○ (d) Thecodont ○

(7) How many milk teeth are present in a child ?

(a) 32 ○ (b) 20 ○ (c) 16 ○ (d) 40 ○

(8) How many permanent teeth are present in each jaw of human being ?

(a) 08 ○ (b) 32 ○ (c) 20 ○ (d) 16 ○

(9) The dental formula of a adult man is...

(a) $\frac{2321}{2321}$ ○ (b) $\frac{1632}{1632}$ ○ (c) $\frac{2123}{2123}$ ○ (d) $\frac{3216}{3216}$ ○

(10) How many types of papillae usually found on a tongue of man.

(a) 3 ○ (b) 2 ○ (c) 4 ○ (d) 6 ○

(11) Which is the largest salivary gland in man ?

(a) Parotid ○ (b) Sub mandibular ○

(c) Sublingual ○ (d) Non of them ○

(12) In which organ of alimentary canal bile and pancreatic ducts open together ?

(a) Fundus of Stomach ○ (b) Ileum ○

(c) Duodenum ○ (d) Caecum ○

(13) The innermost layer of alimentary canal is called...

(a) Serosa ○ (b) Mucosa ○

(c) Sub-mucosa ○ (d) Muscularis ○

(14) Which is the largest gland in a human body ?

(a) Parotid gland ○ (b) Pancreas ○

(c) Liver ○ (d) Gastric gland ○

(15) Hepatic cells secrete bile but it stores in to which organ ?

(a) Urinary bladder ○ (b) Pancreas ○

(c) Duodenum ○ (d) Gall-bladder ○

(16) Which gland is known as exocrine as well as endocrine gland ?

(a) Pancreas ○ (b) Salivary gland ○

(c) Liver ○ (d) Pituitary ○

(17) In which juice ptyalin is present ?

(a) Saccus entericus ○ (b) Saliva ○

(c) Gastric juice ○ (d) Pancreatic juice ○

(18) In which organ of alimentary canal digestion and absorption of chyme take place ?

(a) Stomach ○ (b) Small intestine ○

(c) Large intestine ○ (d) Anal canal ○

(19) Which organ is known as a largest chemical factory of the body ?

(a) Pancreas ○ (b) Stomach ○

(c) Liver ○ (d) Duodenum ○

(20) In which organ of a digestive tract starch is hydrolysed in a maltose ?

(a) Mouth ○ (b) Stomach ○

(c) Small intestine ○ (d) Liver ○

(21) By which enzyme trypsinogen is activated ?

(a) Ptylin ○ (b) Enterokinase ○

(c) Chymotrypsinogen ○ (d) Chymotrypsin ○

(22) Generally due to irregular meals, tension, anxiety and emotional stress, which disorder occurs in a digestive system ?

(a) Vomiting ○ (b) jaundice ○

(c) Peptic ulcer ○ (d) Diarrhoea ○

2. Do as Directed :

(1) Explain dentition in a mouth of men

(2) Role of salivary glands

(3) Location and parts of a stomach

(4.) Functions of digestive system

3. Write short note :

(1) The liver

(2) Absorption

(3) Gastric juice

(4) Lipid digestion

4. Sketch and label only :

(1) Digestive tract of a man

(2) Histological structure of an alimentary canal

5. Answer the following questions in detail :

(1) What is digestion ? Describe fat digestion in duodenum.

(2) Give composition of digestive juices and their role in digestion.

6. Define : Digestion, absorption, dentition.

7. Answer the following questions in short :

(1) Why digestion of a diet is required ?

(2) Which are proteolytic enzymes ?

(3) Which types of teeth are present in a mouth of man ?

(4) Name the salivary glands present in a mouth of man ?

(5) Which types of muscles present in a wall of stomach ?

(6) What are the functions of villi ?

(7) Which enzymes are present in a pancreatic juice ?

(8) Name the disorders of digestive system.

6

Breathing and Exchange of Gases

Metabolism is an essensial function of all living organisms. Catabolism takes place to produce energy which is used for all activities. Cellular respiration is a part of catabolism where generally glucose is oxidised through glycolysis, Tri carboxilic acid cycle (TCA) and oxidative phosphorylation. During these processess CO_2 is produced which is toxic to cell, hence it becomes a compultion to cell to remove it. Same way for oxidative phosphorylation cell has neccesity to get oxygen, thus for removal of CO_2 and to go in O_2 special system is required which is possible through respiratory system. This system has two major paths : inspiration and expiration, where O_2 is accepted and CO_2 is released respectively. Such exchange of gases should be done at two surfaces : Cellular surface and pulmonary surface. Entire process comes under the heading 'Respiration'. Cells need a continous supply of oxygen to carry out activities for their existance. Many of these activities release carbon dioxide. There are the circulatory system and the respiratory system to supply O_2 and eliminate CO_2. Let us see first the role of respiratory system along with its structure. The respiratory system consists of organs that exchange gases between atmosphere and blood. Blood tranports gases between lungs and cells. The overall exchange of gases between atmosphere, blood and cell is called respiration in general.

Respiratory system : The respiratory system of human consists organs like nose, pharynx, larynx, trachea, bronchi and lungs.

Nose : The nose has an external portion jutting out from the face and an internal portion lying hidden inside the skull. It is divided into external nares, nasal chamber and internal nares.

External nares Or Nostrils : On the under surface of the external nose two openings called the external nares or nostrils are present. The two nostrils are separated by the septum.

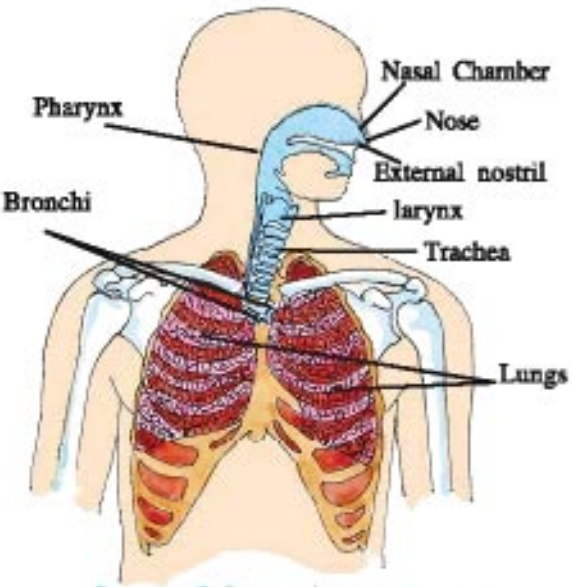
Nasal Chamber : The internal region of nose is a large cavity within the skull. Anteriorly it opens through external nares and posteriorly it communicates with the pharynx through internal nares. The two nasal chambers are also separated by the nasal septum. Each nasal chamber is divided into three regions lower vestibular, middle respiratory and upper olfactory.

Pharynx : The pharynx is a tube about 12.5 cm long, serving as a passage way for air and food. Pharynx is divided into three parts :

(i) **Nasopharynx :** The upper most portion of the pharynx.

(ii) **Oropharynx :** The second portion of the pharynx, lies behind the buccal cavity.

(iii) **Laryngopharynx :** The lowest portion of the pharynx. It extends downward and empties into oesophagus posteriorly and into the larynx (Voice-box) anteriorly.



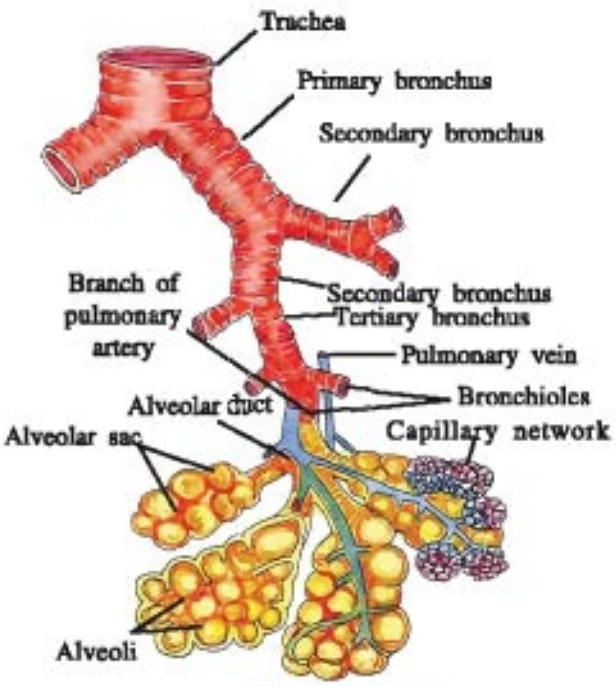
Organs of the respiratory system

Larynx : Larynx is a passage that connects the pharynx with the trachea. The leaf-shaped piece of cartilage called glottis is always remains open except during swallowing. The mucous membrane of the larynx contains vocal cords. It has ability to vibrate. This ability allows us to speech.

Trachea (Windpipe) : Trachea is about 12cm in length and 2.5cm in diameter. It extends from the larynx to the middle of the thoracic cavity, where it divides into right and left primary bronchi. It is a tubular passageway for air.

The trachea is divided into right primary bronchus, which enters the right lung and left primary bronchus, which enters the left lung. The right primary bronchus is more vertical, shorter and wider than the left. Along the length in the trachea and bronchi at short distances 'C' shaped incomplete, cartilagenous rings occur. They keep the respiratory passage open and prevent it from blockage.

When Primary bronchi enter into lungs, divide to from smaller bronchi, called secondary bronchi, one for each lobe of the lung. The secondary bronchi continue to branch, forming still smaller bronchi, called tertiary or segmental bronchi. These bronchi divide into bronchioles. Bronchioles divide into smaller tubes, called terminal bronchioles and ended into alveoli of lung. There are millions of alveoli in each lung. Each alveolus is sac-like structure surrounded by pulmonary cells and enveloped by a network of blood capillaries.



Bronchial tree

The continous branching of the trachea into primary bronchi, secondary bronchi, tertiary bronchi, bronchioles and terminal bronchioles is commonly referred to as the 'bronchial tree'.

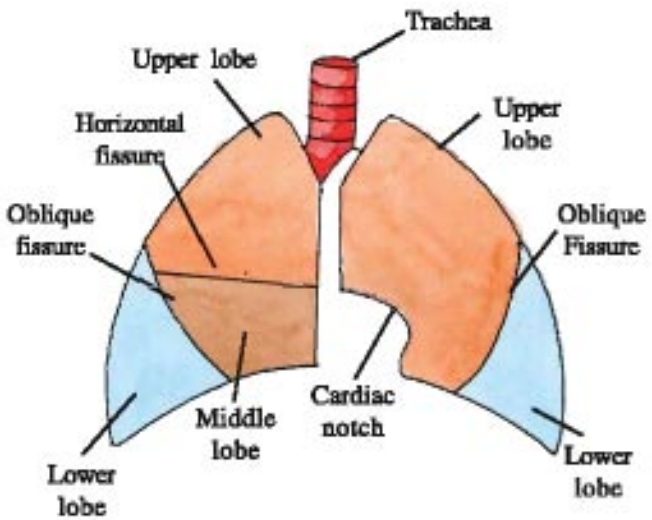
Lungs : The lungs are paired, cone-shaped organs lying in the thoracic cavity. It is protected by rib-cage. The diaphragm is placed under them. The left lung is slightly smaller and lighter than the right one. Two layers collectively called the pleural membrane covers each lung. The outer layer is attached with the wall of thoracic cavity. The inner layer covers, the lungs themselves. The space between two layers contains a lubricating fluid secreted by the membranes. This fluid protects lungs against shock.

The right and left lungs have some structural differences :

Right lung	Left lung
1. It is thicker, broader, longer and heavier	1. It is thinner, narrower, shorter and lighter
2. It has three lobes (Upper, lower and middle lobes) which are demarcated by two fissures (One oblique and one horizontal).	2. It has two lobes (Upper and lower lobes) Which are demarcated by one fissure (oblique)
3. Cardiac notch in which the heart lies is not present.	3. Cardiac notch is present.

Mechanism of Respiration : The principal purpose of respiration is to supply oxygen (O_2) to cells of the body and to remove carbon dioxide (CO_2) produced by cells. The process of drawn in air from the atmosphere towards lungs is called inhalation and the process of exportation of air from lungs into the atmosphere is called exhalation. Both activities occur alternately which is called breathing.

Diaphragm and ribs play an important role in breathing. The 'dome-shaped' diaphragm separates the thoracic cavity and abdominal cavity. It is attached anteriorly with sternum and at its posterior side, it remains attached to the vertebral column. Intercostal muscles are associated with the ribs.



External Structure of Lungs of Human

Inspiration : Inspiration takes place when the volume of the thoracic cavity is increased and the air pressure is decreased. The following steps simultaneously occur during inspiration :

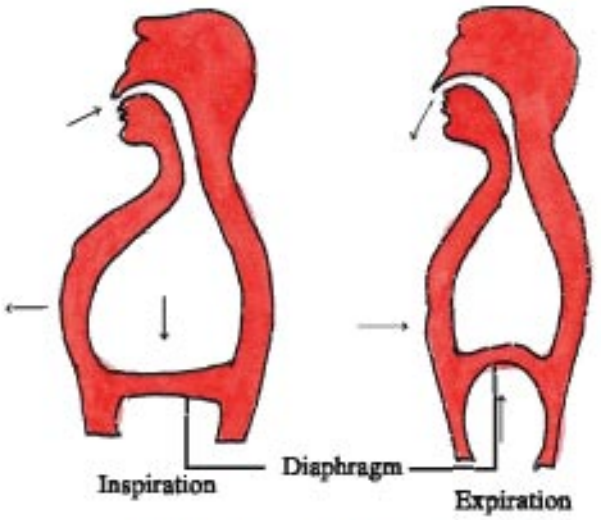
(i) When muscles of diaphragm contract, the diaphragm is pulled down-wards.

(ii) As a result the size of thoracic cavity increases.

(iii) The partial pressure of air in lungs is reduced.

(iv) As a result air from atmosphere moves into lungs through the external nostrils upto equalize the outer and inner pressure.

(v) In the lungs, air reaches alveoli where O_2 diffuses into the alveoli and CO_2 diffuses out of it. When all alveoli receive air, the lungs expand.



Breathing mechanism in human boty

Expiration : Expiration takes place when the volume of the thoracic cavity is decreased. The following steps simultaneously occur during expiration :

(i) When the muscles of diaphragm relax, the diaphragm moves upwards.

(ii) As a result, the size of thoracic cavity reduces.

(iii) As a result lungs becomes compressed and the pressure in them increases.

(iv) Under such pressure the air within the lungs goes out into the atmosphere.

Above mentioned processes of inspiration and expiration occur under normal resting phase.

Respiratory Volumes and Capacities : Many factors effect respiratory capacity viz : person's age, size, sex and physical condition. Let us understand the volumes and capacities :

(1) Tidal Volume (TV) : Normal quiet breathing moves approximately 500 ml of air into and out of the lungs with each breath. This volume is referred as a tidal volume (TV).

(2) Inspiratory Reserve Volume (IRV) : The amount of air that can be inhaled forcibly over the normal (tidal) volume is the IRV. Normally IRV is between 2500 ml to 3000 ml.

(3) Expiratory Reserve Volume (ERV) : The amount of air that can be forcibly exhaled after a normal (tidal) expiration is known as ERV. The ERV is approximately 1000 ml to 1100 ml.

(4) Residual Volume (RV) : It is the amount of air remain in the lungs after a forcible expiration. The approximately RV is 1100 ml to 1200 ml.

(5) Inspiratory Capacity (IC) : It is the total volume of air which can be inhaled by a person after normal expiration i.e. IC is a sum of TV and IRV. It is about 3000 ml to 3500 ml.

(6) Expiratory Capacity (EC) : It is the total volume of air which can be exhaled by a person normal inspiration. i.e. EC is a sum of TV and ERV. It is about 1500 ml to 1600 ml.

(7) Functional Residual Capacity (FRC) : It is a volume of air that will remain in the lungs after normal expiration. FRC is the sum of ERV and RV. FRC is about 2100 ml to 2800 ml.

(8) Vital Capacity (VC) : It is the total volume of air which can be breathe by a person. The VC is the sum of TV, IRV and ERV. VC is about 4000 ml to 4600 ml.

(9) Total Lung Capacity (TLC) : It is the amount of air in the lungs and respiratory passage after a maximum inspiration. The TLC is the sum of TV, IRV, ERV and RV or VC+RV. TLC is about 5100 ml to 5800 ml.

Exchange of gases : As soon as the lungs fill with air, oxygen moves from the alveoli to the blood, through the interstitial fluid and finally to the cells. Carbon dioxide moves in just the opposite direction : From cells, through interstitial fluid to blood and to alveoli. Oxygen and carbon dioxide are exchanged in these sites by simple diffusion mainly based on pressure or concentration gradient. The partial pressures (in mm Hg) of O_2 and CO_2 at different parts is compared with atmosphere as under.

Respiratory gas	Atmospheric Air	Alveoli	Blood (Deoxygenated)	Blood (Oxygenated)	Tissues
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

Transport of respiratory gases

Transport of O_2 in the Blood : Oxygen (O_2) is transported in the blood by two ways : Nearly 97 % O_2 is transported through RBCs. The remaining O_2 is transported through blood plasma.

Haemoglobin, a respiratory pigment, present in RBCs is responsible for transport of O_2. Each RBC transports around one billion molecules of O_2.

At the respiratory surface, haemoglobin in RBC of blood acts as haemoglobinic acid. It reacts with oxygen and forms oxyhaemoglobinic acid.

$$H + Hb \longrightarrow H.Hb \quad \text{(Haemoglobinic acid)}$$

$$H.\ Hb + O_2 \longrightarrow H.Hb\ O_2 \text{ (Oxyhaemoglobinic acid)}$$

Oxyhaemoglobinic acid (H. Hb O_2) reacts with potassium bicarbonate ($KHCO_3$) of RBC and produce $KHbO_2$ along with H^+ and HCO_3^-. H^+ and HCO_3^- again react to form H_2CO_3 (Carbonic acid)

$$H.Hb\ O_2 + KHCO_3 \longrightarrow KHbO_2 + H^+ + HCO_3^-$$

$$H^+ + HCO_3 \longrightarrow H_2CO_3$$

Thus, O_2 is transported in a form of potassium oxyhaemoglobin ($KHbO_2$). Near tissue surface $KHbO_2$ splits to release K^+, haemoglobin and oxygen.

$$KHbO_2 \longrightarrow K^+ + Hb + O_2 \uparrow \text{ (Near tissue surface)}$$

The Transport of CO_2 in blood : CO_2 produced through cellular respiration in cells diffuses into the blood within the capillaries. It is transported in two forms :

(i) In a form of physical solution :

About 10% of CO_2 combines chemically with water of plasma forming carbonic acid

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

Any increase in its concentration causes the dissociation of H_2CO_3 into hydrogen ion and bicarbonate ion

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

If all amount of CO_2 is transported by blood stream, pH of blood would be lowered from its normal level i.e. 7.4 to about 4.5. This would be instantly fatal. Therefore, only about 10 % of the CO_2 produced by the tissue is actually transported in this fashion.

(ii) As chemical compounds :

(A) Carbamino Compounds : About 20 % of total blood CO_2 is transported along with haemoglobin

$$CO_2 + Hb.NH_2 \longrightarrow Hb.NH.COOH$$

(Carbaminohaemoglobin)

(B) Bicarbonates : About 70% CO_2 is carried as bicarbonates in the blood.

(i) In the Erythrocytes (RBC) :

CO_2 from the plasma enters in RBC and combines with water within the cell. There action is catalyzed by carbonic anhydrase and produced carbonic acid, which soon dissociates.

$$CO_2 + H_2O \xrightarrow[\text{anhydrase}]{\text{Carbonic}} H_2CO_3$$

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

In RBC haemoglobin combines with potassium and forms KHb. KHb combines with H_2CO_3 to form $KHCO_3$ and HHb.

$$K + Hb \longrightarrow KHb$$

$$H^+ + HCO_3^- + KHb \longrightarrow KHCO_3 + H.Hb$$

(Potassium haemoglobin) (Haemoglobinic acid)

(ii) In the plasma : Plasma transports CO_2 by three different processes :

(a) By Phosphate buffers : Alkaline phosphates combine with carbonic acid in the plasma and form sodium bicarbonates.

$$Na_2HPO_4 + H_2CO_3 \longrightarrow NaHCO_3 + NaH_2PO_4$$

(Bi-sodium hydrogen phospate) (Sodium bicarbonate) (Sodium dihydrogen phosphate)

(b) By plasma proteins : Proteins of the plasma mostly remain combined with Na (sodium) and form sodium-protein complex. Now this complex react with carbonic acid and form bicarbonate of sodium.

$$Na^+ + Pr. \longrightarrow Na.\ Pr\ Complex$$

$$\text{Na. Pr.} + H_2CO_3 \longrightarrow NaHCO_3 + \text{H. Pr}$$

(Proteinic acid)

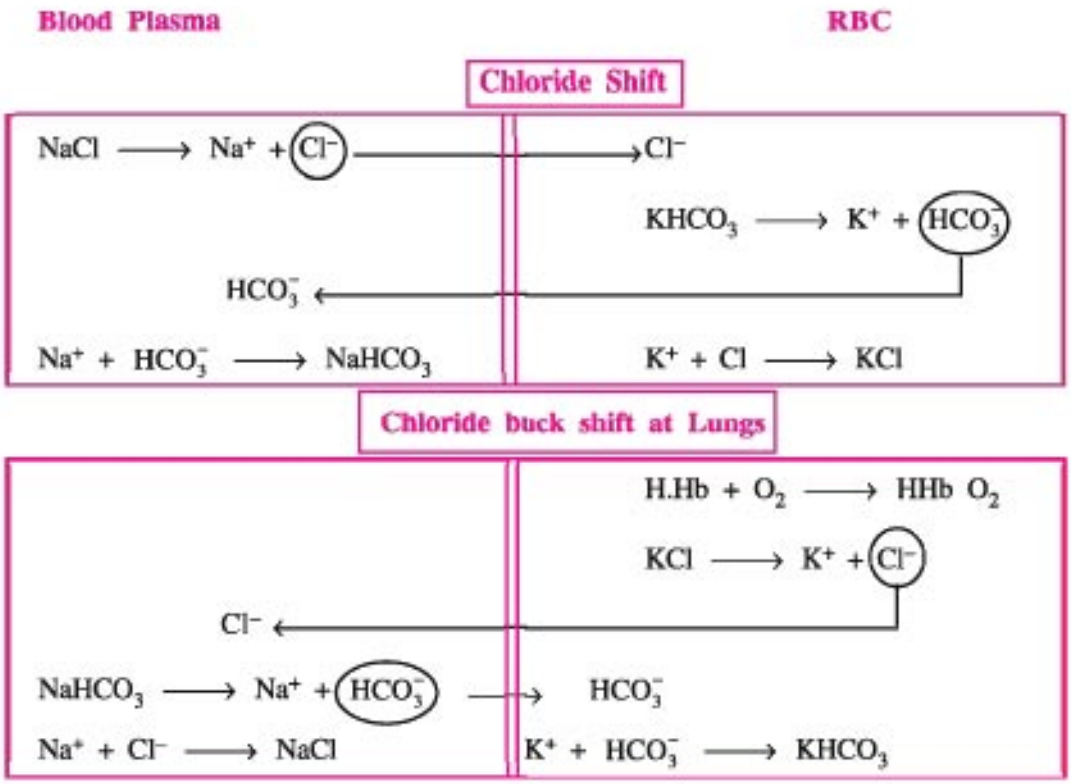
By Chloride Shift : CO_2 released from tissue enters into the RBC. It reacts with water to form carbonic acid.

$$CO_2 + H_2O \xrightarrow[\text{anhydrase}]{\text{Carbonic}} H_2CO_3$$

The carbonic acid is buffered by the intracellular potassium haemoglobin (K.Hb) and form potassium bicarbonate ($KHCO_3$) and haemoglobinic acid (H.Hb)

$$H_2CO_3 + \text{K.Hb} \longrightarrow KHCO_3 + \text{H.Hb}$$

Under normal conditions the wall of the RBC acts as permeable membrane to anions (Cl^-, HCO_3^-) but virtually impermeable to cations (Na^+, K^+). Under these circumstances, chloride (Cl^-) ions obtained by dissociation of NaCl diffuse into RBC from the blood plasma and react with $KHCO_3$. $KHCO_3$ dissociates into HCO_3^- and K^+. The bicarbonate ions (HCO_3^-) which diffuse out of the RBC into the blood plasma, where as Cl^- is neutralized by K^+ in the RBC. In the blood plasma, HCO_3^- combines with Na^+ and forms $NaHCO_3$ (Sodium bicarbonate). This phenomenon is known as chloride shift.



All reactions related to chloride shift become reversible at the surface of lungs. $NaHCO_3$ is present in blood plasma and KCl and H.Hb are present in RBC At the lungs surface O_2 diffuses into blood from atmosphere where it reacts with H.Hb in RBC to form $H.HbO_2$. Now Cl^- is released from KCl and diffused back into blood plasma. This phenomenon is known as chloride back shift. This Cl^- reacts with Na^+ released from $NaHCO_3$ in blood plasma and forms NaCl and HCO_3^-. Now HCO_3^- reenter into RBC and react with K^+ and forms $KHCO_3$.

Release of CO_2 at the respiratory surface (lungs)

Carbonic acid and bicarbonates of sodium and potassium are carried to the lungs where they are broken down and liberate free CO_2

$$H_2CO_3 \longrightarrow H_2O + CO_2 \uparrow$$
$$2KHCO_3 \longrightarrow K_2CO_3 + H_2O + CO_2 \uparrow$$
$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2 \uparrow$$
$$\text{Hb. NH. COOH} \longrightarrow \text{Hb. } NH_2 + CO_2 \uparrow$$

Regulation of Respiration

The regulation of respiration are of two types :

(i) Nervous regulation and (ii) Chemical regulation.

(i) Nervous regulation : According to one concept it is controled by nervous impulses ordered from respiratory center passing through the vagus nerve (10^{th} Cranial nerve) to the diaphragm and the intercostal muscles. Respiratory centre is present in a medulla oblongata.

According to other concept the respiratory centre has two-folds, consisting of inspiratory and expiratory centres which act reciprocally. These respiratory centres are scattered in the brain stem and are constantly giving off rhythmical stimuli to the respiratory muscles in virtue of their inherent rhythm, causing inspiration and expiration.

Whatever view is correct, the respiratory center or centres receive impulses through nerves distributed in the substance of the lungs.

(ii) Chemical regulation : The chemical regulation of respiration is controlled by level of CO_2 in the arterial blood and cerebro-spinal fluid. Chemoreceptors in the brain, aortic arch and carotid sinus detect the CO_2, pH and O_2 levels in the blood and pass information to the brain's rhythmicity centres. This rhythmicity centers transmit the appropriate signals to respiratory muscles.

Disorders of respiratory system

Bronchitis : Bronchitis is the inflammation of bronchi. It is caused by an infection. It may also be caused by smoking. The typical symptom is regular coughing with thick and large amount of phlegm which is secreted out as cough. It appears yellowish or greenish. It reflects severe burning sensation in trachea. Avoiding exposure to smoke, chemical and pollutants can prevent bronchitis. This disease is treated with suitable antibiotics.

Asthma : It is an allergic disease. The muscles wall of tracheal branches remain constantly agitated and undergo spasmic contraction. The aerial allergens are responsible for it. The symptoms are : repeated coughing out of phlegm, difficulty in breathing mainly during expiration and suffocation of tracheal passage. Avoiding the foreign substance or allergens is the best prevention of it. This is treated with suitable antibiotic, antihistamine drugs.

Emphysema : Emphysema is chronic obstructive disease of lung. Where alveoli loss their elasticity. As a result the alveolar sac remains filled with air even after expiration. It is mainly caused by smoking and chronic bronchitis. The symptoms are : difficulty in breathing, cough and suffocation and as a side effect the heart and brain do not get enough O_2 and hence, their functions are damaged. It can be prevented to avoiding of smoking and pollutants. Once it occurs, the elasticity of alveoli is lost and therefore, there is no permanent treatment for it but relief can be obtained through the use of antibiotics and tracheal dialatory drugs.

Pneumonia : Pneumonia is an acute infection of the alveoli of the lungs. It is caused through bacteria *Streptococcus pneumoniae*. The alveoli of lungs becomes filled with fluid and dead WBCs. Such areas become defunct. Wider is the area, greater is the spread of the disease. Children, old individuals and AIDS patients are more susceptible to this disease. It can be treated with antibiotics.

Occupational Lung Disease : As the name indicates, it happens due to the occupation of an individual. These are caused by the exposure of harmful substances like gases, dusts (antigens) etc. The common examples of such diseases are Silicosis and Asbestosis.

Summary

Cells of body need continous supply of O_2 to carry out metabolic activity and CO_2 must be released. For that circulatory and respiratory systems play important role. The respiratory system helps to exchange gases between atmosphere and blood. From their, O_2 travels towards cells and CO_2 toward lungs. This entire process comes under the heading 'respiration'.

The respiratory system of human consists organs like nose, pharynx, larynx, trachea, bronchi and lungs, by which inspiration and expiration like mechanism of respiration take place.

O_2 moves from alveoli ® blood ® interstitial fluid ® cell, while CO_2 moves in the opposite direction. O_2 and CO_2 are exchanged in these sites by simple diffusion which is mainly based on pressure or concentration gradient.

Transport of O_2 in the blood by two way : through RBCs and through blood plasma. Haemoglobin present in RBCs is responsible for it. The transport of CO_2 occurs through physical solution and as chemical compounds viz : carbamino compound, bicarbonate etc. The CO_2 transported is through bicarbonate by RBCs, and blood plasma. Blood plasma transports CO_2 by phosphate buffers by plasma proteins and by chloride shift.

The respiration is regulated by nervous system and chemicals.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) The length of pharynx is...

(a) 12 cm ○ (b) 12.5 cm ○

(c) 14 cm ○ (d) 15 cm ○

(2) Which part of respiratory system allows us to speech ?

(a) Oropharynx ○ (b) Trachea ○

(c) Vocal cords ○ (d) Nose ○

(3) The diameter of trachea is...

(a) 1.5 cm ○ (b) 2.5 cm ○

(c) 3.5 cm ○ (d) 0.5 cm ○

(4) Residual volume (RV) in human is... ml.

(a) 1000 to 1100 ○ (b) 3000 to 3500 ○

(c) 1100 to 1200 ○ (d) 1500 to 1600 ○

(5) How much partial pressure (in mm Hg) of O_2 in alveoli ?

(a) 159 ○ (b) 104 ○

(c) 40 ○ (d) 45 ○

(6) How much O_2 is transported through RBCs ?

(a) 90% ○ (b) 97% ○

(c) 3% ○ (d) 10% ○

(7) Normal pH of blood is...

(a) 7.4 ○ (b) 7.3 ○

(c) 6.5 ○ (d) 7.0 ○

(8) Complete the following reaction.

$2NaHCO_3$® ..... + H_2O + CO_2

(a) $NaCO_3$ ○ (b) $2NaCO_3$ ○

(c) Na_2CO_3 ○ (d) $NaHCO_3$ ○

(9) Vagus is the .... number cranial nerve.

(a) 8^{th} ○ (b) 7^{th} ○ (C) 9^{th} ○ (d) 10^{th} ○

(10) Which of the following is the allergic respiratory disease.

(a) Bronchitis ○ (b) Asthma ○

(c) Emphysema ○ (d) Pneamonia ○

2. Do as directed :

(1) Nose as a part of respiratory system : Describe

(2) Give the differences between right and left lung.

(3) Explain exchange of gases.

(4) Transport of O_2 in the blood-describe

(5) Describe - Regulation of respiration

3. Write short note on :

(1) Lungs

(2) Inspiration

(3) Expiration

(4) Respiratory volumes and capacities

(5) Chloride shift and back shift

(6) Emphesema

(7) Bronchitis

7

Body Fluids and Circulation

The cells of every animal need oxygen and nutrients for performing different metabolic activities. However during such activities cells need a supply of oxygen and nutrients and removal of metabolic wastes. Hence as a carrier, body fluids flow throughout the body. This flow of body fluids in a specific canal is known as circulation.

Blood : The red body fluid that flows through all the vessels except lymph vessels is known as blood. Blood connects every cells, tissues and organ of body so, blood is called fluid connective tissue. Blood constitutes about 8% of the total body weight. The blood volume of an average - sized man is between 5 to 6 liter and an average - sized woman is about 4 to 5 liter. Blood is composed of blood plasma and blood corpuscles.

Blood plasma : The detail of blood plasma is already studied in the chapter, animal tissue. Here only some important information is given. Blood plasma constituted about 55% of blood. It is light yellowish coloured and slightly viscous extracellular fluid. Constituents and major functions of it are given below :

Constitution	Major Functions
• Water	Solvent for carring substances
• **Salts :** Sodium, Calcium, Magnesium, Potassium, Chloride, Bicarbonate,	Osmotic balance, pH buffering and regulation of membrane permeability
• **Plasma proteins** • Albumin • Fibrinogen • Globulins	 Osmotic balance and pH buffering Clotting of blood, defense and liquid transport

Blood Corpuscles : This is also studied in the chapter, animal tissue. The blood corpuscles constituted about 45% of blood. Their types, occurrance in blood (per mm^3) and functions are summarized in the following table :

Table : Blood Corpuscles

Cell (Corpuscles) type	Occurrance in blood (per mm^3)	Function	Figure
(1) Red blood corpuscles (RBCs) (Erythrocyte)	4 - 6 million	Transportation of O_2 and CO_2	 Erythrocytes (RBC)
(2) White blood Corpusclees (WBCs) (Leucocytes)	4000 - 11000	Different types on basis of functions are as follows	
(a) Granulocytes			
(i) Neutrophils	3000 - 7000 (40 - 70% of WBCs)	Active phagocytes	 Neutrophil
(ii) Eosinophils (Acidophils)	100 - 400 (1-4% of WBCs)	Kill parasitic microbes and inactivate some inflammatory chemicals Detoxification	 Eosinophil
(iii) Basophils	20 - 50 (0-1% of WBCs)	Play significant role in allergic reactiion	 Basophils
(b) Agranulocytes			
(i) Lymphocytes	1500 - 3000 (20-45% of WBCs)	It is a part of immune system	 Lymphocytes
(ii) Monocytes	100 - 700 (4.8% of WBCs)	Active Phagocytes	 Monocytes
(3) Platelets			
Platelets	2,50,000 5,00,000	Needs for blood Clotting	 Platelets

Blood group :

There are over 30 common RBC antigens in humans, allowing each person's blood cells to be classified into different blood group. The most widely studied blood groups are the ABO and Rh. These two blood grouping are described here.

ABO Grouping

The ABO blood groups are based on two antigens present on RBCs, namely type A and type B. Similarly, the blood plasma of different persons contains two antibodies which are opposite to antigen hence they are called anti - A and anti - B. On the basis of presence and absence of above antigens and antibodies, four types of blood groups are seen in human i.e. A, B, AB and O. Blood groups are on basis of antigens on RBCs and antibodies in blood plasma. Donors and receipents with respect to blood groups on the basis of Antigens on RBCs and antibodies in blood plasma are given in following table :

Blood group	Antigens on RBCs	Antibodies in Blood plasma	Can give (blood to Donor)	Can receive (blood from Recipient)
A	A	Anti - B	A, AB	O, A
B	B	Anti - A	B, AB	O, B
AB	A and B	None	AB	A, B, AB, O (Universal recipient)
O	None	Anti - A and Anti - B	A, B, AB, O (Universal donor)	O

Rh Grouping

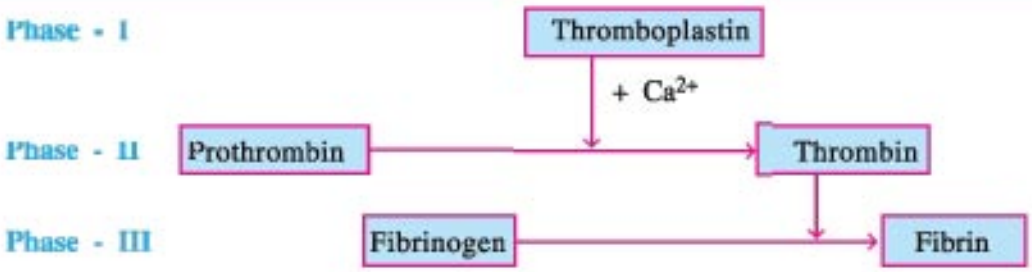
The antigen was originally discovered in the blood of Rhesus monkey, therefore it was named 'Rh'(the rhesus factor). Later the same antigen was discovered in human. Human having Rh antigen in their RBCs, are called Rh positive (Rh^{+ve}) while those who do not possess Rh antigen are called Rh negative (Rh^{-ve}). About 85% people are Rh^{+ve} and 15% are Rh^{-ve} in human population.

An important Rh related problem occurs during pregnancy. In pregnant Rh^{-ve} women who are carrying Rh^{+ve} baby, the first such pregnancy usually results a healthy baby. After it the mother is sensitized by Rh^{+ve} antigens that have passed through placenta into her blood stream, she will form anti Rh^{+ve} antibodies unless treated shortly after giving birth. If she is not treated and becomes pregnant again with an Rh^{+ve} body, her antibodies will cross through the placenta and destroy the baby's RBCs, producing a condition known as haemolytic disease of the new born or erythroblastosis foetalis. This can be avoided by administering anti, – Rh^{+ve} antibodies to the mother immediatelly after the delivery of the first baby.

Coagulation of Blood

The major chemical defence against blood loss is the formation of the blood clot. The process in which the conversion of fluid-like blood into jelly-like clot is called blood coagulation.

The clotting of blood is a complicated biological process in which 13 factors present in the blood plasma and tissues are involved. They are given in a table. However, this process involves three phases : Phase - I - formation of thromboplastin, Phase - II - formation of thrombin and Phase - III - formation of fibrin.



Numerical system for Nomenclature of blood clotting factors

Roman Numeral Designation	Common Name	Activation Product
I	Fibrinogen	Fibrin
II	Prothrombin	Thrombin
III	Thromboplastin	–
IV	Calcium	–
V	Proaccelerin	Accelerin (VI)
VII	Proconvertin	Convertin
VIII	Antiheamophilic globulin (AHG)	Activated AHG
IX	Christmas factor	Activated Christmas factor
X	Stuart factor	Activated Stuart factor
XI	Plasma thromboplastin antecedent (PTA)	Activated PTA
XII	Hageman factor	Activated Hageman factor
XIII	Fibrin stabilizing factor (FSF)	Activated FSF

Phase - I : Formation of thromboplastin

This is the initial phase in the coagulation mechanism. It is divided into two sources : intrinsic and extrinsic pathway.

Intrinsic pathway : Initiated factors of this system are derived from the blood plasma. This type of clotting pathway initiated when blood comes in contact with a damaged vessel surface. It starts with the acitvation of Hageman factor (XII) and at last form 'Intrinsic factor - X Activator complex' (Activated christmas F (IX) + AHG + phospholipid + Ca^{2+}).

Extrinsic pathway : Initiated factors of this system are derived from outside the blood plasma (injured tissue). The phospholipid-protein complex (tissue thromboplastin) is interacts with proconvertin F (VII) to form 'Extrinsic factor - X Activator complex'

The function of factor - X activator complex (intrinsic or extrinsic) is to acitvate Stuart factor (X). This activated factor - X makes a complex with proaccelerin (V), phospholipid and calcium ions (Ca^{2+}) to form thromboplastin.

Phase - II : Formation of thrombin : The formation of thrombin from prothrombin occurs in the presence of thromboplastin and it release Ca^{2+}

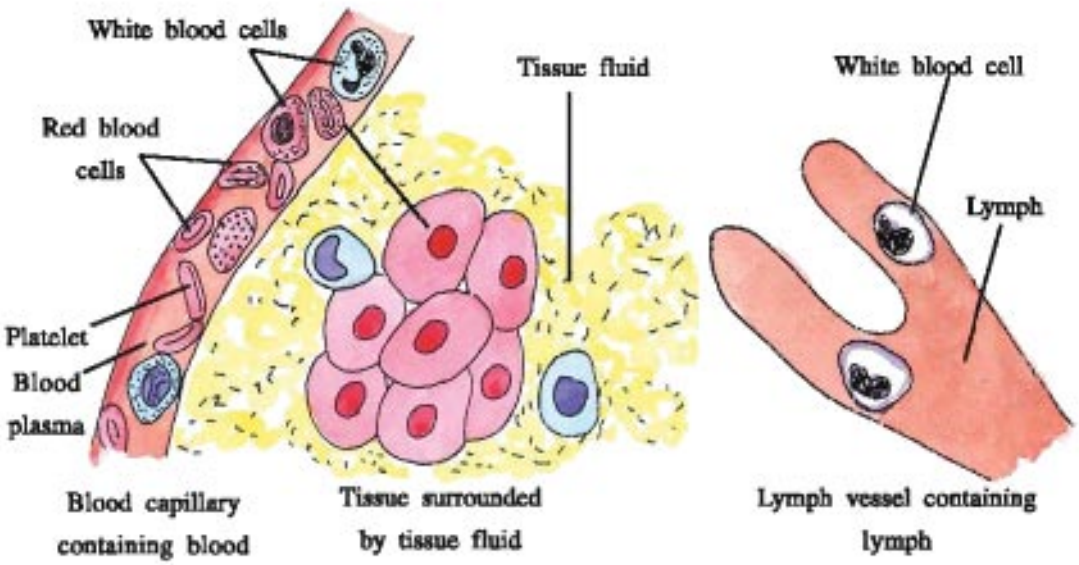
Phase III Formation of fibrin : In the phase - III thrombin of phase - II reacts with fibrinogen and form soluble firbrin, Ca^{2+} and activated fibrin produces stabilizing factor (FSF) (XIII). This activated FSF converts soluble fibrin into stable fibrin. Which results hard blood clot.

Above all and some other extra sources factors which affect the clotting of blood are :

Vitamin - K, Heparin, Defibrinator and hirudin.

Lymph (Tissue fluid)

The major difference between the tissue fluid and blood is based on their location. The fluid surrounds the cells is called tissue fluid. While the fluid which flows through the lymphatic vessels, is called lymph.



Comparison of blood, tissue fluid and lymph.

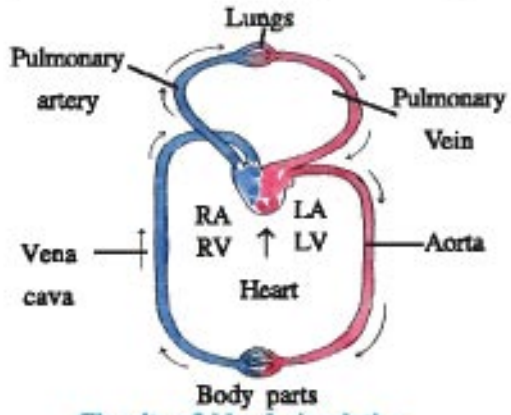
Both fluids are similar in composition. The compositon of lymph is very much like that of the blood plasma but the dissolved substances are in different concentrations. In lymph protein contents are low and it contains less fibrinogen than blood plasma. It acquires waste from tissue metabolism. Lymph in the smallest capillaries have no cells, but it is added when lymph passes through the lymph nodes. The cells present in it are 99% small lymphocytes. The remaining 1% is made up of occasional RBCs, eosinophil or monocytes. In general lymph is a colourless fluid containing specialized lymphocytes which are resposible for immune responses of the body. It is also an important carrier for nutrients, hormones etc.

Circulatory pathways

Blood vessels in animals form circulatory system which is either open or closed.

Open circulation : In an open system, blood flows partly through vessels and partly through free haemocoelic space. This type of circulation is found in arthropods and molluscs (except cephalopod)

Closed circulation : In a closed system, blood flows through vessels. The blood vessels form complex network in the body. This type of circulation is found in annelids and vertebrates.



Circuits of blood circulation

RA - Right atrium RV - Right ventricle
LV - Left ventricle LA - Left atrium

Human circulatory system

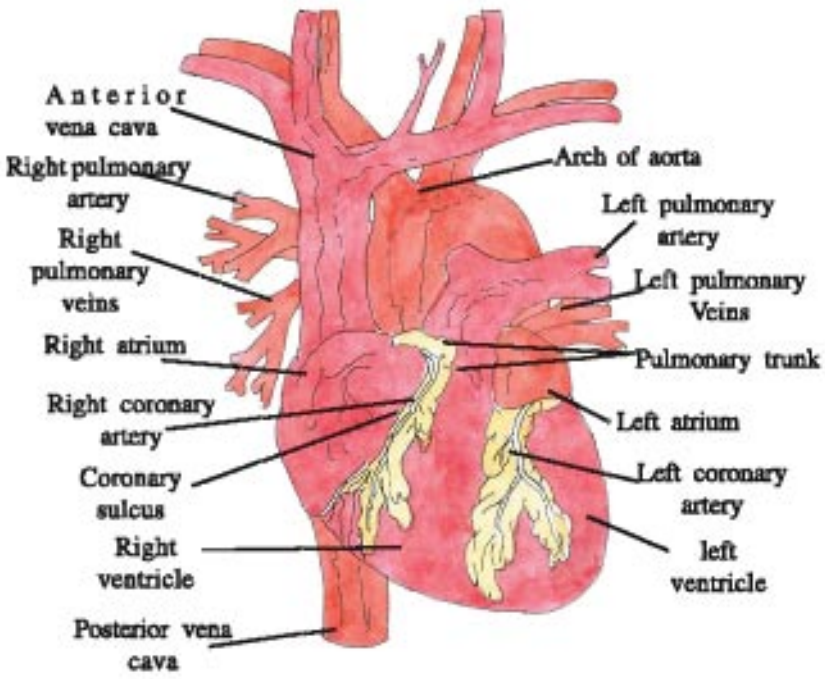
Human circulatory system consists of heart and network of different types of vessels : arteries, veins and capillaries. In human there are two circuits of blood circulation : systemic and pulmonary circulation. In the systemic circulation blood flows from left side of the heart to body tissues by aorta and back to right side of the heart by the vena cava. In pulmonary circulation blood flows from right side of the heart to the lungs by pulmonary artery and back to left side of the heart by pulmonary vein.

Heart

The heart is a hollow, muscular organ that pumps the blood through the vessels. It is situated obliquely between the lungs. It's 2/3 part lies to the left of the midline of the body. It looks like a blunt cone.

Heart is enclosed in a double-walled structure called pericardium. It consists of an outer fibrous layer and on inner serous layer. In between these two layers, there is a very narrow space, called pericardial cavity which is filled with pericardial fluid.

Human heart possesses four chambers, two upper thin walled atria and two lower thick walled ventricles. Ventricles are larger than atria but, the volume of blood is the same in all chambers. Two atria and two ventricles are externally separated by a distinct transverse groove, called coronary sulcus. There are also two grooves present on ventricles : anterior-interventricular sulcus and posterior interventricular sulcus. Coronary arteries supplying blood to the heart are located here.

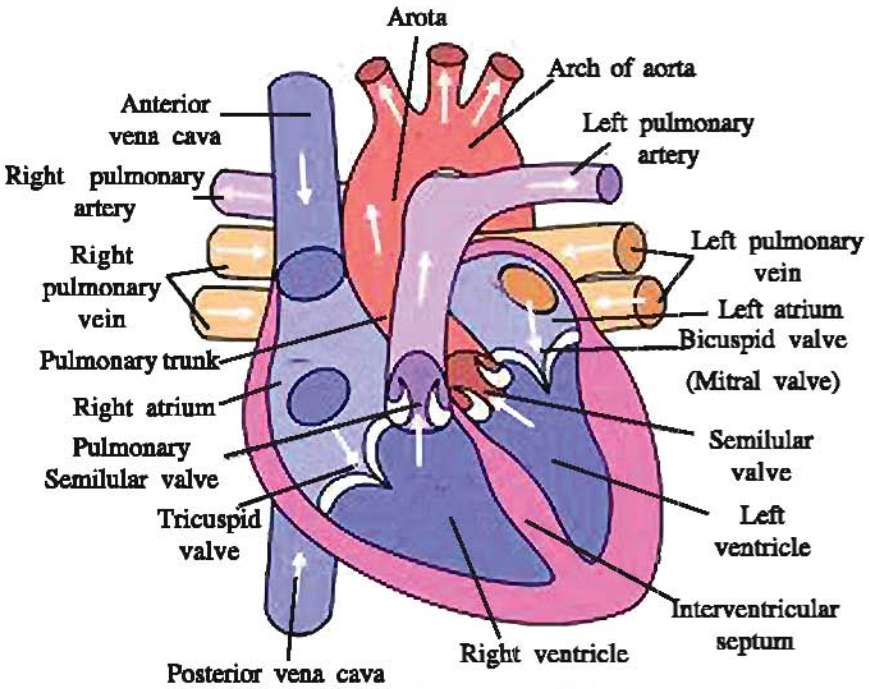


External structure of the heart

The internal structure of the heart can be observed in a longitudinal section.

Internally the human heart is divided into four chambers : Two atria and two ventricles. The two atria are separated from each other by inter atria septum, two ventricles are also separated from each other by inter-ventricular septum. Both atria and ventricles are separated by Atrio-ventriculr septum.

There are four valves present in the cavity of heart. These valves regulate the direction of blood flow.



The internal structure of the heart

Atrio-ventricular (AV) valves separate the atria and ventricles. The right AV valve lies between right atrial and right ventricle. It has three flaps, therefore it is called tricuspid value. Left auricle and left ventricle are separated by left AV valve with two flaps called bicuspid valve. It is also called as Mitral valve. Both bicuspids and tricuspid valves are attached by chordae tendinae to the ventricular walls.

Semilunar valves are present in the initial arteries which leave the heart. These valves prevent back flow of blood towards ventricle. The valve present between right ventricle and pulmonary trunk is called pulmonary semilunar valve and between left ventricle and truncus arteriosus is called aortic semilunar valve.

Superior and inferior vena cava open into right atrium and pulmonary veins open into left atrium.

The wall of heart is made up cardiac muscle tissue, connective tissue and blood capillaries.

A specialized cardiac musculature called sino-atrial node (SA - node) is present in right upper corner of the right atrium. Another such mass of tissue is seen in the lower left corner of the right atrium close to the atrio ventricular septum is called Atrio-ventricular node (AV node). From the AV-node, a tract of conducting fiber called bundle of His runs to the top of the inter ventricular septum. The Purkinje fibers are branches that emerge from the bundle of His.

Cardiac Cycle

The heart acts as a pump and its action consists of a regular sequence of events called the cardiac cycle. In a human being, when heart is beating normally the cardiac cycle occurs about 72 times per minute i.e. each cycle takes about 0.8 second.

The phase of contraction of chambers of heart is called-systole and the phase of their ralaxation is called-diastole. The following stages occur during one complete cardiac cycle.

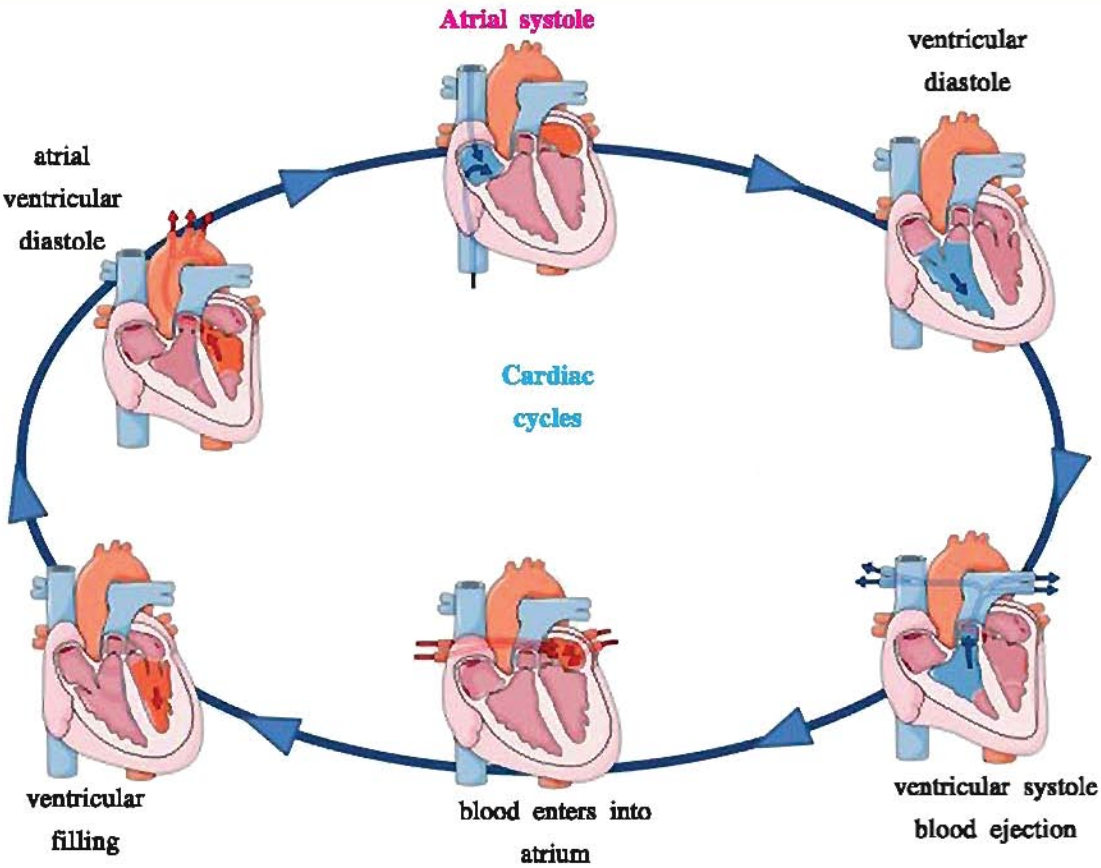


Table : Cardiac Cycle

Time-gap	Atria	Ventricles
0.10 seconds	undergo systole	undergo-diastole
0.30 seconds	undergo diastole	undergo systole
0.40 seconds	undergo diastole	undergo-distole

First of all, auricles contract. At the same time, ventricles relax. During this, blood from right auricle flows into right ventricle and blood from left auricle flows into left ventricle. Their unidirection flow is controlled by valves.

Now, ventricles experience systole i.e. they contract. During this, auricles experience diastole. Due to contraction of ventricles, the blood within them pressurised. This pressure opens the valve located in the pulmonary trunk which arises from right ventricle. Blood flows towards lungs. From left ventricle, blood opens the valve in truncus arteriosus and blood flows to all organs of the body.

In the following phase, all chambers of heart experience disastole during which blood enters into atria. After that a new cardiac cycle begins with contraction of atrium.

Electrocadiogram (ECG)

The eletrical changes induced in cardiac muscles during each cardiac cycle can be registered through electrodes arranged on the body surface. Such a recording is called-Electrocardiogram (ECG). This is an important method for checking the health or health-related problems of the heart.

When atria and ventricles contract, electrical currents are generated which originate in heart and spread towards all organs of the body. Electrodes are arranged at different places on the body. Normally they are placed on wrists and ankles. These electrodes note the effect of electric current. The appearance of ECG depends on the particular placement of electrodes.

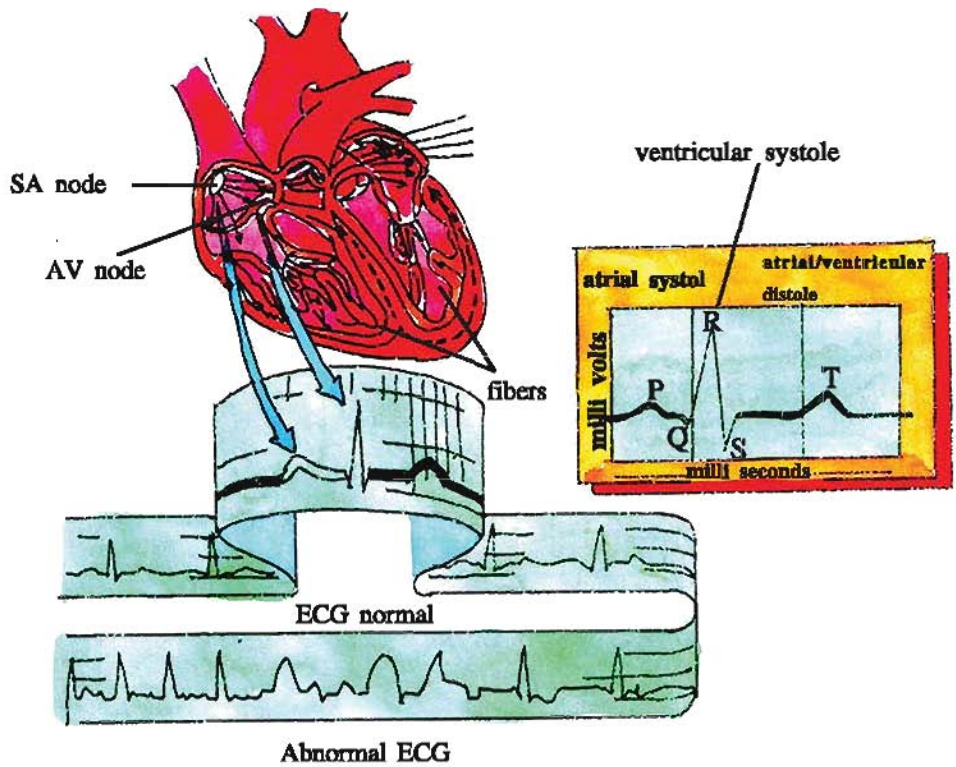
The waves of electrocardiogram are named as P, Q, R, S and T. Each letter indicates a specific events of cardiac cycle.

P wave : Related to systole of auricles. It indicates conduction of stimulus from SA-node to atria.

Q, R, S waves : They collectively indicate the contraction of ventricles. It begins with Q which curves downward. Then 'R' indicates a large upward curve. 'S" indicates a downward curve at the end of this phase.

T wave : It indicates diastole of ventricles. At this time, atria are also in the diastolic condition.

A cardiologist uses the ECG for diagnosis of heart-related disease.



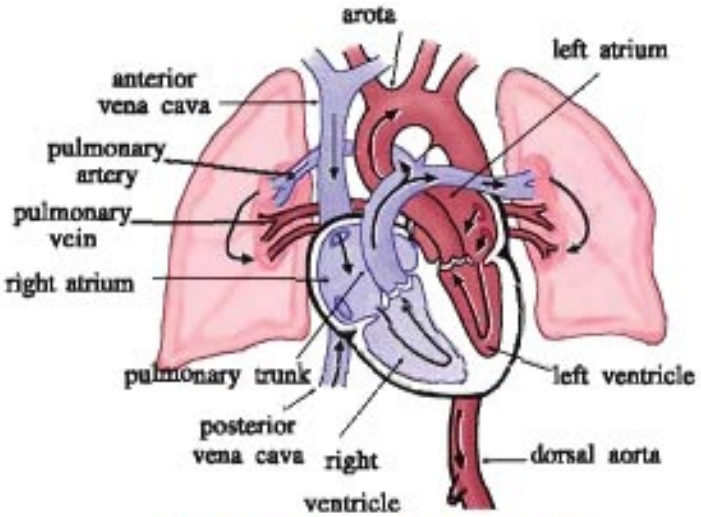
Electrocardiogram ECG

Double circulation

The circulation of oxygenated and dioxygenated blood separatly is called double circulation. The pathway is describe as under.

Anterior vena cava and posterior vena cava collect deoxygenated blood from different organs of the body and empty it into the right atrium.

From the right atrium, blood flows into the right ventricle through tri-cuspid (atrio-ventricular) valve.



Double circulation Path in Heart

From the right ventricle, blood flows to the lungs via pulmonary trunk through pulmonary arteries which possesses semilunar valve.

From the lungs, oxygenated blood is transported to the left atrium through the pulmonary veins.

From the left atrium, oxygenated blood flows into the left ventricle through atrio-ventricular valve which is a bicuspid valve.

From, the left ventricle, oxygenated blood flows to various organs of the body through the arteries.

In order to move from the right side chambers to the left side chambers blood has to pass through lungs. Heart is called a 'double pump'. This is because the right chambers push blood into lungs and the left chambers push blood into entire body. Hence, the wall of left ventricle is more muscular than that of right ventricle.

Regulation of Cardiac activity

The regulation of cardiac activity is under nervous as well as hormonal control. Normally cardiac activity are auto regulated by nodal tissue which has properties of both the muscles and nerve so the heart is known as myogenic. The impulse of contraction originates itself in the heart and the sympathetic nerve fibres supplies to the heart can increase the cardiac activity, while parasympathetic nerve fibres on the other hand, normalize the cardiac activity.

SA-node initiates the heart-beat and sends sitmulatory message for contraction of atria every 0.8 second. Because of this, SA-node is also known as 'pacemaker'. It maintains regulartity and rythmicity of heart-beat. When this stimulation reaches AV-node, AV-node stimulates contraction of ventricles. The conduction of this stimulation is carried out by special fibres (bundle of His and Purkinje muscle fibers) located in the wall of heart.

Disease Related to Blood Circulation

Hypertension and atherosclerosis are main disease related to blood circulation.

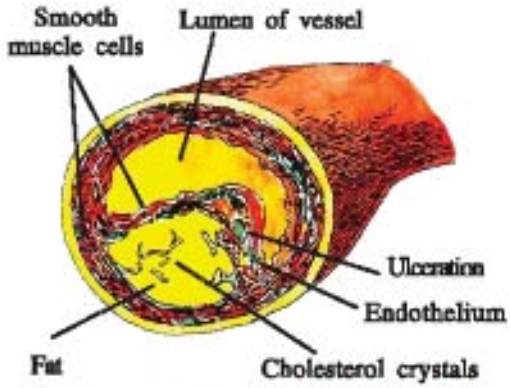
Hypertension : Hypertension is mainly responsible for causing heart disease. In our body blood circulation is maintained under pressure. Blood pressure is measured in large arteries of the body. This instrument is called-Sphigmomanometer. There are two measurements of pressure-systolic pressure and diastolic pressure. In a normal healthy person systolic pressure is 120 (i.e. 120 mm Hg) and diastolic pressure is 80. This is recorded as 120/80. Minor variations can occur in it during varying physiological conditions. When this pressure is recorded higher then 140 for systolic higher then 90 for diastolic is constantly. hypertension is indicated. If this condition persists for a long period, three vital organs of the body-heart, brain and kidneys can be damaged.

Two main factors seem to be responsible for hypertension. Both of them are avoidable. One is smoking and the other is obesity. During smoking, nicotine mixes with blood and cause constriction of arterioles. As a result blood pressure rises. Moreover, blood pressure rises as the oxygen-carrying capacity of lungs is reduced. Carbon monoxide produced during smoking reduces the O_2

carrying capacity of hemoglobin. A person can be considered to be obese, when his weight is higher by 20% from the standard weight determined by age, height and other aspects. In such person more blood is to be supplied to tissues so blood pressure rises. It is essential to avoid smoking and to keep a constant watch over weight.

Atherosclerosis

Atherosclerosis is also known as 'hardening of arteries.' As the symptoms of its effect become apparent after many years, it is called a 'silent killer'. It is responsible for heart attack and brain stroke.



Deposition of Cholesterol in Blood Vessel

In healthy arteries, the innermost layer of the wall is smooth. It becomes injured due to high blood pressure, smoking and consumption of high fat-food. Fatty substance becomes collected at injured regions and form plaques. First of all, the cells of injured region proliferate. Then, smooth muscles of the layer underlying it become incorporated. Lipids and mainly cholesterol becomes collected in these cells. Such a plaque becomes projected in the cavity of artery. Thus, circulation becomes obstructed. Such plaques lead to formation of blood clots on the wall of artery. If such a clot remains localised it is called-thrombus. If it becomes liberated and starts circulating with blood it is called Embolus. If this is not treated, serious consequences result.

The condition of formation of plaques and consequent narrowing of arterial cavities is a disease called-atherosclerosis. Heart attack and brain stroke occur under the effect of atherosclerosis. When the cavities of cardiac arteries, which supply blood to heart, are partially or totally blocked, heart attack can result. It can be treated by processes like angioplasty, by-pass surgery etc.

Arteriosclerosis

This is a condition of hardening of arterial walls. The walls become thick and inelastic due to deposition of cholesterol and calcium salts. Such a brittle artery can break. If it does, the blood from it flows out and clots. Such clots may circulate in blood and may cause problems in some organ.

Summary

Cells of every animal body need sufficient amount of O_2 and nutrient and need to remove CO_2 and wastes during different metabolic activities. Hence as a carrier blood and lymph are present in the body. These carriers have to flow for suppling such substances and it is called circulation.

Blood is a red coloured body fluid that flows through various vessels viz : arteries, veins and cappilaries. It is composed of two portions : blood plasma and blood corpuscles. There are various RBC antigens in human, which classify person's blood cells into different blood groups. The most popular groups in human are ABO and Rh. Blood has a special character, to clot. In the process of clotting 13 factors present in the blood plasma and tissues are involved. The other substances which flow in its special vessel is called lymph. The lymph is very much similar to the blood plasma in structure and function.

Blood in animals is circulated by (1) open circulation and (2) closed circulation. Out of it human circulation is a closed type. The human circulatory system consists of heart and network of different types of vessels. In the human there are two circuits of blood circulation : systemic and pulmonary circulation.

The heart of human is hollow and muscular organ that pumps the blood through the vessels. The heart is having four chambers : Two upper atria and two lower ventricles. There are several valves, septa and nodes present in the heart.

The heart acts as a pump and its action consists of a regular sequence of event called as cardiac cycle which takes about 0.8 second. The electrical charges induced in cardiac muscles during each cardiac cycle can be registered through ECG.

The circulation of oxygenated and deoxygenated blood separatly in human is called double circulation. The regulation of all activities of cardiac is under nervous and hormonal control.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) How much amount of blood is present in the average sized man ?

(A) 4 to 6 liters ○ (B) 5 to 6 liters ○

(C) 3 to 6 liters ○ (D) 5 to 7 liters ○

(2) What is involved in clotting of blood ?

(A) Sodium ○ (B) Albumin ○

(C) Potassium ○ (D) Fibrinogen ○

(3) What percentage of neutrophils is present in the blood ?

(A) 1 - 4% ○ (B) 20 - 45% ○

(C) 40 - 70% ○ (D) 4 - 8% ○

(4) Which of the following is a part of immune system ?

(A) Lymphocytes ○ (B) Erythrocytes ○

(C) Plateles ○ (D) None of them ○

(5) Which blood group is possessed by universal donor ?

(A) A ○ (B) B ○ (C) AB ○ (D) O ○

(6) How many individuals have Rh antigen in their RBCs.

(A) 80% ○ (B) 85% ○ (C) 70% ○ (D) 75% ○

(7) Which of the following is activated factor ?

(A) Fibrinogen ○ (B) Calcium ○

(C) Prothrombin ○ (D) Stuart factor ○

(8) Which group of animal has open circulation ?

(A) Arthropoda ○ (B) Annelides ○

(C) Vertebrates ○ (D) Echinodermaties ○

(9) Which valve separates the atria and ventricles ?

(A) AV valve ○ (B) Semilunar valve ○

(C) Pulmonary semilunar valve ○ (D) All ○

(10) Each cardiac cycle takes about ---------- second.

(A) 0.8 ○ (B) 0.7 ○ (C) 0.1 ○ (D) 0.4 ○

2. Do as directed :

(1) Explain ABO groups.

(2) Give only the common names of all factors involved in blood clotting.

(3) Describe external structure of heart.

(4) Explain double circulation in human.

3. Write short note.

(1) Blood Plasma

(2) Rh Groups

(3) Lymph

(4) Human Circulatory System

(5) Internal structure of heart (with diagram)

(6) ECG

(7) Hypertension

4. Sketch and label only.

(1) External structure of heart

(2) Internal structure of heart.

8

Excretory Products And Their Elimination

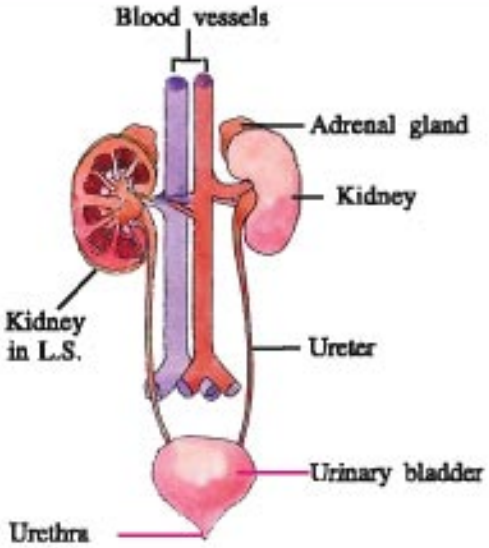
In a broad sense excretion means the separation and elimination of waste material from the body. But in a limited sense the term excretion is applied to the removal of unwanted nitrogenous substances of the body. The waste material is of several kinds and varies from animal to animal and even in the same animal time to time. The difference in the nature of waste substances in animals is correlated with the metabolic processes. Ammonia, urea, uric acid and like substances are eliminated partially or completely from the body.

In this chapter, you will study the mechanisms of removal of above mentioned substances with special emphasis on common nitrogenous wastes. The major nitrogenous wastes like ammonia, urea and uric acid are excreted by animals. Ammonia is the most toxic and can be eliminated with large amount of water. Thus the nature of nitrogenous waste and their excretion depend on the availability of water. Based upon the type of excreted nitrogenous waste, animals are broadly classified into three groups : ammonotelic, ureotelic and urecotelic.

Ammonia is formed as a result of the deamination of amino acid. The process of excretion of ammonia is called ammonotelism. In nature many aquatic insects, bony fishes and tadpole are ammonotelic. Ammonia, as it is rapidly soluble, is generally excreted by diffusion through body surface or in fish across the gill surface, thus kidneys do not take any part in its removal. The production of less toxic nitrogenous waste like urea and uric acid by land vertebrates is adaptation for conservation of water. Animals which excrete urea are called ureotelic animals eg. mammals, marine fishes and many terrestrial amphibians. Ammonia is converted into urea in the liver of these animals and released into the blood which is filtered and excreted out by kidneys. To maintain osmoregulation by these animals they retain certain amount of urea in kidney matrix. To minimize loss of water the reptiles, birds, insects and land snail excrete nitrogenous waste as uric acid in a form of paste or pellet. These animals are called urecotelic. A survey shows that among animals special excretory organs are usually present in the body for the elimination of waste material, that you have studied in semester-1. Utilization of water and consumption of energy for elimination of waste product are inversely proportional.

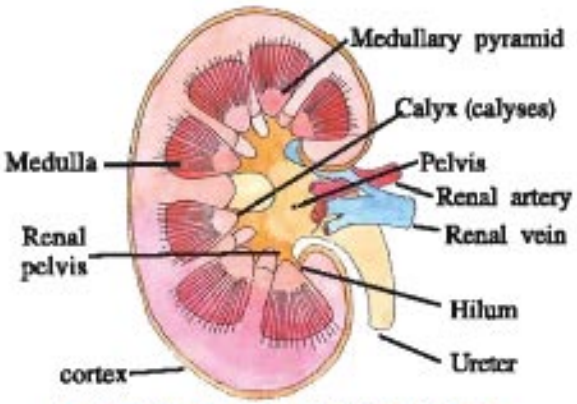
Human Excretory System

The excretory organs are a pair of kidneys, one pair of ureter, urinary bladder and a urethra in human. Kidneys are reddish-brown bean shaped structures placed one on either side of the median vertebral column in the lumbar region. Each kidney is about 10 cm long, 5 cm wide and 3 cm thick. In adult, it weighs about 125-170 gm. The two kidneys are not placed at the same level. The right kidney is slightly on a lower level than the left. This is due to the fact that the right side of the abdominal cavity is occupied by liver.



Human excretory system

The outer surface of the kidney is convex while inner is concave. The longitudinal opening found in the middle of the inner concave region is known as, the hilum, through which nerves and renal artery enter and ureter and renal vein leave the kidney. Inner to the hilum is a broad funnel shaped cavity called the renal pelvis with projections called calyces.

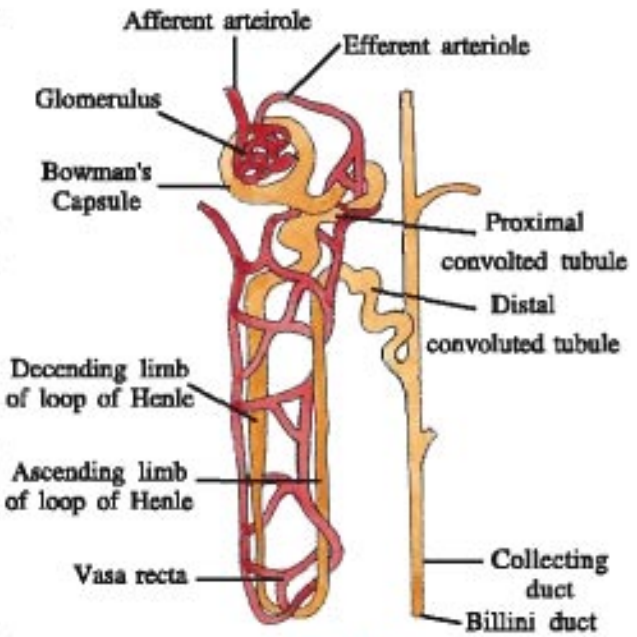


Longitudinal section (L.S.) of Kidney

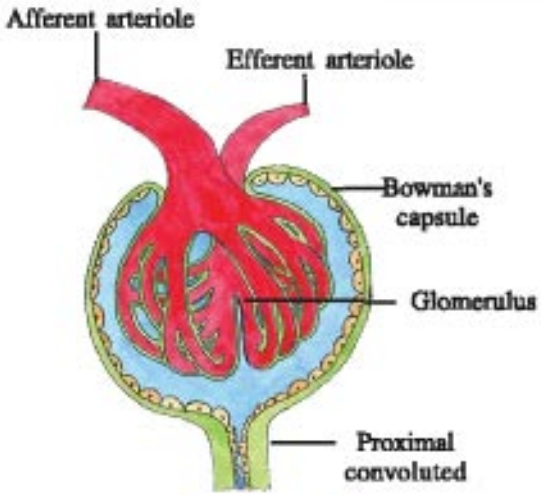
Each kidney is enclosed in a tough, thin, fibrous, whitish capsule. Examining the vertical section of the kidney we find two distinct regions of the kidney. An outer dark red zone the renal cortex containing the nephrons where urine is formed. An inner zone, the renal medulla is differentiated to form a number of cone like structure known as medullary pyramids. Renal pyramid extend as calyx. The cortex extends in between the medullary pyramids as renal columns called columns of Bertini.

Each human kidney is containing about a million nephrons. Nephrons are referred to as the structural and the functional units of the kidney. Each nephron is about 3 cm long and 20-30 µm in diameter. Nephron consists of malpighian corpuscle and a long renal tubule. Malpighian corpuscle comprises glomerulus and Bowman's capsule.

A tuft of capillaries present in Bowman's capsule is known as glomerulus. Glomerulus is formed by the arteriole (a fine branch of renal artery). The blood from the glomerulus carried



A nephron



Malpighian body

away by an efferent arteriole. The filtration of blood takes place in glomerulus. Bowman's capsule is a double walled cup shaped structure.

The lumen of the capsule is continuous with the narrow lumen of renal tubule. Bowman's capsule is formed of two layers, outer parietal layer and inner visceral layer. The malpighian corpuscle is followed by portion called the neck. The neck leads into highly coiled network proximal convoluted tubule (PCT). The proximal convoluted tubule, a 'U' shaped region is known as a Henle's loop. Henle's loop is formed of two limbs, a thin descending limb is lined with flat epithelial cells, while thick ascending limbs is lined with cuboidal epithelium. The ascending limb continues as other highly coiled and twisted tubular part known as distal convoluted tubule (DCT). It is present in the cortex region which is lined by cuboidal epithelium and opens into collecting tubule. Many collecting tubules open into a large duct called Bellini duct, which opens into renal pelvis. Many collecting ducts join to form the large Bellini duct. Urine collected from the nephron is drains into the pelvis. The formation of urine takes place only in the nephron, while the collecting tubules simply carry the urine to the pelvis for removal.

Types of nephrons

Nephrons are of two types according to their position. **(1) Juxta medullary nephrons** are of about 15% of total nephrons. These nephrons are large in size. Their loops are associated with vasa recta. The blood first passes through the capillaries of glomerulus, and then passes through the vasa recta of the loop of Henle.

(2) Corticle nephrons are of about 85% of total nephrons. They mostly lie in the renal cortex. The loops of Henle are short and extended to a short distant into the medulla. Vasa recta are absent or reduced. The efferent arteriole comes out from the glomerulus and forms a capillary network. Surrounding renal tubule it is known as peritubular capillaries. A small vessel of this network runs parallel to the loop of Henle's forming a 'U' shaped vasa recta.

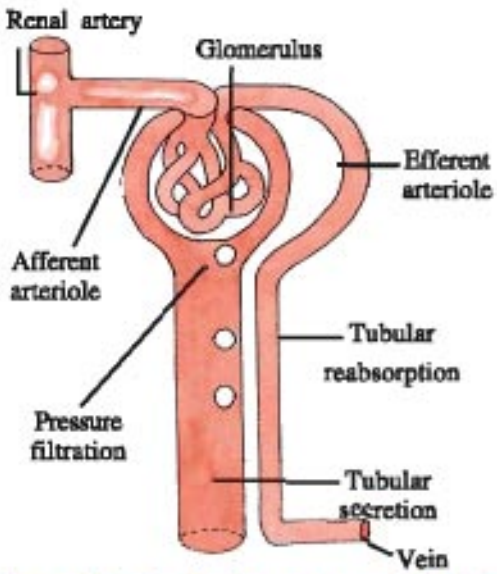


Diagram showing the three processes of urine formation in different parts of a nephron

Urine formation : Urine formation involves three main processes which include glomerular filtration, selective re-absorption and tubular secretion, take place in different parts of the nephron.

Glomerular filtration : The filtration of blood which is carried out by the glomerulus is known as glomerular filtration. It takes place at the rate of on an average 1100 to 1200 ml/min. blood is filtered by kidneys per minute.

The glomerular capillaries are much narrow than the afferent renal arterioles. Thus the blood pressure is very high in the glomerular capillaries, so there is continuous process of filtration under pressure.

Some epithelial cells of the Bowman's capsule are known as podocytes. These podocytes are arranged in a

complicated manner so as to leave some small space known as filtration slits. The blood is filtered through very thin membranes. Thus many substances and water from blood are filtered into lumen of the Bowman capsule. The glomerular filtrate contains large amount of water and other substances. The quantity of filtrate formed per minute in all nephrons of both the kidneys is called as **glomerular filtration rate** (GFR). GFR in a healthy individual is about 125 ml/minute.

Selective reabsorption : The volume of the filtrate per day is 180 liters compared to which the urine released per day is about 1.5 liters. It means about 99% of the filtrate is reabsorbed by the process of re-absorption.

The glomerular filtrate when flows through proximal convoluted tubules, water, solutes like glucose, amino acids, vitamins, sodium chloride, and sodium bicarbonate in the filtrate are re-absorbed in to the blood by active or passive mechanism. The remaining substances in the filtrate are waste products to be excreted.

Tubular Secretion : In process of urine formation, the tubular cells secrete substances like H^+, K^+ and ammonia into the filtrate for the maintenance of ionic and acid balance of body fluid. The tubular secretion is an important step in process of urine formation. The filtrate progressing from the proximal convoluted region becomes more concentrated in Henle's loop. It has been noted that as the length of Henle's loop increases, urine becomes more concentrated.

Tubular secretion occurs in the distal convoluted region. Such substances are secreted in the cavity of uriniferous tubule which have not been transported through the glomerulus. Ammonia, uric acid, hydrogen ions and medicinal drugs like penicillin are secreted in this way.

Thus urine is prepared which flows into collecting tubules. Finally,this concentrated urine is emptied into renal pelvis.

Functions of the tubules : Glomerular filtrate, almost identical to plasma, gradually filtrate its character as it passes down the renal tubule. During this transport constitution of filtrate changes and formation of urine takes place.

(1) Proximal convoluted tubule (PCT) : PCT is lined by cuboidal brush border (having microvilli) epithelium which increases the surface for re-absorption of filtrate. Nearly two-third of the water and NaCl in the filtrate are re-absorbed by these segments. The PTC also helps to maintain a constant pH in body fluid by the secretion of H^+ and by re-absorbtion of the buffer HCO_3^- from the filtrate. Drugs, ammonia and other toxic substances are secreted into filtrate in this segment. The filtrate is isotonic blood plasma.

(2) Descending limb of the loop of Henle : This segment is permeable to water but nearly impermeable to salts. Also helps to concentrate NaCl in the filtrate. The filtrate is hypertonic to blood plasma.

Ascending limb of the loop of Henle : This segment is in fact impermeable to water but permeable to electrolytes and transports them actively or passively. Thus as the concentrated filtrate pass as upwards, it gets diluted due to the diffusion of electrolytes out to the medullary fluid.

Distal convoluted tubule (DCT) : In this segment the re-absorption of water, Na^+ etc. takes place. DCT also reabsorbs the HCO_3^- for the maintenance the pH and sodium potassium balance in blood.

Collecting tubule : The collecting tubule is long duct extends from cortex to the inner part of the medulla. Large amount of water is re-absorbed in these segments to make urine concentrated. The bottom portion of tubule is permeable to urea. Collecting tubule plays an important role in the maintenance of pH and ionic balance of blood by the secretion of H^+ and K^+ ions.

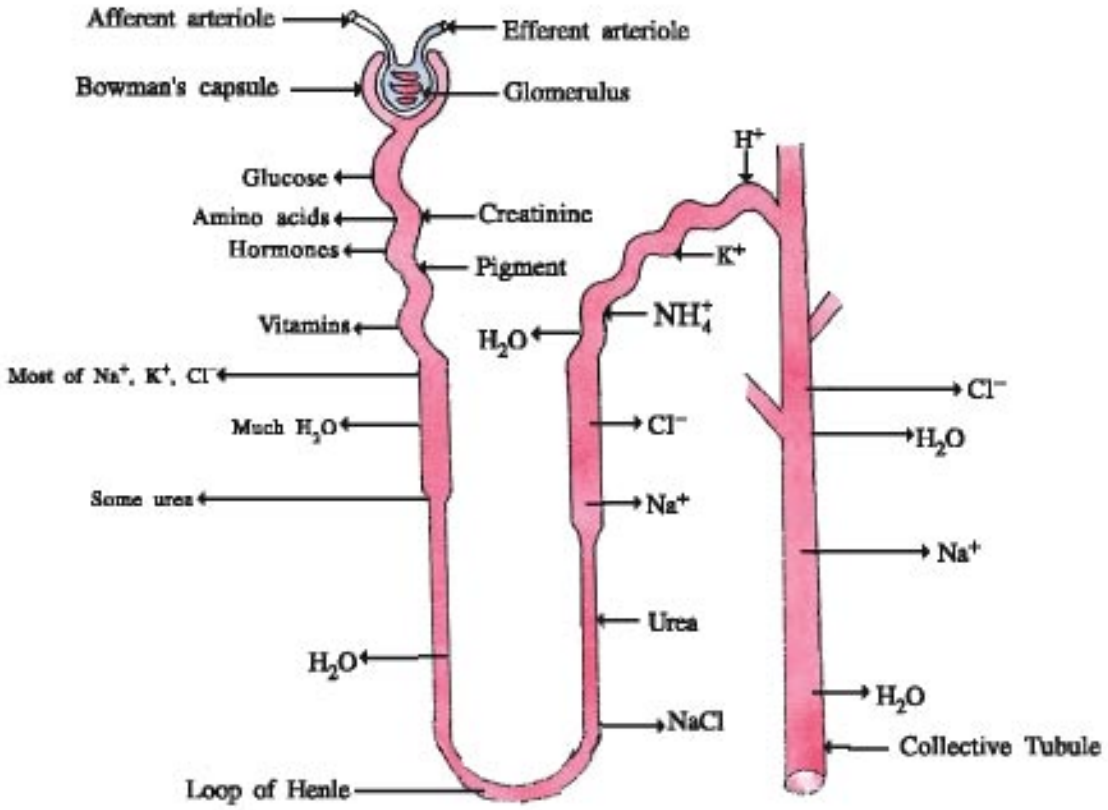


Figure shows how urine is formed from filtrate

Mechanisms of concentration of the filtrate :

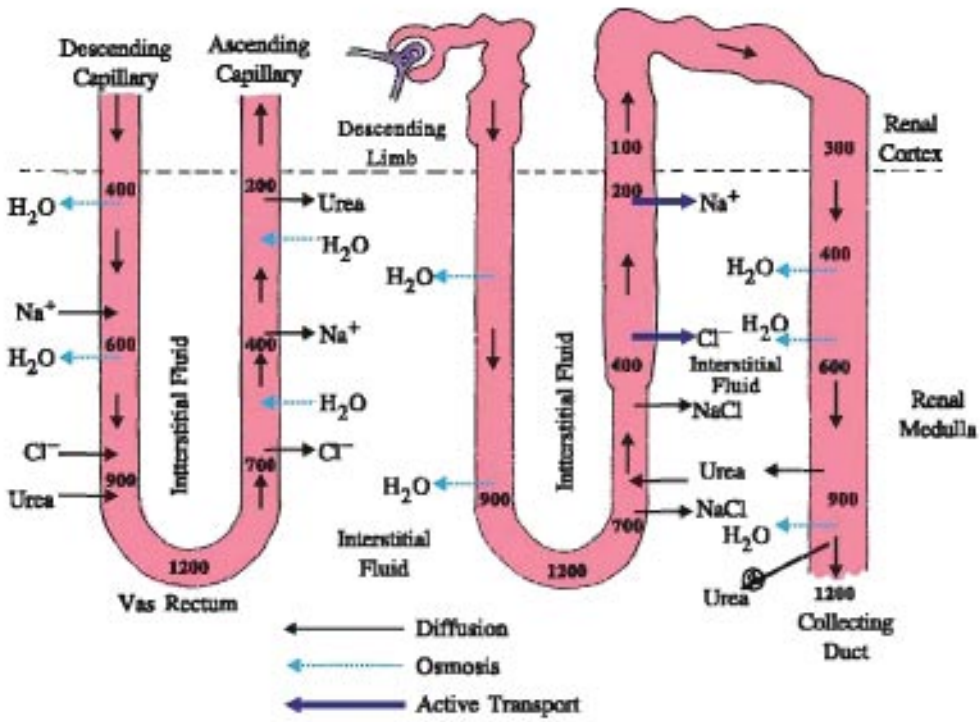
For the concentration of urine the kidney has a mechanism that is known as concentration mechanism. The birds and mammals have the ability to excrete concentrated hypertonic urine (more concentrated than blood). For this they have evolved a counter current mechanism, for conservation of water. Henle's loop and vasa recta (capillary in the form of loop) play a significant role in it. The flow of filtrate in the two limbs of Henle's loop is in opposite direction which forms a counter current. The flow of blood in the two limbs of vasa recta is also in opposite direction and thus forms a counter current. Thus these two counter current systems play an important role in concentrating the urine.

The proximity between the vasa recta and loop of Henle and the counter current in them help in maintaining an increasing osmolarity towards the inner medullary interstitial fluid. i.e. from 300 mOsmol/ L in the cortex to about 1200 mOsmol/L in the inner medulla. This gradient is mainly caused by NaCl and Urea. In the interstitial fluid concentration of the solutes increases which draws out water by osmosis from collecting duct and also from the narrow region of the descending limbs, both being permeable to water.

Henle's loops : When the filtrate passes through the ascending limbs of the Henle's loop, it loses NaCl by diffusion in its narrow region to the interstitial fluid in the renal medulla and Na^+ and Cl^- ions by active transport in its wide region of the ascending limbs.

The water so drawn enters the vasa recta and is transported away. The interstitial fluid in the medulla is nearly as concentrated as the urine leaving the collecting duct.

Vas Rectum : The walls of the vasa recta is made up of endothelial cells and are freely permeable to water, urea and ions. Blood flows from ascending capillary towards water is drawn out by the process of osmosis from the blood and there will be an increase in the concentration of the interstitial fluid, by diffusion of urea and Na^+ and Cl^- enters the blood plasma. As the blood enters in the ascending capillary towards the renal cortex, the reverse condition occurs. It means water re-enters the blood plasma while urea and Na^+ and Cl^- drawn out due to a decrease in the concentration of interstitial fluid. The counter current exchange in the vasa recta : (A) prevent the loss of sodium and chloride ions from the renal medulla and (B) helps to maintain concentration gradient in the renal medulla. Certain urea diffuses from the last part of the collecting duct into interstitial fluid, to increase density which increases water re-absorption from the bottom of Henle's loop as well as from collecting duct.



The function of counter-current mechanism is to maintain high concentration in surrounding nephrons and collecting ducts. Thus hypertonic urine is produced in human. Thus urine produced is nearly four times concentrated than the initial filtrate formed.

Regulation of kidney function :

The function of the kidney is efficiently monitored and regulated by hormonal feedback mechanisms involving mainly hypothalamus, pituitary, JGA (Juxtaglomerular Apparatus) and heart at certain extent. Two important hormonal negative feed back controls of the kidney function regulation are known. The vertebrate kidney is flexible mechanisms in its functioning. When water is abundant in the body tissue kidney excretes large quantity of dilute urine, and when body tissues are short of water small quantity of concentrated urine is excreted. The regulation of water and solute content of the body fluid by kidney is known as osmoregulation. Change in ionic concentration, blood volume and volume of body fluid activate the osmoreceptor in the body. Excessive loss of fluid from the body

activates these receptors which stimulate the hypothalamus to release antidiuretic hormone (ADH vasopressin) from the posterior pituitary. ADH facilities water re-absorption from posterior parts of the tubules and thus prevent diuresis. An increase in volume of body fluid, can switch off the osmoreceptors and suppress the ADH release to complete the feedback.

Micturition

Urine is formed and drained continuously by the nephrons is ultimately carried down the ureters by peristaltic movement and then carried into urinary bladder. The function of bladder is to store urine temporarily till a voluntary signal is given by central nervous system (CNS). This signal initiates the stretching of the urinary bladder as it gets filled with urine. In response, the stretch receptors on the walls of the bladder send signals to the CNS. The CNS passes messages to initiate the contraction of smooth muscle of the bladder and relaxation of the urethral sphincter surrounding the opening of the bladder which causes release of urine.

Thus the process of release of urine from bladder is called micturition or urination and the neural mechanisms causing micturition is known as the micturition reflex. Contraction and relaxation of the bladder are caused by impulses from the sympathetic and parasympathetic nerve fibres. An adult man excretes, on an average 1 to 1.5 liters of urine per day.

The normal urine is a light yellow coloured watery fluid which is slightly acidic (pH – 6.0) and with a characteristic odour. Per day on an average, 25 – 30 gm of urea is excreted. Analysis of urine helps in clinical diagnosis of disorders and malfunctioning of the kidney eg. Presence of glucose (Glycosuria) in urine indicates the diabetes.

Role of other organs in Excretion

Other than kidneys, skin, lungs and liver help in the elimination of excretory wastes. Many aquatic animals like starfish and Hydra excrete ammonia into surrounding water through skin by diffusion. Mammalian skin also play role in excretion with the help of sebaceous and sweat glands. Sebaceous glands discharge waxes, sterols, fatty acids and hydrocarbons which is collectively known as sebum. It lubricates the hair and prevents drying up of skin and wetting of hair, while sweat gland secretion is watery and stimulated by increase in body temperature. The secretion consists of water, salts, mainly Nacl, urea, lactic acid, little amino acids, which discharge on the surface of skin.

Lungs : During respiration carbon dioxide and water vapour produced in body are regularly eliminated through lungs. About 18 liters of CO_2 and about 400 ml of water per day are removed by human lungs. In aquatic animals gills remove CO_2. In the saliva drugs, heavy metals and probably small amounts of nitrogenous waste could be eliminated.

Disorders of the excretory system

Uremia : Presence of an excessive amount of urea in the blood leads to uremia. It occurs due to bacterial infection (nephritis) or some mechanical obstruction. Excretion of urea by kidney decreases. Uremia is highly harmful and may lead to kidney failure. Urea can be removed by a process called hemodialysis. Haemodialyzer (Artificial kidney) is a machine that is used to filter the blood of a person whose kidney is damaged. Haemodialzer is a cellophane tube suspended in haemodializing solution having same content as the normal blood plasma except urea. Patient's blood is pumped from one of the arteries into the cellophane tube after cooling it to 0°C and mixing with a heparin (anticoagulant) from the pores of the cellophane tube urea, uric acid, creatinine and excess of salts

diffuse out from the blood into the surrounding solution. Thus blood is purified and it is then pumped into vein of the patient after adding anti-heparin to it. Hemodialysis method is a blessing for thousands of uremic patients.

Kidney failure : Partial or total inability of kidney to carry excretory functions is known as kidney failure. Many factors can cause kidney failure. These include infection tubular injury, bacterial toxins, drug reaction etc. Dialysis should be started immediately after diagnosis.

Renal calculi : Stones or insoluble masses of crystallized salts are formed by oxalate or uric acid precipitation formed in the kidney stone. It blocks the kidney tubules. It causes severe back-pain. The stone may pass into urinary bladder and cause severe pain. Surgery may be done to remove stone.

Nephritis : It is an inflammation of renal pelvis interstitial tissue and calyces. It is due to bacterial infection. Bacteria reach kidney via urethra and ureter. Inflammation affects the counter current mechanism disease. Back-pain and painful and frequent urination are its symptoms.

Summary

Many nitrogen containing substances, CO_2, ions and water etc. that accumulate in the body have to be discharge regularly. Nature of nitrogenous wastes formed and their excretion is different among animals, mainly depending on the water availability. Nitrogenous materials are the major waste products which include ammonia, urea and uric acid. Beside removal of nitrogenous waste it helps in maintenance of ionic and acid base balance of body fluids.

In human, the excretory system consists one pair of kidneys, a pair of ureters, a urinary bladder and a urethra. Each kidney has over millions of nephrons. Nephron is the functional unit of kidney and has two parts : Malpighian corpuscle body and renal tubule. Glomerulus is a tuft of capillaries formed from afferent arterioles, fine branches of renal artery. The Bowman's capsule encloses the glomerulus to form malpighian body.

The renal tubule starts with Bowman's capsule which is double wall and is further differentiated into a proximal convoluted tubule (PCT), Henle's loop (HL) and distal convoluted tubule (DCT). The DCT of many nephrons unite to form a common collecting duct which opens into the renal pelvis passing through the medullary pyramids. Filtration, selective re-absorption and tubular secretion are three main processes of urine formation. Filtration process performed by the glomerulus using the glomerular capillary blood pressure.

Through different parts of nephrons mostly 99% re-absorption of the filtrate takes place. The major site of re-absorption and selective reabsorption is PCT, while Henel's loops helps to maintain osmolar gradient. DCT and collective duct allow widely re-absorption of water and certain electrolytes, which maintain, osmoregulation. H^+, K^+ and NH_3 could be secreted into the filtrate by the tubules to maintain pH of body fluid and ionic balance between the Henle's loop and those of vasa recta. It is by counter current mechanism. The filtrate becomes concentrated as it carried down the descending limb but is diluted by the ascending limb.

In urinary bladder urine stored, until a voluntary signal from CNS carried out and urine is release through urethra which is known as micturition. Lungs, skin and liver are also additional excretory organs.

Exercise

1. Put a dark colour in a given circle for correct answer.

(1) Uric acid is excreted by

(a) Frog ○ (b) Rabbit ○ (b) Man ○ (d) Pigeon ○

(2) Cells named podocytes occur in

(a) Glomerulus of kidney ○ (b) Wall of capillaries ○

(c) Neck of nephron ○ (d) Wall of Bowman's capsule ○

(3) Reabsorbtion of water in the kidney is mainly controlled by ..... .

(a) Aldosterone ○ (b) Antidiuretic hormone (ADH) ○

(c) Oxytocin ○ (d) Growth hormone (GH) ○

(4) In micturition

(a) Urethra contracts ○ (b) Urethra relaxes ○

(c) Ureters contract ○ (d) Ureters relax ○

(5) Antidiuretic hormone (ADH) ..... .

(a) Increases water reabsorption ○ (b) Increases water release ○

(c) Increases Na^+ reabsorption ○ (d) Decreases urea synthesis ○

(6) Presence of urea in the blood is called ..... .

(a) Uraemia ○ (b) Haematuria ○

(c) Diurea ○ (d) Anuria ○

(7) An accessory excretory organ is

(a) Heart ○ (b) Stomach ○

(c) Liver ○ (d) Pancreas ○

(8) Presence of glucose in urine is ..... .

(a) Glycosuria ○ (b) Haematuria ○

(c) Oligourea ○ (d) Anuria ○

2. Answer the following questions in short :

(1) How is urea formed in the animal body ?

(2) Name the three common nitrogenous waste materials in vertebrates. Which of these is most toxic and which is least toxic ?

(3) How do lungs help excretion ?

(4) What are ureotelic animals? Which of the following are ureotelic ? Hydra, Frog, Cockroach, Man, Birds.

(5) What are ammonotelic animals ? Give two examples

3. Do as directed :

(1) Write a note : Haemodialysis

(2) Where do ultrafilteration, reabsorption and secretion occur in nephorn ?

(3) Explain the process of micturition

(4) Describe the mechanism of ultrafiltration in Bowman's capsule

4. Answer the following questions in detail :

(1) Explain the mechanism of urine formation in human kidney.

(2) Describe the role of ADH in urine formation.

5. Sketch and labeled only :

(1) Excretory system in man.

(2) Internal structure of kidney.

(3) Ultrastructure of nephron.

9

Locomotion and Movement

Movement is one of the significant features of all living organisms. Animals and plants exhibit a wide range of movements. At the cellular level the cytoplasm shows streaming of protoplasm in the unicellular organisms like Amoeba. It is a simple form of movement. Movement of flagella, cilia and tentacles are shown by many living animals. Human beings can move jaws, eyelids, tongue, limbs etc. Some of the movements bring in a change of place or position, such voluntary movements are called locomotion. Plants move their parts by phototropism and geotropism.

Running, walking, flying, swimming, climbing are all some sort of locomotory movements. Locomotory structures are different from those affecting other types of movements. For example, in Paramoecium cilia help in locomotion and in the movement of food through cytopharynx as well Hydra can use their tentacles for capturing its prey and also use them for locomotion. The human use their limbs for changes in body postures and locomotion also as such. It is very difficult to separate movement from locomotion. The above remark gives a hint that movement and locomotion cannot be studied separately. These two may be linked by stating that all locomotion are movements but all movements are not locomotion. In animals locomotion is closely related to movement. Animals are different with their habitats and according to demand of the situation. Thus, locomotion is commonly for shelter, search of food, escape from enemies or predators, mate, suitable breeding grounds or favourable climate conditions.

Type of movement :

The act of changing place or position by the entire body or by one part or more of its part is called movement. Cells exhibit three main basic type of movements, namely amoeboid, ciliary and muscular.

Amoeboid type's movement is found in Amoeba as well as in some specialized cells in our body like macrophages and leucocytes in blood. In Amoeba this movement helps in food collection and change of place also. Movement is effected by pseudopodia formed by the streaming movement of protoplasm. Cytoskeleton elements like microfilaments also exhibit amoeboid movement. Ciliary movement occurs in trachea, oviducts and vasa efferentia, propelled by their lashing movements. The

coordinated movements of cilia of the upper respiratory track of human help in removing dust particles, some foreign substance involved and microbes invading out. The cilia of the oviduct and vasa efferentia of human transport eggs and sperms respectively in specific direction in these organs. Paramoecium as a animal shows ciliary movement for different functions.

Movement of our limbs, jaws, tongue etc. require muscular movement. The contractive property of muscle is used for locomotion. It also takes place in lower animals having no skeleton. Muscular locomotion required a perfect arrangement, interaction and coordination of the nervous, muscular and skeletal system of body in higher animals like vertebrates. In this chapter, you will study about types of muscle, their structure, and mechanism of their contraction and important aspects of the skeletal system.

Muscle :

Muscle is a specialized tissue of mesoderm origin. In adult humans, it constitutes about 40 – 50 percent of the total body weight. Muscle has some distinguishing properties like ability to conduct (impules), excitability, contractibility, extensibility and elasticity. The electrical excitability is due to the energy stored in an electrical potential difference across the plasma membrane. Muscles have been classified using different criteria, namely location, appearance and nature of their activities. Based on their location three types of muscle are classified.

(1) Skeletal or striated or voluntary muscles.

(2) Smooth or non-striated or involuntary or visceral muscle

(3) Cardiac muscle

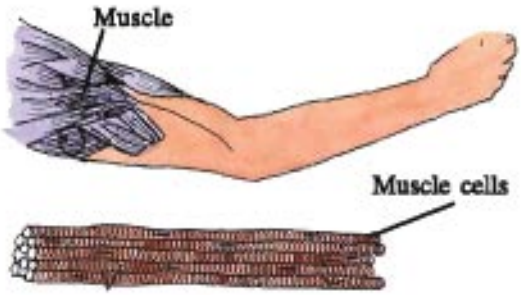
Skeletal muscle :

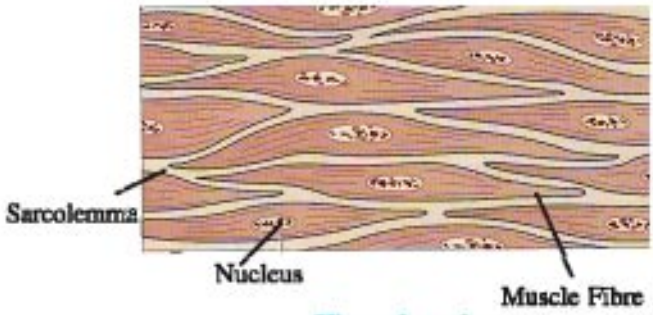
The skeletal muscles are generally closely attached to skeletal components like head, trunk and limb region, hence they are called skeletal muscles. Under the light microscope, these skeletal muscles exhibit transverse stripes appearance, therefore, they are also called striated muscles. As their activities are under the voluntary control of the nervous system, they are also known as voluntary muscle. Skeletal muscles are responsible for locomotory actions and change in body postures.

Visceral muscles are located in the inner walls of hollow visceral organs of the body such as alimentary canal, reproductive track, and respiratory organs. They do not show any striation and are smooth in appearance. Hence they are known as smooth or non-striated muscle. Smooth muscle fibre are of spindle shaped. These are involuntary and are innervated by autonomous nervous system. These muscles help in the movement of the substances through the canals of organs.

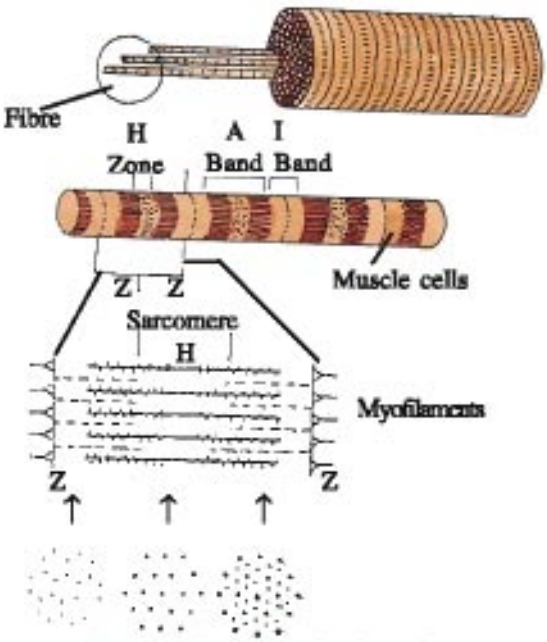
Cardiac muscle :

Cardiac muscles are exclusively found in the wall of the heart and maintain rhythmicity of heart beat. A cardiac muscle cell is short cylindrical, uninucleated, branched and striated. Every cardiac muscle cells are connected to each other known as intercalated disc by a special zigzag junctions. They are involuntary in nature as the nervous system does not control their activities directly. The cardiac muscles are innervated by autonomous nervous system. The cardiac muscles contract quickly, rhythmically, powerfully. The indefatigable fibers join by short oblique bridge and their blood supply is abundant.

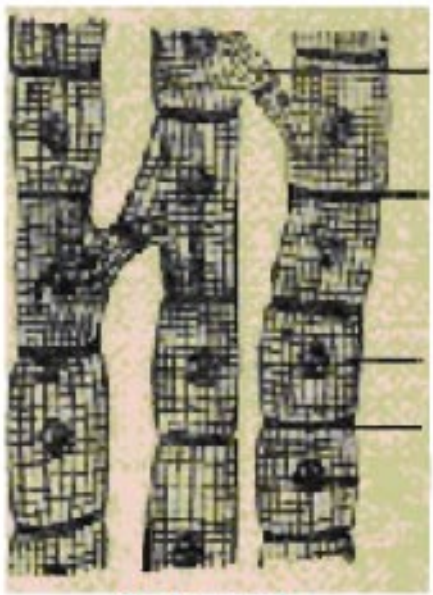




Visceral musle



Organisation of skeletal muscles



Cardiac muscle

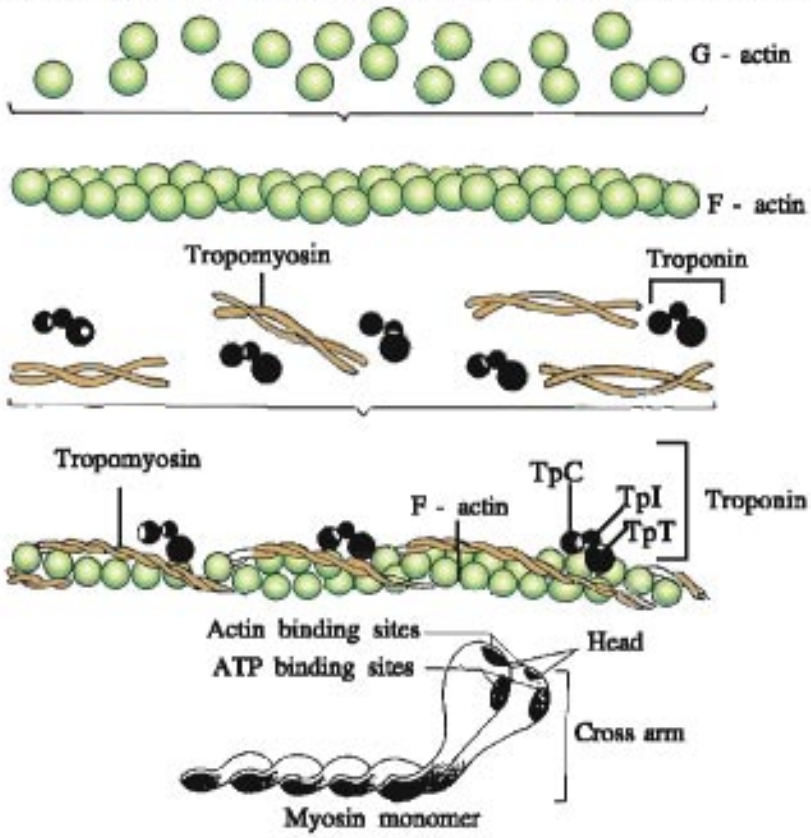
Ultra structure of skeletal muscle

Let us study a skeletal muscle in detail to understand the structure and mechanism of contraction. It consists of numerous fibres. Each muscle fibre is an elongated, narrow, cylindrical and un-branched and contains many flattened, elongated nucleus located near the sarcolemma. Multinucleate condition results from cell fusion. Thus a skeletal muscle fibre is syncytium. Sarcoplasm contains mitochondria known as sarcosome. The sarcoplasma contains endoplasmic reticulum known as sarcoplasm reticulum. It contains a large number of fine and rod-like myofibrils. A myofibril has light and dark bands. The light bands are isotropic (having same refractive index in all planes) and are known as isotropic or I-band.

The dark bands are anisotropic (refract light differently in different plane) and are known as anisotropic or A bands. Each A band possesses a light zone in its centre which is known as Hensen's line or H-Zone. In the centre of the H-zone is the M-line. In the centre each I band has a dark membrane known as Z-line. The Z-line is also known as Z-disc or membrane of Krause. The part of the myofibril between two successive Z-lines is known as sarcomere. Thus sarcomere consists of the A-band in the centre and half I-band on both the sides. It is contractile and a functional unit of myofibril. In each sarcomere thin filaments (actins) are located at the two ends, while the thick filaments (myosins) are present in the centre. Thus each sarcomere is a bundle of thick and thin myofilaments. The thick and thin filaments are alternately arranged. The I band contains only thin filament while H-zone contains only thick filaments. While A-band has both thick and thin filaments at both the ends.

Structure of contractile proteins

Actin filaments occur in two forms, the monomer G-actin and the polymeric 'F' actin. G-actin polymerizes in presence of Mg^{2+} to the fibrous form F-actin. Two filaments of another protein, tropomyosin also run close to 'F-actin' throughout its length. Tropomyosin is a rod-shaped fibrous protein. Tropomyosin forms two helical strands, which are wrapped around the F-actin. Troponin is a complex small globular protein which is distributed at regular intervals on the tropomyosin. In the resting state a subunit of troponin makes the active binding sites for myosin on the actin filaments.



(TpC : Troponin C, TpI : Troponin I, TpT : Troponin T)

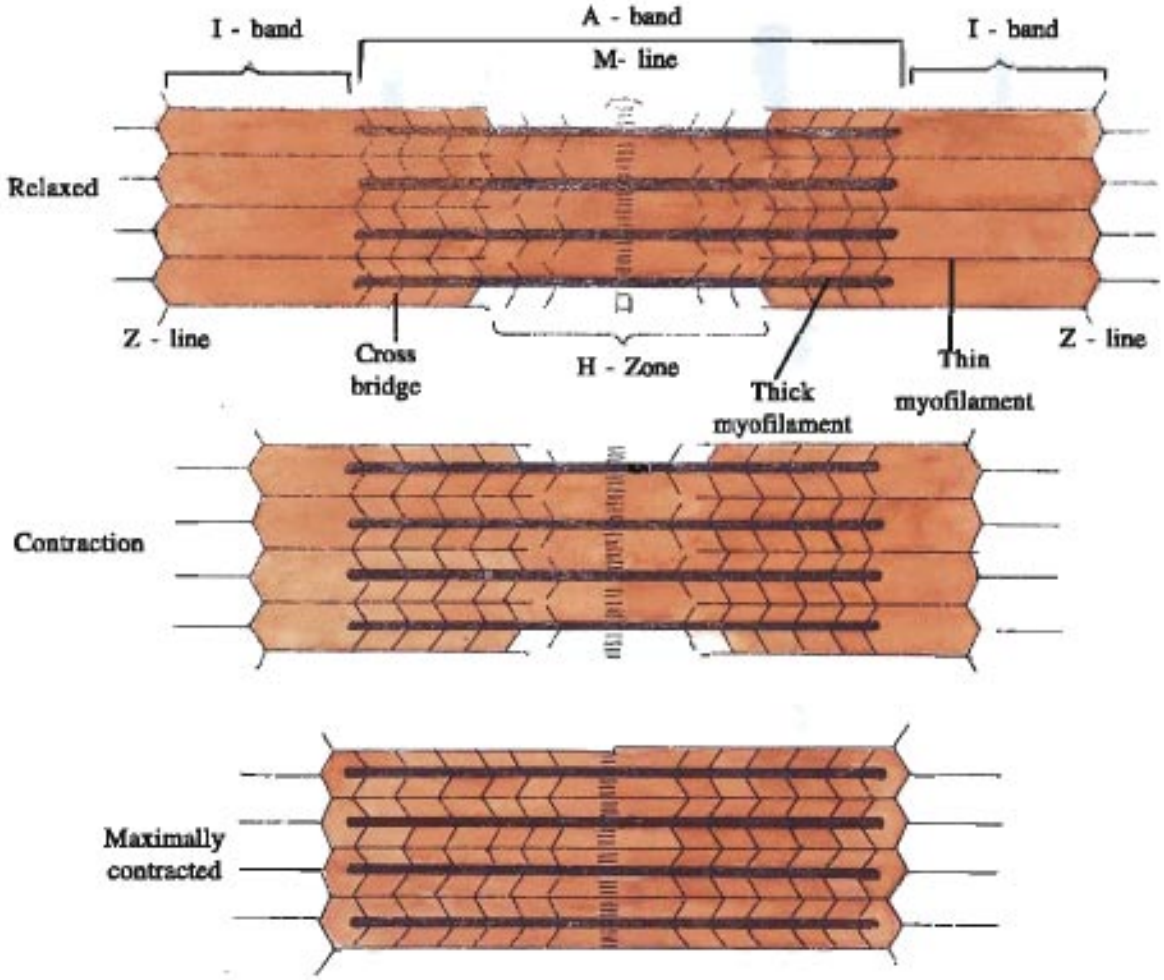
Figure showing contractile protein

Each myosin filament is also a polymerized myosin protein contend to A band only. Many monomeric proteins known as meromyosin form one thick filament. Each myosin molecule has two important components, a globular head with a short arm, and a tail. The tail is formed of a light meromyosin (LMM) while the head is form of heavy meromyosin (HMM). The HMM component projects outward at an angle from a polymerized myosin filament at regular distance which is known as cross arm. The globular head has ATPase action and binding sites which has site for attachment with ATP and actin.

Mechanism of muscle contraction

Mechanism of muscle contraction is explained by the sliding filament theory. According to this theory the contractile units of muscle composed of thick and thin filaments which overlap somewhat in relaxed muscle. On stimulation when muscle contract. The length of filament does not change but merely slide over one another. Thus actin filaments slide in the space between the myosin filaments. Due to I-band or light band shorten, while there is no change in the A or dark band. But disappearance of H-Zone in dark band may be seen. This is because two Z-line come close to each other. It is thought that the cross bridges on the myosin filaments might pull the actin filaments, during muscle is contracted

and during relaxation of muscle these cross bridge disappear. Thus contraction and relaxation of muscles are brought about by the repeating formation and disappearance of cross-bridges between myosin filaments of A band and actin filaments of I-band.



Sliding filament theory of muscle contraction Events during muscle contraction.

Muscle contraction is initiated by a signal sent by the central nervous via motor neuron. The junction between a motor neuron and the sarcolemma of the muscle fibre is known as neuromuscular junction or motor-end plate. A neural signal reaching this junction releases a neuro transmitter, the acetylcholine, which potential spreads deep into muscle fibre and causes the release of calcium ions into the sarcoplasm. Calcium activates the interaction of myosin and actin, but only through the intervention of tropomyosin and troponin utilizing the energy produced by ATP hydrolysis. The myosin head now binds to the exposed active site of actin to form a cross bridge. It pulls the attached actin filaments towards the centre of 'A' band, the Z line attached to their actins are also pulled in wards thus causing a shortening of sarcomere. i.e. contraction. The myosin, releasing the ADP and P_i goes back to relaxed state. A new ATP binds and the cross-bridges is broken. The most significant molecular basis of muscle contraction is formation and breakage of cross-bridge which is repetitive. These cross bridge are formed in between the myosin filament of A-band and Actin filament of I band. These two sets of filaments start movement passing on one another and causing in the shorting

of sarcomere. It is fact that cross bridge is formed only in absence of ATP. While breaking of cross bridge is in presence of ATP.

The duration of process is till the Ca^{2+} are pumped back to the sarcoplasm resulting in the masking of actin filaments. Thus the return of 'Z' line back to original position. i.e. relaxation. Thus relaxation is brought about when the Ca^{2+} ions concentration is reduced. In different types of muscles the reaction time of the fibres can vary. Prolong time activation of the muscles can lead to the accumulation of lactic acid because of anaerobic breakdown of glycogen in them causes fatigue. The muscle which does not respond to stimuli, is said to be a state of fatigue.

Skeletal muscle

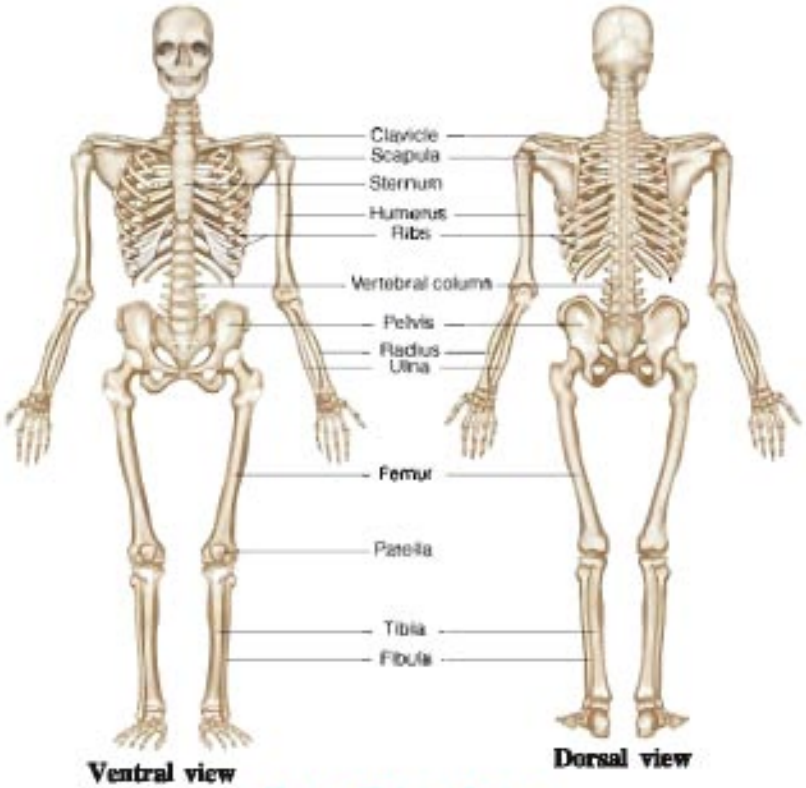
The skeletal muscle are of two types, red and white muscle. In red muscle there is the presence of very high amount of myoglobin, which gives a reddish appearance. Such muscles are also known as red fibres. The red fibres also contain large amount of mitochondria, which can utilize the large amount of oxygen stored in them for ATP production. These muscles thus also known as aerobic muscle eg. Red muscle, flight muscle of birds. The white muscles contain low amount of myoglobin, hence they appear pale or whitish. The white fibres contain small amount of mitochondria, but the quantity of sarcoplasmic reticulum is high eg. Muscles of eye ball of human.

Skeleton System :

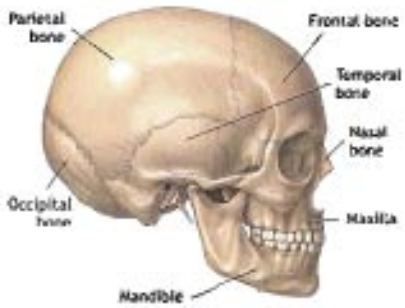
The hard, supportive or protective elements of the animal body form the skeleton or skeletal system. The study of skeleton is called osteology. (osteon = bone, logs = discourse). The greater number of animals have some skeleton. Skeleton may vary from simple spicules of sponges to complex frame work of vertebrate. Design of the skeleton depends on the animal's mode of life. Different design of skeleton is necessary for the terrestrial or aquatic animals, bipedal or quadrapedals and for flying. Skeletal system consists of bones and a few cartilages. This system has an important role in movement shown by the body. Bone and cartilage are specialized connective tissues. The bones have a very hard matrix due to calcium salts while cartilage has a slightly pliable matrix due to chondroitin salts. In human beings this system is made up of **206** bones and a few cartilages. It is grouped into the principal division – the axial and appendicular skeleton.

Axial skeleton :

It is made up of **80** bones distributed along the main axis of the body. Axial skeleton constitutes the skull, vertebral column, sternum and ribs. The skull consists main regions cranium and face, composed of two sets of bones, cranial and facial bones, the total bones are **22**. Cranium possesses **8** flattened bones, which are tightly interlocked, forming a box called cranium. The bones which forms cranium are: 1 frontal bones, 2 parital bones, 2 temporal bones, 1 occipital bone, 1 sphenoid and 1 ethmoid bone. The cranial bones fit together by wavy, immovable boundaries called sutures. Facial bones include 2 nasal bones, 2 maxillae, 2 palatine, 2 zygomatic, 2 lacrymal bones, 2 interior nasal conchae, 1 vomer and 1 mandible. The palatine, inferior nasal conchae and vomer are not visible from the outer surface. A single U-shaped bone called hyoids is present at the base of the buccal cavity. Each middle ear contains three tiny bones, malleus, incus and stapes, collectively known as ear ossicles. The skull region articulates with the superior region of vertebral column with the help of occipital condyles.

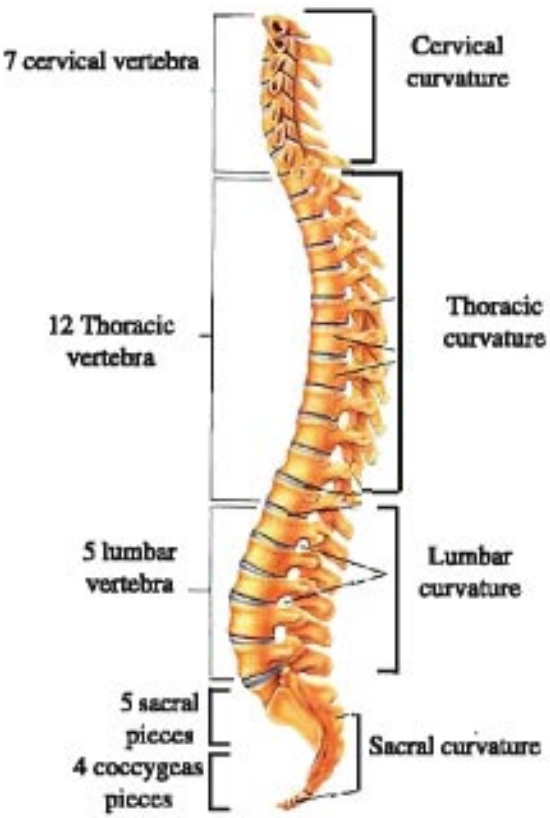


Human Skeleton System



Human Skull

Vertebral Column



Vertebral column

Vertebral Column is formed by **26** serially arranged bones called vertebrae and is dorsally place. The vertebral column is the main axis of the body, which articulates with skull, pectoral girdle, pelvic girdle and ribs. Each vertebrum has centrally hollow portion through which the spinalcord passes. The vertebrae are named on the basis of region of the body where they are located. In neck region, they are known as cervical vertebrae. Cervical (7), thoracic (12), lumber (5). In the lower most region of the vertebral column the sacral vertebrae are 5 in number and they are fused. Coccygeal vertebrae are 4 in number and found in the vestigial tail, and are very small and fused to form a curved, triangular bone, the coccyx.

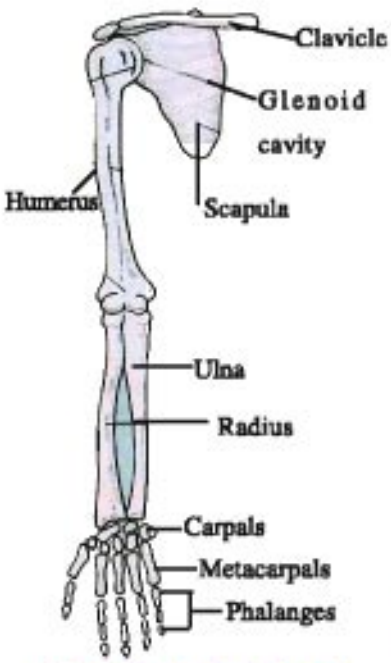
Thus vertebral formula of human is C_7, T_{12}, L_5, S_5, and C_4. The vertebral column encloses and protects the spinal cord and supports the head above. It strengthens the neck and the trunk for upright posture in standing and walking. It serves as the point of attachment for the ribs and musculature of the back. Sternum is a flat bone on the ventral midline of thorax.

Ribs

There are 12 pairs of ribs. Each rib is a thin flat bone connected dorsally to the vertebral column and ventrally to the sternum. The ribs have two articulation surface on its dorsal end and is hence called bicephalic. The upper 7 pairs of rib are attached in front directly to the sternum. These are called true ribs. The 8th, 9th, 10th pairs of ribs do not articulate directly with the sternum but join the seventh rib with The help of cartilage. They are known as false ribs. Last 2 pairs (11th and 12th) of ribs are not connected ventrally and they are termed as floating ribs. The thoracic vertebrae, ribs and sternum together form the rib cage. They protect the heart, large blood vessels and lungs. They provide the surface for attachment of respiratory muscle.

Appendicular skeleton

(1) Bones of Limbs : The bones of the limbs along with their girdles constitute the appendicular skeleton. Each limb is made of **30** bones. The bones of the fore limb are humerus, radius and ulna. **8** carpals in the wrist, **5** metacarpals in the palm and **14** phalanges in the fingers. Each leg has **30** bones: **1** femur in the thigh bone – the largest and heaviest bone. **1** patella in the knee, **1** tibia and 1 fibula, **7** tarsals in the ankle, **5** metatarsal in the sole and **14** phalanges in the toes.



Human pectoral girdle and arm bones (Anterior view)

Phalangeal formula for human arms and legs is 2, 3, 3, 3, 3. Function of bones of the arms is to provide strength to make the arms effective in working with them. While the leg bones strengthen the legs to bear the body weight, to balance the body while standing and help in locomotion.

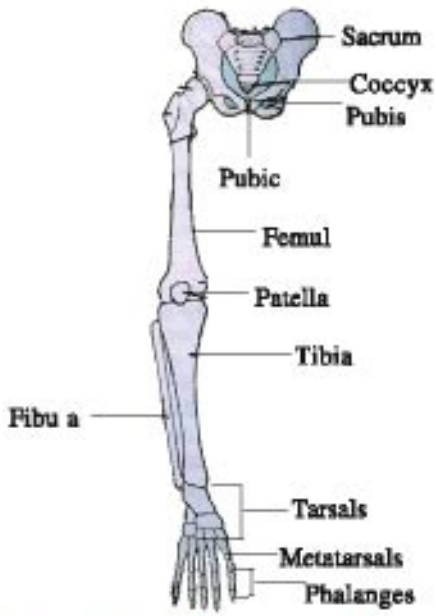
(2) Girdles : The girdles give articulation to the limbs. There are 2 girdles on each side. Pectoral girdle and pelvic girdle. Each girdle formed of two halves.

Pectoral girdle

Each half of the pectoral girdle consists of a clavicle and a scapula. The scapula is large, flat, triangular bone place on the dorsal side of the thorax above second to seven rib. There is a ridge, called spine which projects as a flat, expanded process termed as acromion process. The clavicle articulates with this. Below this process a cavity is present, called glenoid cavity which articulates with the head of the humerus to form the shoulder joint. The each clavicle is a long, slender rod-like bone with two curves. This bone is commonly known as collar bone.

Pelvic girdle

Pelvic girdle consists of two coxal bones. Each coxal bone is formed by the fusion of **3** bones; upper illum, lower ischium and inner pubis, faced to form a stout hip bone. At the point of



Human pelvic girdle, sacrum and coccyx

fusion of the above bones. There is a cavity termed as acetabulum to which the head of the thigh bone femur articulates. The two halves of the pelvic girdle meet ventrally to form the pubic symphysis containing fibrous cartilage.

Joints

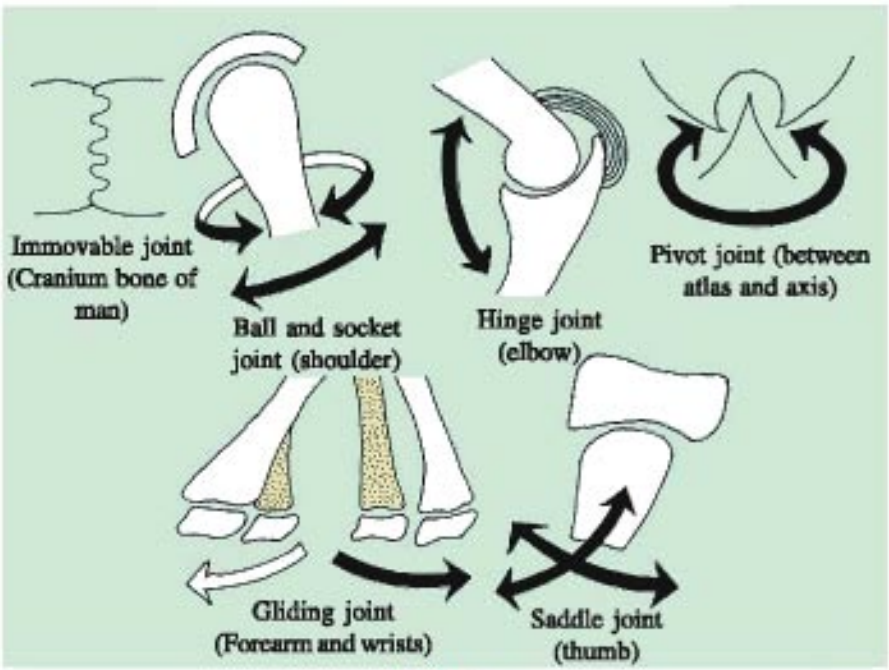
The structural arrangement of tissues which connects two or more bones together at their place of meeting is termed as joint. Joint are essential for all types of movements involving the bony part of body. Joints are points of contact between bones, or between cartilage and bones. Force is generally by muscle which is used to carry out movement of joints, here the joints acts as fulcrum.

Types of Joints :

There are three main types of joints. Joints have classified into three major structural forms, namely fibrous, or immovable. Cartilaginous and synovial and movable.

Fibrous, fixed or immovable joints occur between the bones of the cranium. They do not allow movement because the bones are held firmly together by bundle of strong white collagen fibres. The immovable joints are known as the sutures.

Cartilaginous or slightly movable joints are found between the centra of vertebrate, at the pubic symphysis. The articulating ends of bones are provided with elastic dense disc of fibro cartilage which separates the bone that are held together. The disc allows a limited little movement like bending and slight rotation at the joints.



Joints

Synovial or freely movable joints : The end of articulating bones are capped with a layer of hyaline cartilage. The articular surface between the articulating bones enclose a space between them known as synovial cavity. This cavity is filled with viscous synovial fluid, which lubricates the joint for easy considerable movement of bone. These joints help in locomotion and many other movements. These joints are ball and socket joint (between humerus and pectoral girdle), hinge joint (knee joint) pivot joint (between atlas and axis), gliding joint (between the carpals) and saddle joint (between carpel and metacarpal of thumb)

Disorders of skeletal system

Myasthenia gravis : It is an auto immune disorder that affects neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscle.

Tetany : It is a muscular disorder in which rapid spasms in muscle occur due to lesser Ca^{2+} in the body fluid.

Summary

Movement is an essential feature of all living organisms. Animals generally show two types of movement i.e. locomotion and movement of the body parts. Streaming of protoplasm, ciliary, movement, movements of fins, limbs, wings, etc. are some forms shown by animals. Locomotion takes animal to favourable environment. Animals move generally in search of food, shelter, mate, breeding ground, better climate, and protect themselves. The three basic types of movements exhibited by human cells. are amoeboid, ciliary and muscular movement. Skeletal muscle are attached to skeletal element. They show striation and are voluntary in nature. Visceral muscle are involuntary and non-striated. Cardiac muscles are found in heart. They are involuntary, branched and striated.

Muscle fibre is the anatomical unit of muscle. Each muscle fibre has many myofibrils arranged parallely. Each myofibril consists of many serially arranged units known as sarcomere. Each sacromere has a central 'A' band made of myosin (thick) filaments and two half 'I' band made of actin (thin) filament on either side of it marked by 'Z' lines. Actin and myosin are polymerise protein with contractibility nature. The active side for myosin on resting actin filament is masked by a troponin. Myosin head contains ATP ase and has ATP binding sites and active site for actin. A motor neuron carries signals which generate an action potential in muscle fibre. Because of this the release of Ca^{++} from sarcoplasmic reticular occurs. Ca^{2+} activates actin which binds to the myosin head to form a cross bridge. This cross bridge pulls the actin filament causing them to slide over myosin filament and causing contraction. Calciumions are then returned to sarcoplasmic reticulum which activates actin. These cross bridges are broken and muscles relax.

Muscles are of two kinds: the red fibres are thin, dark red and contain a high content of myoglobin, while white fibre are thick, white and contain a less content of myoglobin.

Bones and cartilage forms the skeletal system. This system is divisible into axial and appendicular. Axial skeleton constitutes skull, vertebral column, ribs and sternum. Limb bones and girdles form the appendicular skeleton. Joins are of two types, formed between bones or between bones and cartilage.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Number of floating ribs in human body is ..... .

(a) 6 pairs ○ (b) 5 pairs ○ (c) 3 pairs ○ (d) 2 pairs ○

(2) Number of vertebrae in human skeleton is ..... .

(a) 30 ○ (b) 32 ○ (c) 33 ○ (d) 26 ○

(3) Total numbers of bones in the hind limb is ..... .

(a) 21 ○ (b) 14 ○ (c) 30 ○ (d) 24 ○

(4) Functional unit of striated muscle is ..... .

(a) I Band ○ (b) Z line ○

(c) Myofilament ○ (d) Sarcomere ○

(5) Total number of bones in human skull is ..... .

(a) 26 ○ (b) 22 ○ (c) 30 ○ (d) 107 ○

(6) The joint between atlas and axis is ..... .

(a) Ball and socket ○ (b) Pivot ○

(c) Saddle ○ (d) Collagen ○

(7) ATPase enzyme needed for muscle contraction is ..... .

(a) Myosin ○ (b) Actin ○

(c) Tropomyasin ○ (d) Troponin ○

(8) The contractile protein of skeletal muscle involving ATPase activity is ..... .

(a) Troponin ○ (b) Tropomyosin ○

(c) Myosin ○ (d) Actin ○

(9) The region between two successive Z line in a myofibril is ..... .

(a) Sarcomere ○ (b) Sarcosome ○

(c) Fascia ○ (d) Anisotropic band ○

2. Answer the following questions in very short :

(1) How do ilium differ from ischium ?

(2) What causes muscle fatigue? How is it removed ?

(3) Human has 3 kinds of ribs. Name these with examples.

(4) What is acetabulum ?

(5) What is muscle ? Write the name of different types of muscles.

(6) How do the joints help in movement ? Explain.

(7) Name the major parts of human skeleton. Give the number of bone in its each part.

(8) Explain the sliding filament theory of muscle contraction.

(9) What makes the synovial joint freely movable ? List the various types of synovial joints

4. Answer the following questions in detail :

(1) Explain : The types of movements found among the animals.

(2) Write the difference between :

(a) Bones of Fore Limb - Bone of Hind Limbs

(b) Red muscles and white muscles

(c) Pectoral girdle - Pelvic girdle

10

Organisms and Population

The term 'Ecology' is derived from two Greek workds, namely Oikos and Logos (Oikos = home = habitation = a place to live in & Logos = study) i.e. Ecology is the study of organisms where they live. Ecology is defined by Odum (1969) as 'the study of the inter-relationsships between organisms and environment.' Ecology is divided into many branches, they are : Animal Ecology, Plant Ecology, Habitat Ecology, Marine Ecology, Freshwater Ecology, Terrestrial Ecology, Population Ecology, Community Ecology, Applied Ecology, Human Ecology.

Environment :

Ecology is a part of environment study. The science of environment is called Environmental studies. The study of basic components of our surroundings and their interactions is called Environmental studies. As per syllabus we will study the following aspects.

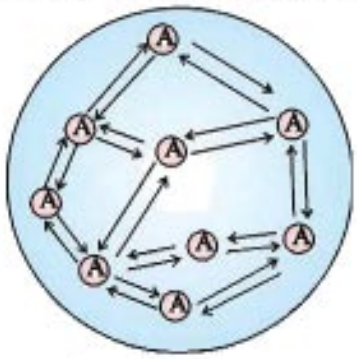
- The major components of the environment.
- The interactions and the intradependence of the various components of the environment.
- Population ecology
- Biotic community
- Population ecology and reaction and interactions between various components of biotic community.

Habitat : Habitat refers to the place where the organisms live. The habitat is broadly classified into four groups : Fresh water habitat, Marine habitat, Estuarine habitat and Terrestrial habitat. (1) The fresh water habitat has its own characteristics such as salinity, osmosis, pH, dissolved gases, temperature, etc. Ponds, lakes, rivers are the fresh water bodies. Freshwater fauna and flora is addapted to it with respect to attachment, osmoregulation, etc. (2) Marine habitat refers to the dwelling place of organisms in the sea and oceans. Marine habitat is the largest one in the biosphere and it covers an area of 3,62,000,000 sq. km. It is nearly 71% of the earths' surface. Fauna and flora are adapted to it with respect to salinity, osmosis, pH, currents, tides, temperature and light. (3) An estuary is a body of water in which river water mixes with the sea water.

Osmoregulation is the major problem to living fauna to such habitat. Terrestrial habitat refers to the land where the organisms live. It is characterised by a variety of climate, diversity of abiotic factors and biotic communities. Ecologically, the terrestrial habitat is subdivided into a number of sub-units called biomes. A biome is defined as a major terrestrial community characterised by distinctive plants and animals e.g. Forest biome, Grassland biome, Desert biome, etc.

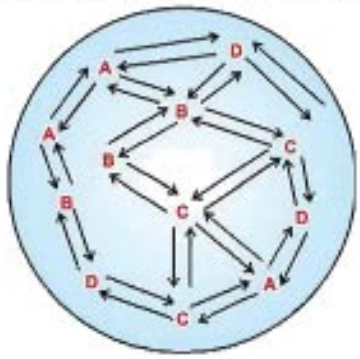
Basic Concepts of Ecology :

Previously we have studied that our living world is fascinatingly diverse and complex. We studied its complexity by its various levels of biological organisation - macromolecules, cells, tissues, organs, individual organisms, population, communities, ecosystems and biomes. A population is a group of individual organisms of the same species in a given area. A community is a group of populations of different species in a given area. An ecosystem is the whole biotic community in a given area plus its abiotic environment. The dynamic environment and organisms make ways for the development of different kinds of organisms through a process known as succession.



Diagrammatic sketch showing the pouplation of species 'A', where its individual interact with each other

Population ecology



Diagrammatic sketch showing a community of four different species A,B, C, D interacting with each other

Community ecology

Major abiotic factors :

All the external factors, conditions and influences that affect an organism or a biological community is known as environment. Thus environment is a complex of light, temperature, water, soil, etc. which surrounds an organism. Any external force, substance or condition, which surrounds and affects the life of an organism in any way, becomes a factor of its environment.

(1) Light-factor :

Light is the most important abiotic factor without which life cannot exist. All plants depend on light for their energy and all animals depend on plants and so without light there is no life. Organisms get light from the sun, the moon, stars, etc. Among these the sun is the important source. Sunlight is formed of electromagnetic waves. Light is a form of energy called radiant energy.

Light in relation to plants :

Directly or indirectly light affects the plant's life on chlorophyll production, Photosynthesis, transpiration, distribution of plants etc. The existence of other life forms, which depend upon plants for food is due to light. Indirectly light affects transpiration rates through increase in temperature. Transpiration rates correspondingly affect water absorption also. Opening and closing of stomata is regulated by light.

Total amount of radiation received by the earth's surface differs with latitude. (distance from the equator). This may be one of the reasons for difference in vegetation at poles and other parts of the earth.

Light in relation to animals :

The intensity of light influences metabolic rate in animals. Increased intensity of light results in increased enzyme activity. Light induces photochemical reactions resulting in the formation of colour pigments, because of that cave animals are colourless. It has influence on locomotion and movement of animals. The migration of birds is affected by light. In animals like birds, light initiates the breeding activities. In some birds gonads become active with increased light intensity during summer.

(2) Temparature factor :

All metabolic processes are influenced by temperature because temperature regulates the activity of enzymes, All chemical reactions in the body of organisms are controlled by temperature.

Temperature in relation to plants : Temperature effects the rates of transpiration, photosynthesis and respiration in plants. Temperature is an important factor in the phenology of plants. Variation in temperature affects distribution of plants. The division of earth's vegetation into different zones as equatorial, tropical, coniferous vegetations are dependent on variation in temperature. Altitudinal zonation of vegetation is clearly seen on mountains.

Temperature in relation to animals : In some animals, as rotifers and daphnids, sex-ratio is effected by temperature. Under normal condition daphnids give parthenogenetic eggs that develop into females, where as with increase in temperature they give sexual eggs which after fertilization develop either into males or females. Some insects, birds and mammals in warm humid climatic bear darker pigments than the races of same species present in cool and dry climate. Birds and mammals obtain greater body size in cold regions than in warm areas. But poikilotherms are smaller in cold region. Animals are two types with respect to maintain their body temperature. They are Homoeothermic or warm-blooded animals as birds and mammals and Poikilothermic or cold-blooded animals as reptiles, fishes, amphibians.

(3) Water :

Water is described as the mother of life. It is the universal solvent. It is the largest medium of life. It exists in three forms, namely liquid, solid and vapour. Liquid state exists in two forms, namely sea water and fresh water. The sources of water are precipitation, ground water, springs, sea, ponds, lakes, rivers, etc. Water has special properties like solvency, specific heat, latent heat, thermal conductivity, viscosity, surface tension, buoyancy, salinity, pressure, transparency, pH etc.

Temperature variation is much lesser in aquatic habitat than in terestrial habitat. The changes occur very slowly, compared to marine habitat, the temperature variation in freshwater habitat is higher. In deep freahwater habitat, such as lakes and ponds, there is a gradual decrease in temperature from the surface to the bottom. As a result, different layers of water with different temperatures are noticed. This is called thermal stratification.

Water balance and adaptations :

The salinity of freshwater is very low. The body fluid of freshwater animals is highly concentrated. Hence their body fluid is hypertonic and the freshwater is hypotonic. As a result

endosmosis occurs. This results in a continous entry of freshwater into the body. Hence freshwater animals have adaptations to remove the excess of water entering the body. In freshwater fishes, the excess of water in the body is eliminated in the form of urine by kidney. However along with urine some amont of salt is also lost. This loss of salt is compansated by the absorption of salts from the freshwater by chloride cells present in the gills. In the case of crustacean Astacus, the excess of water is removed in the form of urine by the green glands, where as in Amoeba it is maintained by contractile vacuoles. Certail freshwater fishes develop accessory respiratory organs to utilise atmospheric air when the freshwater dries up. e.g. Ophiocephlus, Clarias, Anabus, etc.

Water problem in sea water :

Sea water has high salt contents. Hence sea water is hypertonic and the body fluid is hypotonic. As a result exosmosis occurs. The body tends to lose water. To compensate for the loss of water the marine animals drink sea water. Its excess salt is exuded by chlorine secretory cells present in the gills. In marine turtles the excess of salt is removed by salt glands present near the eye.

Water problem in terrestrial habitat :

Terrestrial habitat is characterized by scarcity of water. The terrestrial animals are faced with two main problems, namely a). getting water and b). conserving water. They possess a variety of water adaptations to solve theses problems. These are as follow :

- Evoparation through body surface is prevented by developing spines, scales, scute, shields etc.
- Certain animals are active during night.
- Certain animals like Kangaroo rat and protopterus aestivate during periods.
- Skin of spiny lizard is hygroscopic. It absorbs water from the atmosphere.
- The lizard uromatrix stores water in the intestine. The excess amount of water is stored in the water cells present in the rumen and reticulum of stomach in camel.
- Mammals regulate their body temperature by producing sweat.

(4) Soil :

Soil is an abiotic ecological factor. It acts as suitable substratum and medium for plants and animals. It is a bridge between inorganic and organic materials. Soil is defined as any part of earth's crust in which plants root. According to Treshow (1970) soil is a complex physical-ecological system providing support, water, nutrients and oxygen for the plants. It is formed of five major components. Mineral matter, organic matter, soil water, soil air and biological system.

Soil is inhabited by variety of organisms. All the organisms living in the soil constitute soil community. The organisms living in the soil are classified into four major groups : Microflora, microfauna, Mesofouna and macrofauna

Microflora : Bacteria, fungi, blue green algae and algae.

Microfauma : Protozoans, nematodes, mites etc. (size 20 to 200 micron).

Mesofauna : Mites, nematodes spiders insect larvae, molluscs, etc. (size between 200 micron to 1 cm)

Macrofauna : These are animals with a size of more than 1 cm large size e.g. earthwarms, snakes, moles, rates etc.

The nature and properties of soil in different places vary. It is dependent on the climate. Various characteristics of the soil such as soil composition, grain size and aggregation determine the percolation and water holding capacity of the soil. These characteristics along with parameter such as pH, mineral composition and topography determine to a large extent the vegetation in any area.

The majority of animals living in soil lead either burrowing or cursorial mode of life. Hence they have adaptation for burrowing and cursorical mode of life. Animals living inside burrow have some special adaptations of digging and burrowing, their bodies are spindle shaped and tapering head, short tail, the eyes and necks are reduced.

Response to Abiotic Factors :

We have studied that the abiotic conditions of many habitats may very drastically in time. We now ask how do the organisms living in such habitats copes or manage with stressful conditions. During evolution, many species would have evoluted a relatively constant internal enrivonment that permits all biochemical reactions and physiologcal functions to proceed with maximal efficiency, and thus, enhance the overall 'Fitness' of the species. This constancy, for example, in terms of optimal temperature and osmotic concentration of body fluids, the organisnm try to maintain the constancy of its internal environment despite varing external environmental conditions that tend to upset. (a process called homeostasis)

To cope with unfavourable condition : Regulate : Some organisums are able to maintain homeostasis by physiological means e.g. birds and animals.

Conform : Majority of animals and nearly all plants cannot maintain a constant internal environment and these animals and plants are called conformers.

Migrate : The organism can move away temporarily from stressful habitat to a more suitable area and return when stressful period is over.

Suspended : In bacteria, fungi and lower plants various kinds of thick walled spores are formed which help them to survive in unfavourable conditions - these germinate when availability of suitable environment. Animals show hibernation during winter and aestivation during summer.

Adaptations :

Adaptationis defined as 'the adjustments made by individuals in response to specific environmental conditions. Living organisms are equipped in a variety of ways to cope with their environment. Adaptations make the organism fit to its environment, some are able to respond through certain physiological adjustments while others do so behavioully. These responses are also actually, their adaptations. So we can say that adaptation is a characteristic of any living organism (non phological, physiological, behavioural) that enables the organism to survive and reproduce in its habitat. Many adaptations have evolved over a long evolutionary time and are genetically fixed. Kangaroo and rat in a desert is capable of meeting all its water requirements through its internal lipid oxidation. In most animals, the metabolic reactions proceed optimally in a narrow temperature range (37°C), but there are microbs (archae bacteria) that flourish in hot spring where tempreture for exceed 100°C. Many fish in Antartic waters where the temprature is always below zero. A large variety of marine inverted rates and fish live at great depths in the ocean where the pressure could be > 100 times the normal atmospheric pressure.

Organisms in nature rarely grow as separated from each other. Invariably they grow organised as populations, communities and ecosystems.

Population :

Population refers to a group of organisms of the same species living in a particular area at a given time e.g. All the *Rana tigrina* living in a pond constitute a frog population. In the same way we can say fish population. Bamboo population in forest etc.

Population of Bamboo, Fish and Frog

A Population has the following salient features :

- All the individuals of a population belong to one species.
- The individuals are morphologically and anatomically similar
- The individuals are genetically related.
- The individuals are reproductively isolated from other species.

Each population has the following characteristics :

(1) Density (2) Natality (3) Mortality

(4) Age distribution (5) Population growth (6) Population equilibrium

(7) Population fluctuation (8) Population interaction

(1) Population density :

It refers to the total number of individuals in an unit area or unit volume in a given time. For example; the number of plants per acre of land ; the number of people per square km. The density of any population can be expressed by the following formula :

$$D = \frac{n/a}{t}$$ where, D = Density, n = Number of individuals

t = time, a = area

(2) Natality or Birth Rate :

Birth rate refers to the average number of new individuals produced by a population in a given time. The size of population increases because of natality

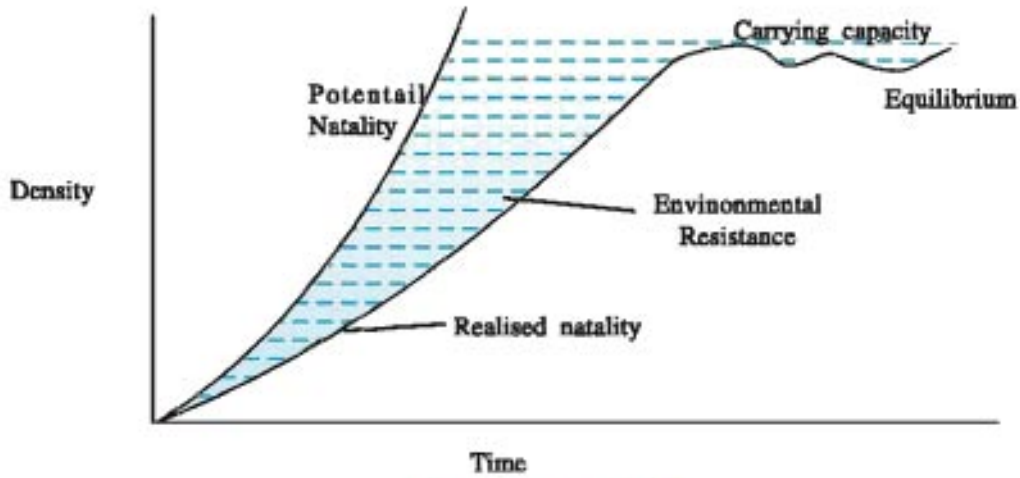
$$\text{Birth rate} = \frac{\text{Number of births per unit time}}{\text{Average population}}$$

Carrying capacity :

The total number of individuals that can be accomodate in an area at a particular time is called carrying capacity.

Potential Natality (Maximum Natality) :

The maximum possible rate of reproduction for a population under optimal candition is called potential natality. For example Salmon (Fish) produces 2,80,000,000 eggs in a season. So the potential natality of Salmon is 2,80,000,000 eggs in a season. But all eggs do not be hatched and reach adulthood. Hence, it is essential to see a Realised natality. It refers to the actual number of new individuals added to the population in a given time. It is always lesser then the potential natality.



A population of fish

Mortality or Death Rate :

Mortality refers to the number of individuals dying in a population at a given time. The size of the population decreases because of mortality. There are two aspects of mortality. The potential mortality or minimum mortality and realised mortality are actual mortality. Potential mortality refers to the number of deaths due to old ege. But realised mortality is the number of deaths that occur at all ages. Realised mortality is higher than Potential mortality.

$$\text{Mortality rate} = \frac{\text{Number of deaths per unit time}}{\text{Average population}}$$

Vital index :

The ratio between birth rate and death rate is called Vital Index. It is represented by the following formula

$$\text{Vital Index} = \frac{\text{Birth rate}}{\text{Death rate}} \times 100$$

Vital Index helps to understand the rate of growth of a population.

If birth rate and death rate remain equal the population becomes stable and remains at equilibrium.

(4) Age Distribution :

A population is formed of individuals with ups according to their ages. They are :

(1) The pre-reproductive group which included immature animals.

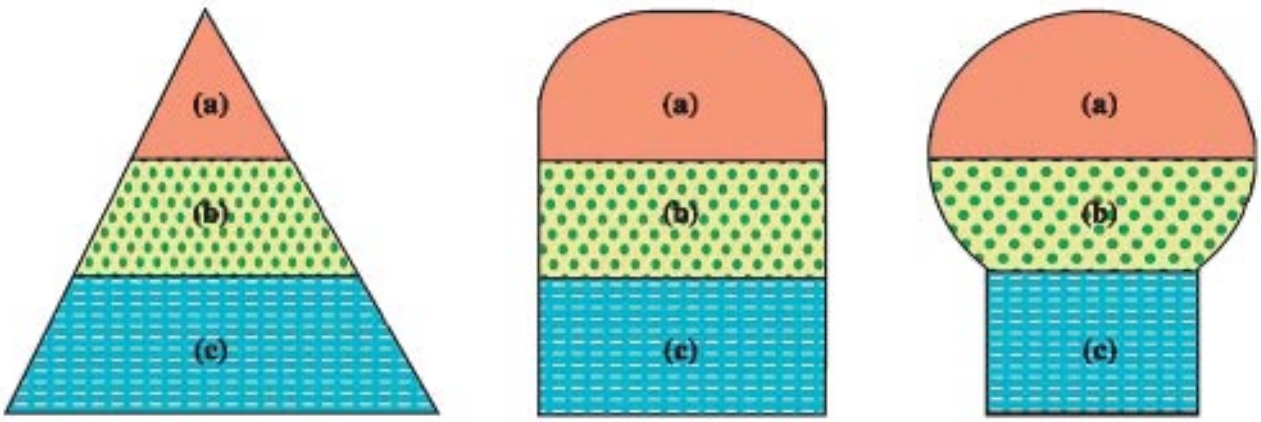
(2) The reproductive group comprising sexually mature animals.

(3) The post-reproductive group comprising old animals where the reproductive ability has been stopped.

The birth rate, death rate and the growth of a population are determined by the age groups of the population.

Age pyramids :

The different age groups of a population can be represented in the form of a graph called Age Pyramid. In the age pyramid, the pre-reproductive age group is represented at the bottom, the reproductive age group in the middle and the post-reproductive age group at the top. The shape of the pyramid shows the growth or decline or equilibrium of the population. For example, when a population contains more of pre-reproductive and reproductive age groups, the pyramid is bell-shaped. The bell-shaped pyramid shows that the population is stable.



(a = Post reproductive, b = reproductive, c = Pre reprodctive)

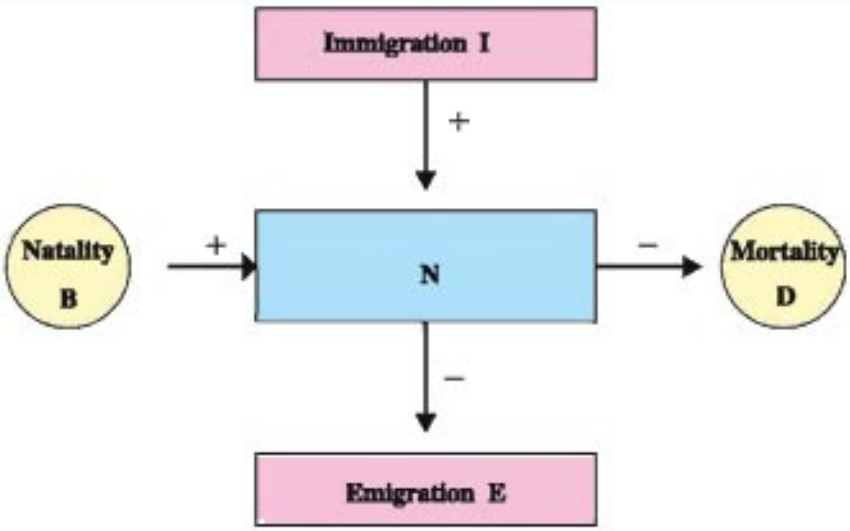
Expanding Population **Stable Population** **Declining Population**

Age pyramids

When the pyramids is triangular, the population is growing, when urn-shaped, the population is declining, when bell-shaped, it is stable.

(5) Population growth :

The increase in size of population is called population, tells us a lot about its status in the habitatrt. The size of a population far any species is not s static parameter. It keeps changing in time. Depending on various factors including food availbility, predation, pressure and reduce weather. The density of a population in a given habitat during a given peroid, fluctuates due to changes in four basic processes. Two of which (natality and immigration) contribute an increase in population density and two (mortahity and emigration) to a decrease.



So, if N is the population density at time t, then its density at time t+1 is

$N_{t+1} = Nt + [(B+I) - (D+E)]$

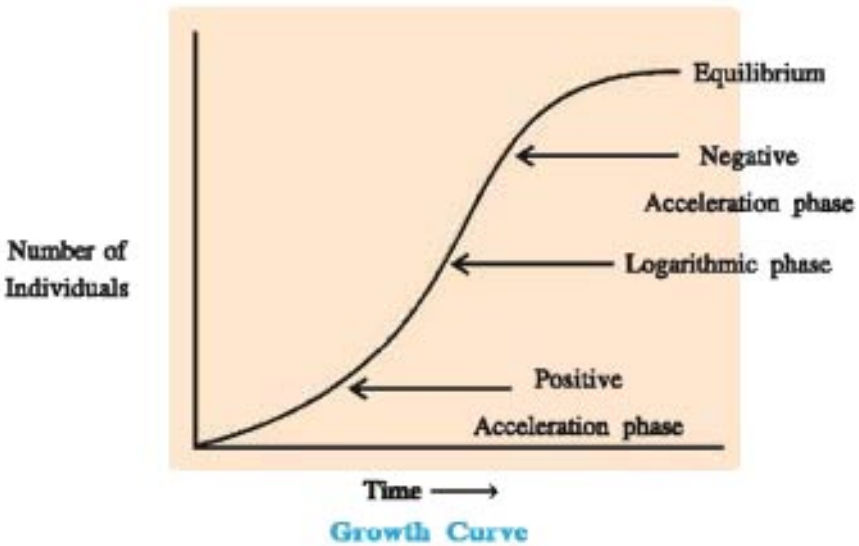
(6) Population Equilibrium :

When the increase in the number of animals is plotted against time factor, a curve is obtained called the growth cruve. The pattern of growth curve. is difffernt for different populations. Mainly, two patterns of growth curves are significant, they are :

(1) S – Shaped Growth Curve or Sigmoid Curve and

(2) J – Shaped Growth Curve

(1) S – Shaped Growth Curve : During population growth, three phases are observed i.e. positive accelaration phase, logarithmic phase and negative acceleration phase. Let us see it with examples. If we introduce Yeast in a specific medium, its population grows gradually. In the begining, the growth is slow. This phase is called positive acceleration phase. Then, the growth is rapid and the population increases steepwise. It is a logarithmic phase. After reaching the maximum size the growth rate slows down. This stage is called negative acceleration phase. It is represented graphically.

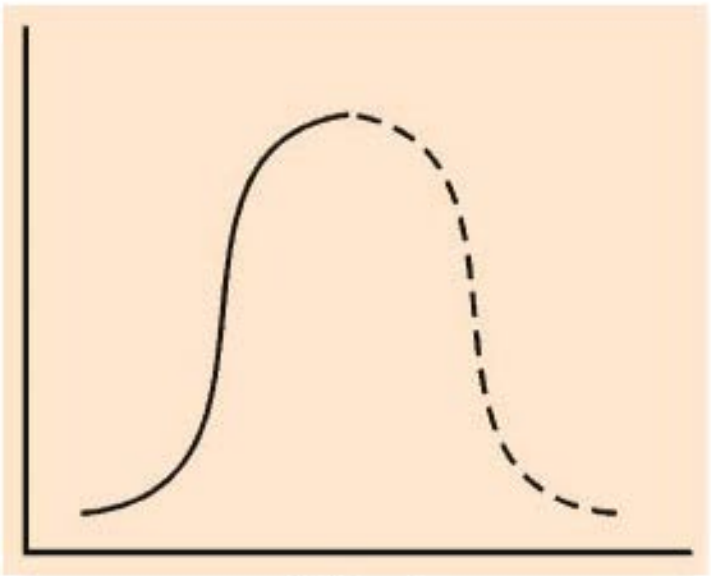


Growth Curve

Every population has its carrying capacity, where no more increase can occur in a population. It is defined as the maximum number of individuals of a population that can be supported in a habitat at a given time.

(2) J- Shaped Growth Curve :

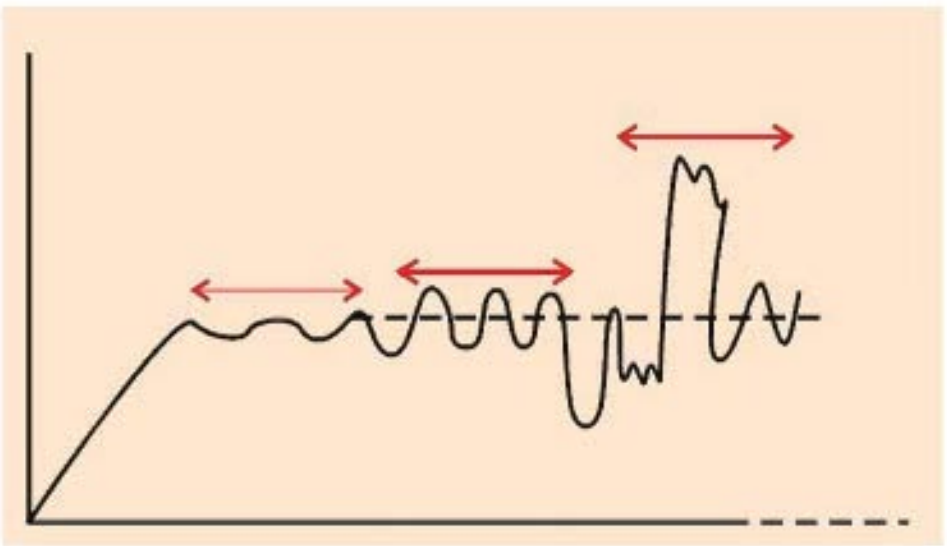
In certain population, the growth is very rapid and the number of organisms increases in compound interest fashion and then the growth stops abruptly and the population declines suddenly. It is a J-shaped growth pattern.



J-shaped Growth Curve

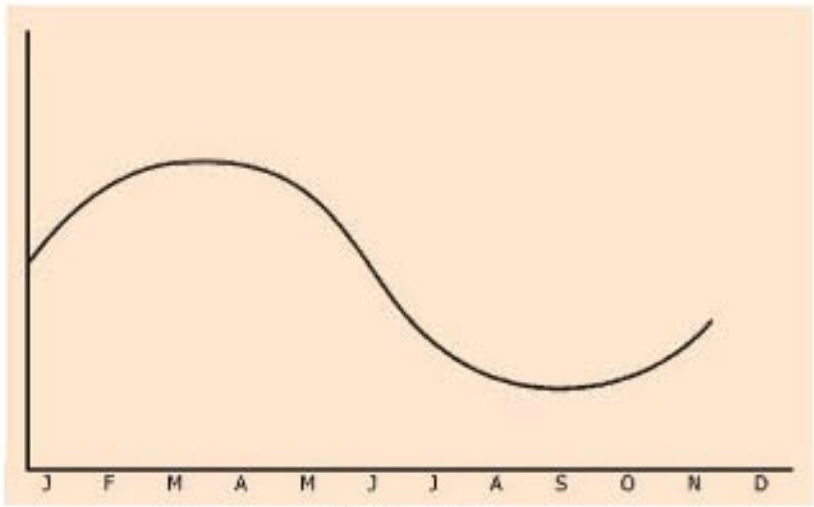
(7) Population Fluctuations :

The increase and decrease in the number of individuals in a population is called population fluctuation. It may be flat, cyclic or irruptive. It is caused by factors.



Population Fluctuations

Study on bird population at different areas of North Gujarat was studied for 10 (2000-2010) years. Its fluctuation at different seasons is given in a graph. Its fluctuation is under the influence of seasonal effect, migration, etc.



Seasonal Variation in Population of Birds

Factors affecting on population growth

Food, space, shelter, weather, etc are the extrinsic factors. As the example, A bacterium is allowed to grow in a petrydish with limited volume of food. The bacterium divides and redivides up to food is available.

The density dependent factors are intrinsic. They arise within the population. They are compitition, predation, emigration, reproductivity, diseases, etc.

Competition : It is the interaction between animals for a common resource, mainly for food. It may be interspacific or intraspecific.

Predation : Predation is the killing of one by other for food. Biological control methods adopted in agricultural pest control are based on the ability of the predator. Predator also helps in maintaining species diversity in biotic community.

Emigration : It is the outward migration of individuals from a population. This reduces the increase in population density. A terrestrial turtle (Abingdon) became extinct whithin one decade only on Galapagos island after goats were introduced on the island. It is due to the greater browing efficiency of a goats.

Reproductivity : When the density increases the reproductive ability decreases.

Diseases : Diseases reduces the population density.

Life History Variation

Populations evolve to maximise their reproductive fitness, in the habitat in which they live. Some organisms breed only once in their life time e.g. Pacific salman fish, bamboop while others breed many times during their life time (most birds like pigeon and mammals). Some produce a large number of small sized offsprings (Oysters, pelagic fishes). Some produce a small number of large sized offsprings (predatory birds, birdsmammals). Ecologists suggested that it is under the influence of abiotic and biotic factors of the habitat where organisms live.

(8) Population Interactions :

The individuals of a population interact in various ways. It may be intraspecific (within the members of a species) or interspecific (between species)

Interspecific interactions :

They could be beneficial, detrimental or neutral (neither harm nor benefit) to one of the species or both. Assigning a '+' sign for beneficial interaction, '–' sign for detrimental and '0' for neutral interaction, let us look at all the possible outcomes of interspecific interactions

Table : Population Interactions

Species A	Species B	Name of interation	General results
+	+	Mutualism	Favourable to both
–	–	Competition	Harmful to one another
+	–	Predation	Favourable to A
+	–	Parasitism	Favourable to A
+	0	Commensalism	Favourable to A
–	0	Amensalism	One species is affected while other is unaffected

In mutualism, both parteners are benefited, e.g. Hermit crab and Sea anemone. Both lose in competition in their interactions with each other. In both parasitism and predation only one species is benifited benetits (parasite and predator, respectively). The interaction where one species is benefited and the other is neither benefited nor harmed is called commensalism. In amenasalism, on the other hand one species is harmed where as the other is unaffected.

Mutualism

This term literally means 'living together'

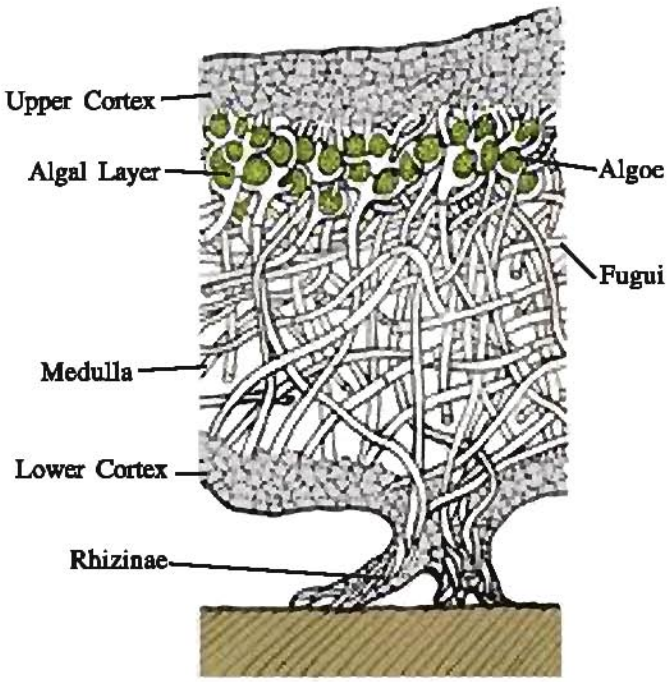
The hermit crab lives inside the empty gastropod shell. The sea anemone is inhabited on the shell. The hermit crab is protected from enemies by the stinging cells of sea anemone. The sea anemone is transported from place to place and also get food shared by crab.

The bacterium *Rhizobium* produces nodules on the roots of leguminous plants. The bacteria fix up atmospheric free N_2 in the nodules in a form of nitrates. The plants utilize these nitrates. The bacteria, in turn, obtain shelter, and nutrients from the plants.

Hermit crab and Sea anemone

Root Nodules

T.S. of Root Nodule



Lichen

Lichens are formed of algal cells and fungus. The fungus provides moisture and minerals for the algal cells. The algal cells prepare food for both by photosynthesis.

Competition :

Here two individuals are involved. The two partners may be harmed or only one partner will be harmed as a result of compitition. The compititions is of two types, namly.

(a) Intraspecific competition : Occuring between members of the same population.

(b) Interspecific competion : Occuring between population of different species.

Some species have the same type of requirements such as food, shelter, mate, etc. e.g. Many male dogs compete among themselves to mate a female dog. Lichens compete with each other for space on a dry ledge, Barncales compete for space on a submerged rock. In a laboratory experiment it is observed that there is interspecific competition between *Paramoecium caudatum* and *P. aurelia* for food.

Predation

Predation :

We have studied that predation also controls population e.g. All animals and insectivorous plants are predatory. The predation are of two types. They are herbivores (e.g. cow) and carnivores (e.g. tiger).

Liver Fluke

Parasitism : Parasitism is a one sided relationship. The partner which is benefited is called parasite. The other partner is called host. There are different types of parasites.

(1) Temporary Parasites : An animal spends only a part of its life cycle as a parasite e.g. larval form.

(2) Parmanent parasites : The animals which spend their entire life as parasites e.g. Ascaris, Tapeworm, etc.

(3) Ectoparasites : The parasites which live on the outer surface of the host. e.g. Mites, Leeches, etc.

(4) Endoparasites : The parasites live inside the body of the host (in a cell tissue or organs) e.g. Plasmodium, Ascaris, etc.

Commensalism : It is a symbiotic interspecific relationship. The partners are called commonsals. e.g. Suckerfish sucks on the body of shark. Flagellates living inside the body of the termites.

Amensalism : Here one species is harmed where as the other is unaffected e.g. Penicilium fungi, gram positive bacteria etc.

Commensalism Shark and sucker fish

Biotic community :

In nature, different kinds of organisms group in association with each other. A group of several species (plants and/or animals) living in a particular area with mutual to erance (adjustment) is known as community or more appropriately biotic community. A forest, a grassland, a desert, or a pond are natural communities. By definition, a comunity must include only living entities of the area. If non-living (abiotic) factors together with the living (biotic) entities are also considered then we would be dealing with an ecosystem rather than a community.

Examples :

(1) Pond community : All organisms living in a pond constitute a pond community. It is formed of different kinds of water plants, fishes, frogs, insects, planktons, etc.

(2) Forest community : It is formed of various kinds of trees, shrubs, insects, rabits, snakes, lions and so on.

Characteristics of a biotic community :

Like populations it has a number of characteristic features like species diversity, structure, community dominants, ecological niche, succession etc.

Species diversity :

Each community is made up of much different organisms - plants, animals, microbs, which differ taxonomically from each other.

Structure :

Each community has a definite structure, It is formed of three groups of organisms namely producers, consumers and decomposers.

(1) Producers : The green plants are the producers. They are autotrophs. They produce food by photosynthesis utilizing chlorophyll, CO_2, water, minerals and solar energy.

(2) Consumers : Consumers are the heterotrophs. They cannot produce food. But they depend on the producers and other organisms of the community for their food. They are of two types, namly herbivores and carnivores. Herbivores are animals which eat the producers. e.g. rabbits, grasshoppers sparrow, etc. They are also called primary consumers. Carnirovers are animals, which eat other animals for their food. They are also called secondary consumers. e.g. fox, lion, tiger of forest community and fishes, frogs, snakes of pond community.

(3) Decomposers : Decomposers include micro-organisms like bacteria and fungi. They decompose the dead bodies of plants and animals of the community and convert them into micro and macro nutrients. These nutrients are again utilized by plants.

Community dominants

A community is formed of many species. Of these one or a few species play a dominanat role in a community by virtue of their number, size etc. These species are called community dominants. Trees are community dominants in a forest community.

Ecological Niche : Niche refers to the functional status of an organisms in its community. According to Odum niche is the profession of an organism in the community. Organism compared the habitat to the address and the niche to the profession. Niche refers to the role of organism in the community. Role means activities, behaviours, responds to the environment and its interaction with the organism in the community e.g. lion and deer live in the same habitat but lion is a carnivore (niche) and deer is a herbivore (niche).

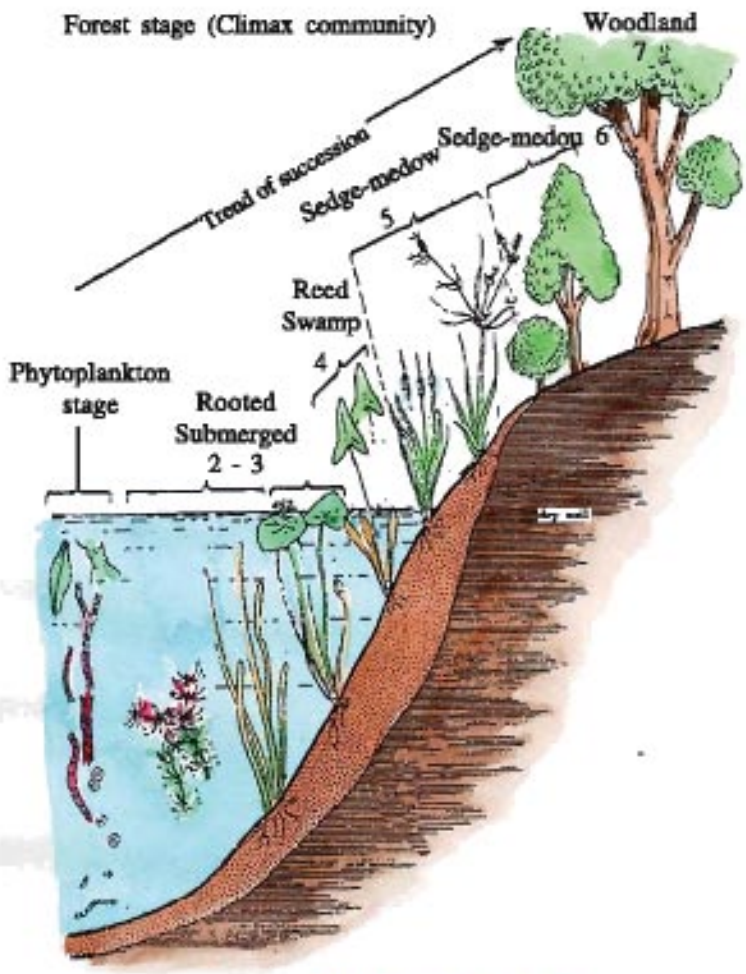
Ecological succession

Communities are never stable, but changing more or less regularly over time and space. Communities are never found permanent due to variation in climatic and physiographic factors and the activities of the species of the communities. These influences bring about marked changes in the existing community, which is thus sooner replaced by another community at the same place. Thus the process of development of a new communities is called ecological succession.

Succession is an orderly and progressive replacement of one community by another till the development of a stable community in that area. For example, a pond community can be transformed into a marshy land community, if the pond is gradually filled with sand and mud. The marshy land in the course of time may give rise to a grassland community.

Ecological succession is directional and predictable. There is an increase in structural complexity during succession.

Basic types of succession : The various types of succession are observed on the basis of different aspects as follows :



Hydroseric Succession

Primary succession : Primary succesion strats from the primitive substratum, where there was no previously any sort of living matter. The first group of organisms establishing there is known as the pioneer.

Secondary succession : It starts from previously built up substrates with already existing living matter.

General process of succession

In the development of a community, a series of communities develope and they replace one another in an orderly sequence unitl the stable community is produced. The various developmental stages of a community are called as seral stages. The first seral stage is called the pioneer community. The final stable community is called climax community. The climax community of an area is determined by the total environmental factors of the area in which it exists.

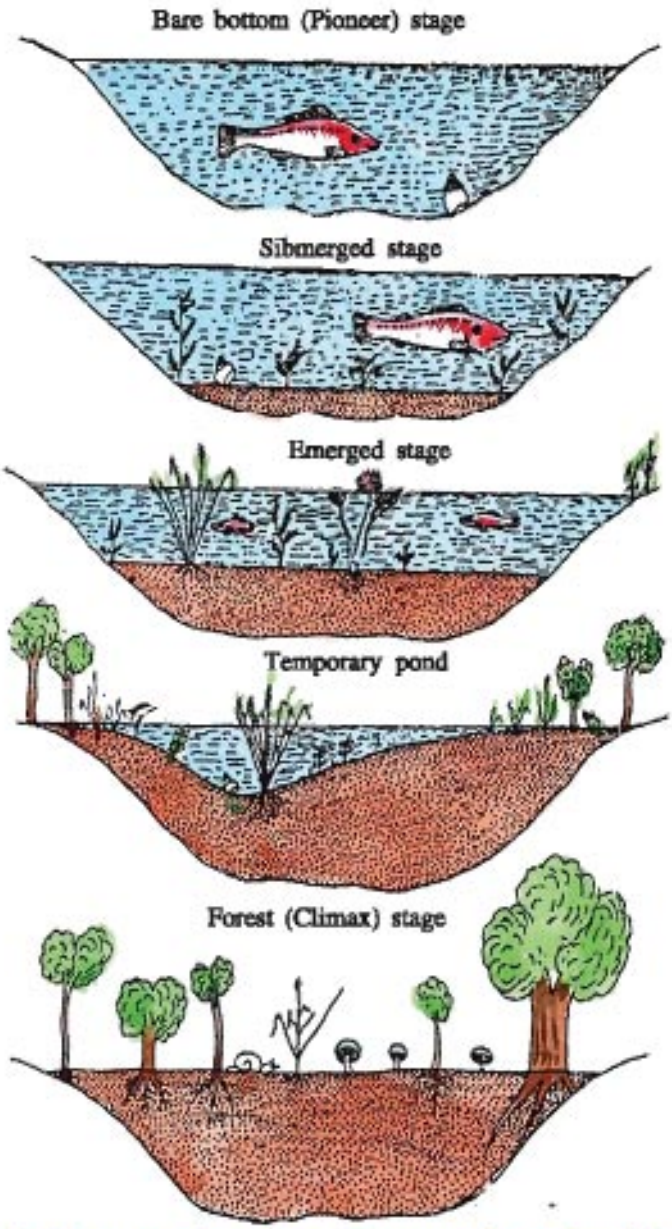
Pattern of succession : Based on the place where succession occurs, three different patterns of succession, can be recongnised. They are :

1. Xerosere, 2. Hydrosere and 3. Mesosere

Xerosere : It begins from a dry place. Succession starts from the rocks is an example of xerosere, Lichens are the pioneer of it. Mosses, herbs and shrubs develop afterward.

Hydrosere : When succession starts in water, it is called hydrosere. The first organisms to inhabit the pond are the planktons. Then submerged and floating plant enrich the pond.

Mesosere : Such succession is intermediate between xerosere and hydrosere. It occurs in moist places.



Ecological succession. A pond community replaced by a forest community throw ecological succession

Summary

Ecology is the study of organisms where they live. Ecology is diveded into many branches. Population ecology is one of them. The study of basic components of our surrounding and their interactions is called environmental studies. The habitat refers to the place where the organisms live. They are fresh water, marine, esturine and terrestrial habitat. Each habitat has its own salient features. Population refers to a groups of organisms of the same species living in a particular area at a given time. The individuals of a population interact in various ways. It may be intraspecific or interspecific. A group of several species living in a particular area with mutual tolerance is known as community or biotic community. It has species diversity, structure, succession etc. Each community has producers, consumers and decomposers. Such communities are never stable. New communities also devlop time to time. It is an orderly and progressive replacement of one community by another.

Population in a community is always effected by abiotic and biotic factors. Living organism are always trying to adapt to its habitat for surrival. Each population has characteristics : like density, natality, mortality, age distribution, growth, equlibrium population interaction and competition. The individuals interact in various ways like mutualism, compitition, predation, parasitism, commensalism and Amesalism.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) The study of inter relationships between organisms and environment is called ....

(a) Physiology ○ (b) Evolution ○

(c) Ecology ○ (d) Taxonomy ○

(2) The area where water of river mixes with seawater is known as

(a) Terrestrial habital ○ (b) Estuary ○

(c) Marine habitat ○ (d) Freshwater habitat ○

(3) A group of individual organisms of the same species in a given area is known as...

(a) Biotic community ○ (b) Ecosystem ○

(c) Biome ○ (d) Population ○

(4) Generally which factor regulates the enzyme activity.

(a) Light ○ (b) Temperature ○

(c) Water ○ (d) Humidity ○

(5) At which place altitudinal zonation of vegetation is marked ?

(a) River ○ (b) Mountain ○

(c) Grassland ○ (d) Desert ○

(6) At which body part chlorine secretory cells are present in Fish.

(a) Kidney ○ (b) Fine ○ (c) Gill ○ (d) Liver ○

(7) In which organ uromatrix stores water ?

(a) Intestine ○ (b) Kidney ○

(c) Urinary bladder ○ (d) Anal canal ○

(8) In which type of interspecific interactions both species are benifited ?

(a) Commensalism ○ (b) Competition ○

(c) Mutualism ○ (d) Predation ○

(9) Interspecific relation between Rhizobium and leguminous plant is the example of...

(a) Mutualism ○ (b) Commensalism ○

(c) Competition ○ (d) Parasitism ○

(10) If succession pattern begins on a dry place, it is known as....

(a) Hydrosere ○ (b) Mesosere ○

(c) Xerosere ○ (d) Non of them ○

2. Define :

Ecology, Population, Biotic community, Succession, Niche

3. Write short note :

(1) Osmoregulation in fishes

(2) Population density

(3) Age pyramids

(4) Mutualism

4. Answer the following questions is short :

(1) Who are the pionears in primary succession ?

(2) What is mesosere ?

(3) Which are the branches of Ecology ?

(4) Which are specific characters of water ?

(5) Which are Function of salt gland in mariner turtles.

(6) Which type of microflora are found in a soil ?

(7) What is carrying capacity of a habitat ?

5. Explain

(1) Birth rate

(2) Death rate

(3) Amensalism

(4) Consumers

6. Give only graphical representation of the following :

(1) Age pyramids

(2) J-shaped growth curve

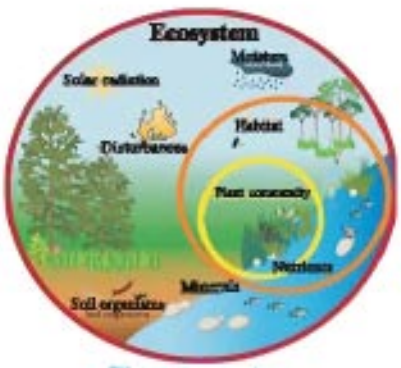
(3) Population fluctuations

11

Ecosystem

Aquatic ecosystem

Biogeography reveals that living organisms are found practically everywhere on this earth. The term ecosystem was first proposed by **A.G. Tansley** (1935), who defined it as the



Giant ecosystem

system resulting from the interaction of all the living and non-living factors of the environment. The ecosystem consists interacting system of biotic components (e.g., plants, animals and microorganisms) and abiotic components (e.g., solar energy, water, air, soil etc). The biotic and abiotic components are linked with each other through unidirectional energy flow and nutrient cycling.

We have studied that living organisms are produced through chemical evolution. They are unicellular or multicellular. Individuals of each species can produce population in the same time and space. Such population forms a biotic community in a particular habitat. Each biotic community has its own structure and function. It can be changed time to time. There is a interrelationship in each biotic community or community to community. When abiotic factors regulate such biotic community is known as ecosystem. In living multicellular higher animals different systems maintain the body. Same way ecosystem also maintain a nature. Thus ecosystem is a structural unit of ecology. Each ecosystem is composed by biotic community and environmental factors. Its structural aspects show interrelationship of biotic components, biomass, food chain, food web and different pyramids. Each ecosystem is maintained and remained healthy due to energy flow. The main source of energy in

ecosystem is sun. Autotrophs convert solar energy into chemical energy. Such energy is used as a food by heterotrophs through different trophic levels. Such phenomenon is called energy flow. Let us see all these aspects basically as well as in detail.

Kinds of Ecosystem

Different types of ecosystems of nature, constitute the giant ecosystem—the biosphere. The ecosystems are categorised in to two as as follows :

(1) Natural ecosystems :

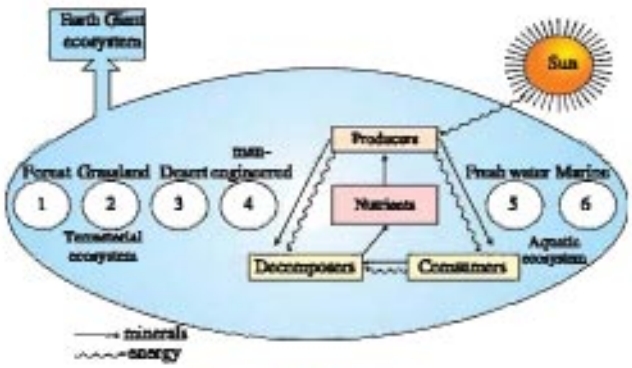
They are operated by themselves under natural conditions without any major interference by man. Based upon the particular kind of habitat, these are further divided as :

(i) Terrestrial ecosystems : (a) forest (b) grassland (c) desert.

(ii) Aquatic ecosystems : They may be further divided as:

(a) Freshwater, which may be non stagnant (running-water as spring, stream, or rivers) or stagnant (standing-water as lake, pond, etc.).

(b) Marine (an ocean and estuary).



Types of Ecosystem

(2) Artificial (man-engineered) ecosystems :

These are maintained artificially by man, natural balance is disturbed regularly. For example croplands like wheat, rice-fields, nursery, poultry farm etc.

Structure and Function of an Ecosystem :

The characteristic structure of an ecosystem is obtained by the systematic physical organisation of the abiotic and biotic components of that particular ecosystem.

There are two major aspects of an ecosystem

(1) Structure : It includes (i) the composition of biological community (as species, numbers, biomass, life history and distribution etc.) (ii) the quantity and distribution of the non-living materials (as nutrients, water etc.) and (iii) the range, or gradient of conditions of existence (as temperature, light etc.).

(2) Function : It includes (i) the rate of biological energy flow (ii) nutrient cycles, and (iii) biological or ecological regulation.

Thus, in any ecosystem, structure and function are studied together.

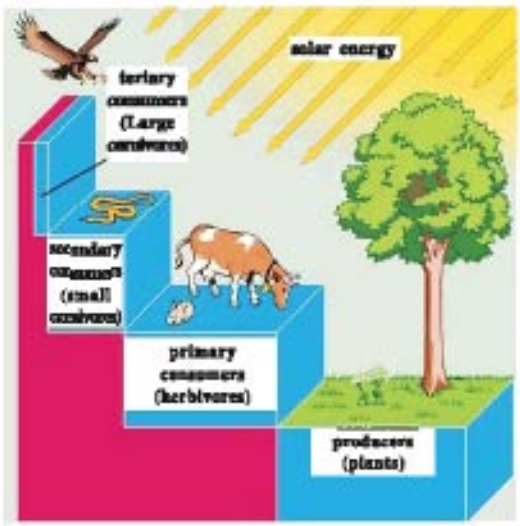
Structure of Ecosystem :

(1) Abiotic (non-living) components :

It includes (i) inorganic substances -as macronutrients(C, H, O, P, K, N, S, Mg and Ca) and micronutrients (Mn, Cu, Mo, B, Zn, Fe, and Cl, Co, Ni, V) etc. (ii) organic materials - as proteins, carbohydrates, lipids etc., (iii) environmental factors as - (a) The climatic factors-(light, temperature, wind, precipitation, humidity etc.) (b) The edaphic factors-(Soil, Water and Air).

(2) Biotic (living) components : Trophic structure of any ecosystem has two components:

(1) Autotrophic components : The component is constituted mainly by green plants, including photosynthetic bacteria, in which fixation of light energy is used to build up complex substances from simple substances. Members of the autotrophic component are known as **producers.**

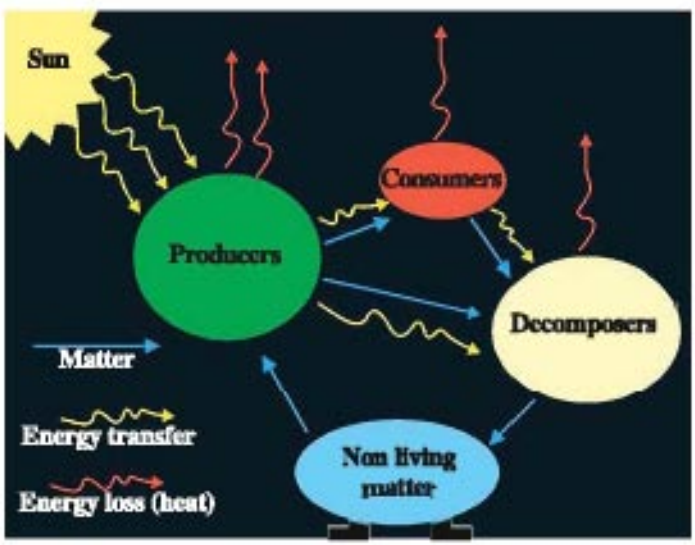


Ecosystem structure

(2) Heterotrophic components : The component is constituted mainly by animals and microorganisms, in which utilisation, rearrangement and decomposition of complex materials occur. As they consume the matter built up by the producers (autotrophs), the organisms involved are known as **consumers.** The consumers are further categorised as :

(a) Macroconsumers : These are the consumers, which in an order as they occur in a food chain are, herbivores, carnivores and omnivores. Herbivores are also known as primary consumers. Secondary and tertiary consumer, if present, are carnivores or omnivores. They all are depended on herbivores.

(b) Microconsumers : These are popularly known as **decomposers or detritivores.** They are saprotrophs which include chiefly bacteria, actinomycetes and fungi. They breakdown complex compounds of dead or living protoplasm, absorb some of the decomposed or breakdown products and release inorganic nutrients in environment, making them available again to autotrophs.



Function of Ecosystem

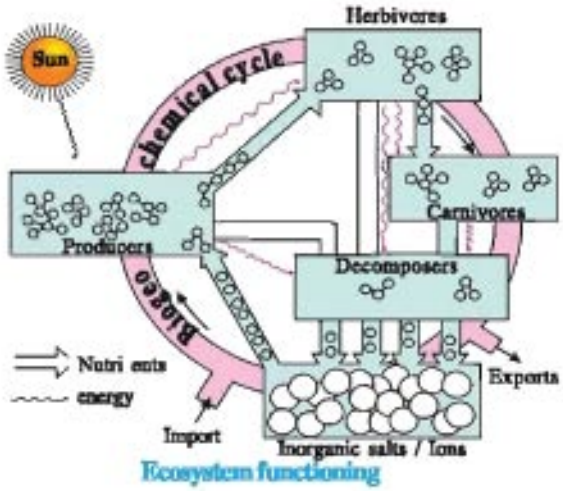
Following two important functions are carried out in every ecosystem :

(i) Flow of energy

(ii) Bio-geo-chemical cycling of materials

The flow of energy begins when the producer organisms absorb sunlight and convert it into chemical energy through photosynthesis. Consumers utilize this chemical energy as food and it is finally released into atmosphere in the form of heat energy. As organisms use only chemical energy, the heat energy cannot be reused. In this way the flow of energy is one-way. The ecosystem must be supplied energy continuously.

The material cycle begins when the inorganic nutrients which are absorbed by the producer organisms. The chemical elements present in these nutrients flow through various organisms are released into the physical environment. These elements are once again absorbed by the producer organisms. Thus, their transport occurs from physical world into the living world and from there back into the physical world. This process is called - biogeochemical cycle.



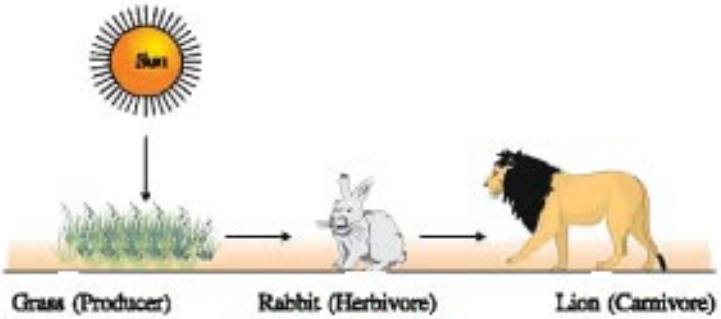
Ecosystem functioning

The ecosystem structure and function may be analyzed in terms of: (i) Food chains, food webs and ecological pyramids; (ii) Energy flow; (iii) Productivity; (iv) Nutrient cycles etc..

Food chain

The transfer of food energy from the producers, through a series of organisms (herbivores to carnivores to decomposers) is known as a food chain. The food chain usually starts with primary producers and ends with carnivores. Food chains are of two types-

(1) Grazing food chain : A grazing food chain begins with chlorophyllous producers and extends through herbivores, carnivores and decomposers. Producers are directly dependent upon solar radiations which are green plants.

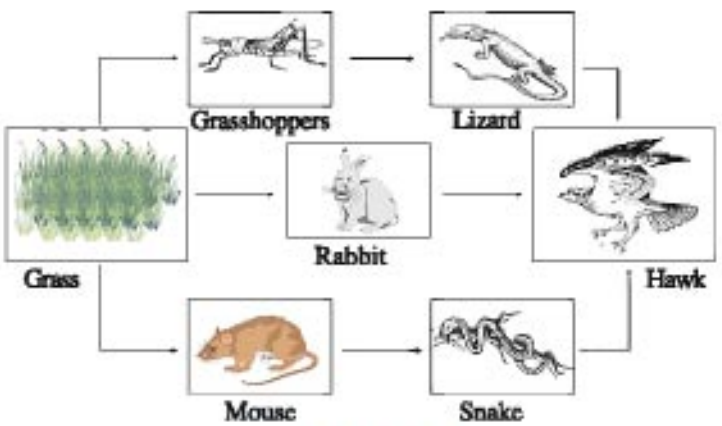


Grazing food chain

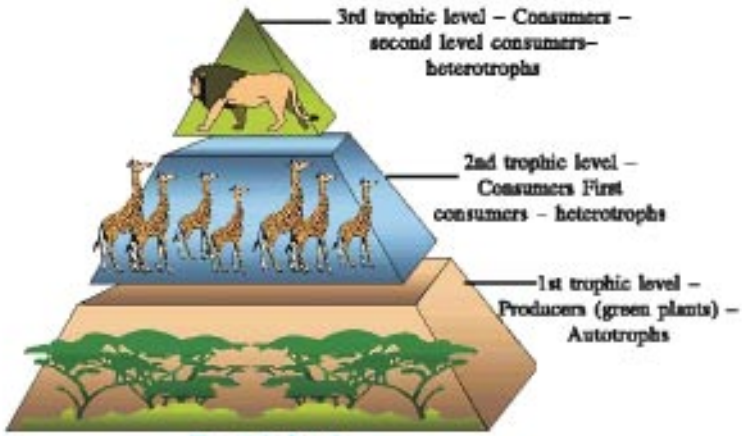
(2) Detritus food chain : A detritus food chain begins with decomposers which live on dead organic matter. Primary source of energy is dead organic matter called 'detritus' which are fallen leaves, plant parts or dead animal bodies.

Food web

Living organisms depend on each other for their food requirement and form a chain which is termed as food chain. A food chain describes how energy and nutrients move through an ecosystem. However, the trophic inter-relationship between animals in nature cannot be explained as simple food chains only. Among the various ecosystems , each one is having definite food chain. The individuals involved are also linked with food chains of other ecosystem. In this way, the animals are inter-dependent for food and they form a net which is termed as a food web.



Food web



Trophic levels

Trophic levels : The trophic structure of an ecosystem is one kind of producer consumer arrangement, where each "food" level is known as trophic level. In other words "successive levels of nourishment in the food chains and food webs of a community" is called **trophic level**. So each trophic level contains organisms whose food is obtained from plants by the same number of steps.

Ecological Pyramids

The trophic structure and function at successive trophic levels, i.e. producers->herbivores->carnivores, may be graphically represented by means of **ecological pyramids** where the first or producer level constitutes the base of the pyramid and the successive levels, the tiers, making the apex. Ecological pyramids are of three general types-

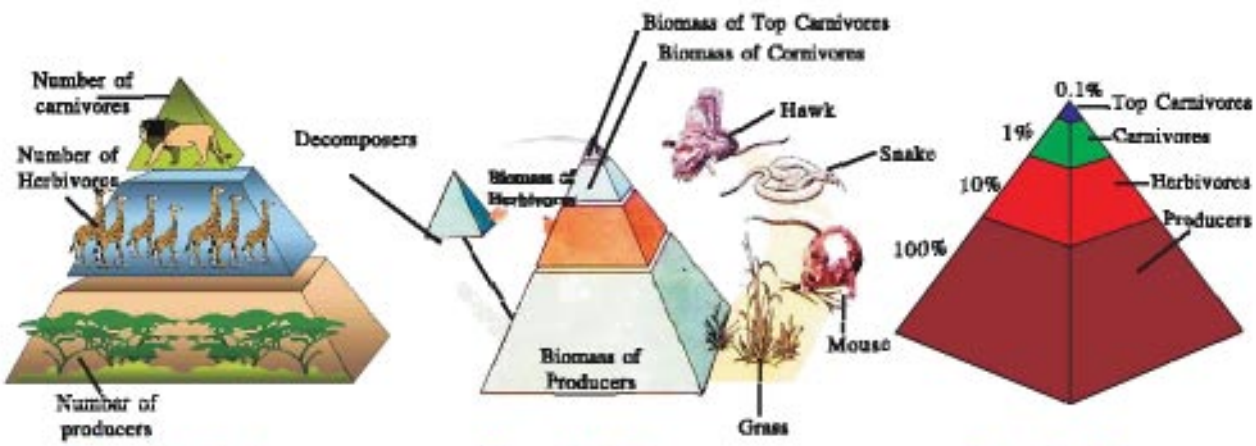
(1) Pyramid of Numbers : It shows the number of individual organisms at each trophic level. Producers occur in the largest number and top level carnivores are in the smallest number. Normally, the pyramids of numbers is upright.

(2) Pyramid of Biomass : It shows the total dry weight or the average biomass of organisms at a particular trophic level. These pyramids are also upright. According to law of thermodynamics, amount of available energy decreases during utilization.

Note : Pyramids of numbers and biomass may be upright or inverted depending upon the nature of the food chain in the particular ecosystem.

(3) Pyramid of Energy : It shows the rate of energy flow and/or productivity at successive trophic levels. Pyramids of energy are always upright. According to low of thermodynamics amount of available energy decreases during utilization.

Note : Pyramids of energy are always upright in each and every ecosystem.



Pyramid of Number | Pyramid of Biomass | Pyramid of Energy

Energy flow

The behaviour of energy in ecosystem can be termed "energy flow" due to unidirectional flow of energy. Energy is the capacity to do work. The flow of energy in ecosystem is regulated by two important laws. According to the first law of Thermodynamics, energy can neither be destroyed nor can it be created. Thus the quantum of energy is constant. Energy can be converted from one form into another. According to the second law 'whenever energy is converted from one form into another, some energy is dissipated in the form of heat'.

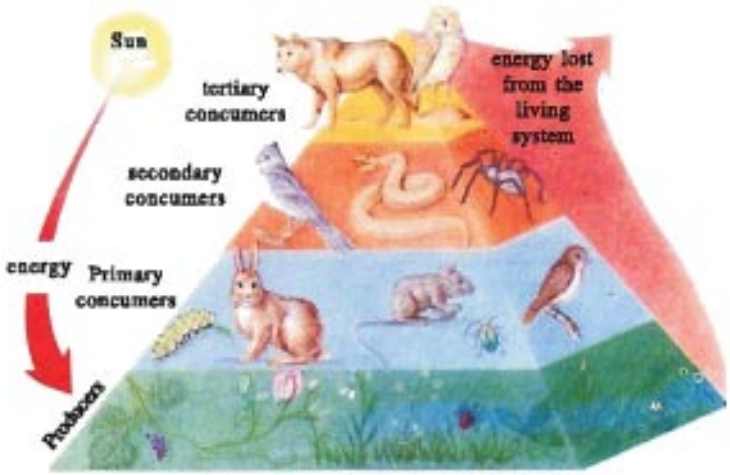
Solar energy is transformed into chemical energy by the process of photosynthesis, and is stored in plant tissue and then transformed into mechanical and heat forms during metabolic activities.

From energetics point of view it is essential to understand for an ecosystem

(i) the efficiency of the producers in absorption and conversion of solar energy,

(ii) the use of this converted chemical form of energy by the consumers,

(iii) the total input of energy in form of food and its efficiency of assimilation,



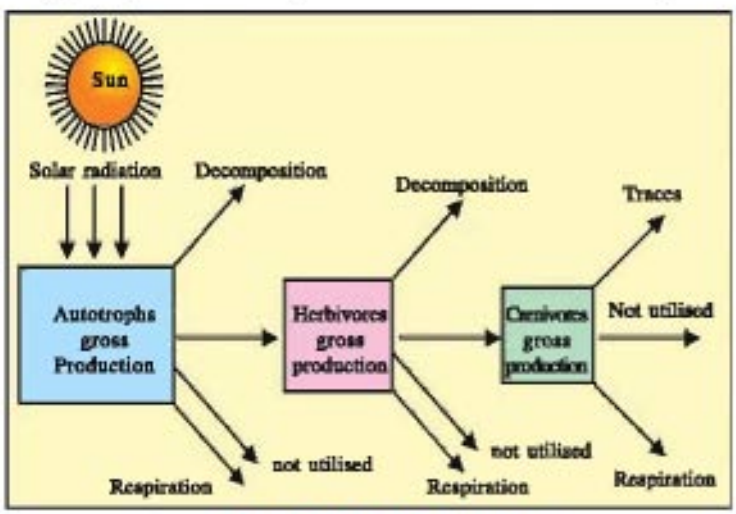
Energy is recieve in an eco-system

(iv) the loss through respiration, heat, excretion etc. and

(v) the gross production.

A food chain describes how energy and nutrients move through an ecosystem. Each constituent of a food chain forms one trophic level. Thus, producers form first trophic level, herbivores the second and carnivores the third.

Energy supports all the activities of living world. At each trophic level, the amount of available energy keeps decreasing, because heat is lost during the energy transformations. The energy that is captured by green plants does not revert back to the sun and the energy which passes to the herbivores does not come back to the autotrophs. Thus the flow of energy in an ecosystem is always unidirectional.



Single Channel Energy Flow

Productivity :

'The amount of organic matter or biomass produced by an individual organism, population, community or ecosystem during a given period of time is called productivity'.

Productivity is of the following types :

(1) Primary productivity : It is associated with the producers which are autotrophic. These are the green plants and some photosynthetic bacteria. In a given region the total production over a given period of time is called primary productivity of that ecosystem. It is generally measured as annual grams of dry weight (measured as tons) per hectare g/m^2/ yr. "Primary productivity is further distinguished as:

(a) Gross Primary Productivity(GPP) : The total rate of photosynthesis carried out by all producer organisms in an ecosystem is called-gross primary production (GPP). It depends on the chlorophyll content. The rate of primary productivity is estimated in terms of either chlorophyll content as, Chl/g dry weight/unit area, or photosynthetic number i.e. amount of CO_2 fixed/g Chl/hour. (GPP = NPP + Respiratory loss).

(b) Net Primary Productivity(NPP) : It is the rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants during the measurement period. Energy remains after such a use by producers, is available to the consumer organisms. This amount is referred to as the net primary production (NPP). This energy is located in the plant biomass. This biomass is utilized by consumers as food.(NPP = GPP-Respiratory loss).

(2) Secondary Productivity : The amount of energy storage at consumer(herbivores) level is called secondary productivity. Consumers obtain energy by consuming producers as food. Using this energy they build up their own body tissues and maintain their life.

(3) Net Productivity : The amount of storage of organic matter not used by the heterotrophs (consumers) is known as net productivity, which may be consolidated on days, month, season or year basis.

Different ecosystems have different productivity. It is high in forests, medium in grasslands and low in deserts. In aquatic habitat also it decreases with the increasing depth.

Decomposition :

Death and decomposition are important parts of all lives on the earth and they are essential for every ecosystem. The process by which dead or complex organic material is broken down into simpler forms of matter which resembles with the soil is called decomposition.

Bacteria, fungi, and some worms break down the body of dead plants, animals, and insects. Such bacteria, fungi, and worms are called decomposers. Decomposers need to eat some of the dead things so they can live and grow.

The tiny pieces of inorganic matters, left over after decomposers eat become part of the soil. Living plants take what they need from these inorganic matters so they can grow. The parts of these inorganic matters that living plants take to grow are called nutrients. So, green plants make their own food, but they also need to get nutrients from the soil. Decomposers help to provide these nutrients.

Common decomposers of ecosystem are: bacteria, fungi and earthworms.

Process of Decomposition

There are three stages in the process of decomposition : (1) Fragmentation, (2) leaching and (3) catabolism.

(1) Fragmentation : First of all, the detritus is fed upon by detritus-feeding animals. As the detritus passes through the alimentary canal of these animals, changes occur in the size and form of detritus. The food is chewed, grind and filtered. Thus a larger surface area is made available for future degradation. These materials are added to the soil as faecal material of such animals.

(2) Leaching : It is a process in which water leaches deep down into the soil and hence, the dissolved materials in the soil move towards the deeper layers of soil.

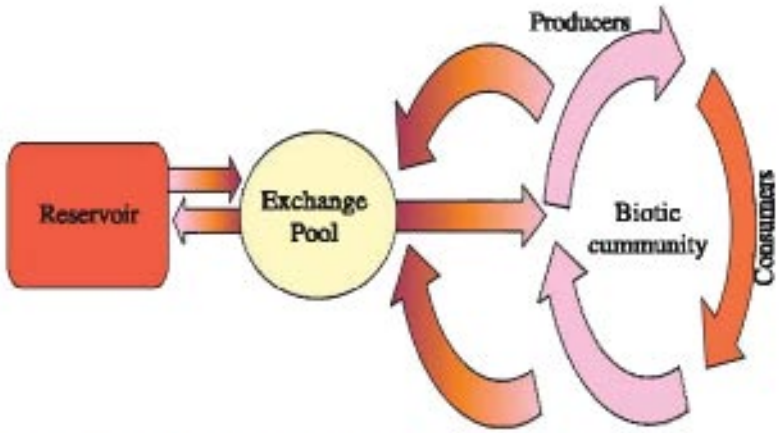
(3) Catabolism : Extracellular enzymes secreted by various kinds of fungi and bacteria begin the process of catabolic activities. First, complex organic matter is converted into simple organic forms. Then, these simple organic substances are transformed into inorganic ions and salts.

Decomposition

Then after these matters undergo to the processes of humification and mineralization. When humus is mineralized, these salts and ions are released in the forms which are available to plants.

Biogeochemical cycles

The cyclic pathways through which chemical elements travel from the environment into the organisms and from the organisms into the environment regularly and continuously are called biogeochemical cycles.



Components of Bio-Glo-chemical cycles

Bio-includes the organisms, geo-includes the soil, rocks, water etc., chemical- includes the chemical elements like carbon, nitrogen, sulphur, etc., Nutrients are continuously go round in the cycle.

There are two types of biogeochemical cycles.

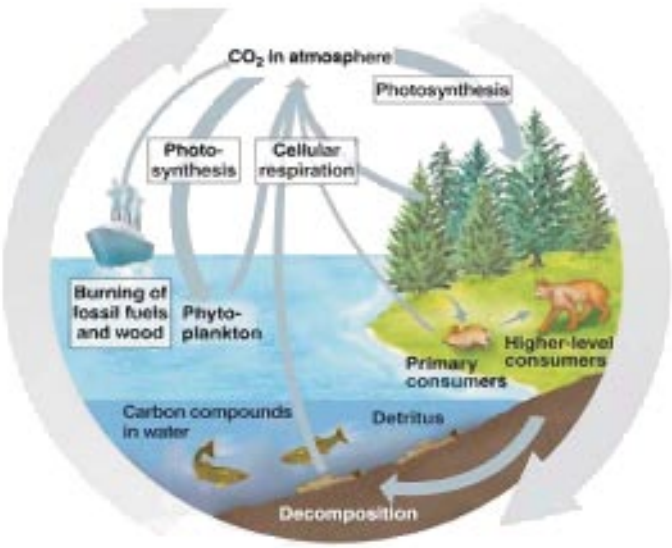
(1) Gaseous cycle : Carbon Cycle, Nitrogen Cycle, Oxygen Cycle, and

(2) Sedimentary cycle : Phosphorus Cycle, Sulphur Cycle.

The Carbon Cycle

Carbon occurs as carbon dioxide in the atmosphere. It is also found as graphite and diamond in nature. Carbon cycle is an example of gaseous type of biogeochemical cycle of nature.

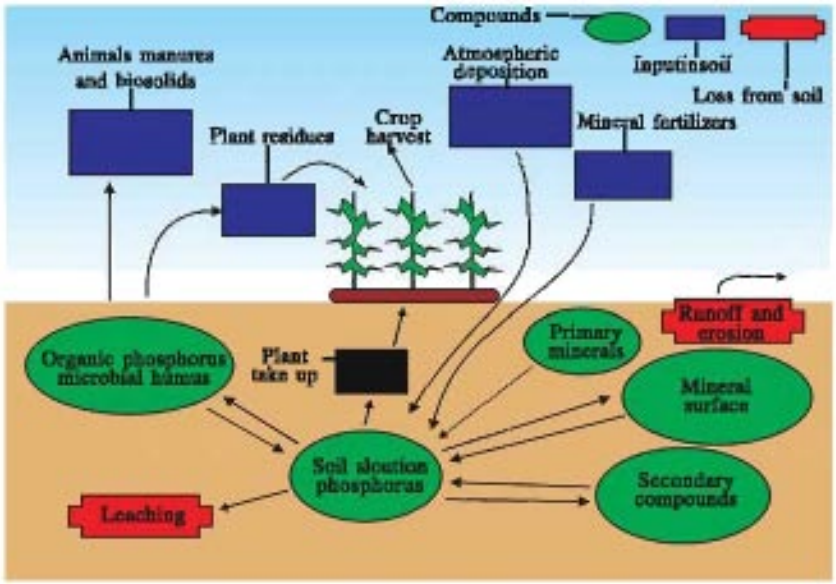
Carbon is one of the most essential element of organic compounds. Carbon taken from carbon dioxide of the air is incorporated into the molecules of carbohydrate by green plants by the process of photosynthesis. When animals



Carbon cycle

feed upon plants or products of plants, carbohydrates enter into the bodies of these animals. In the final respiratory pathways taking place in the mitochondria of the cells of animals, carbohydrates are broken down yielding energy. CO_2 and water are the waste products. This CO_2 is liberated into the air or water during respiration. Plants also liberate CO_2 during the process of respiration.

The burning of coal and fossil fuels (petroleum products) also adds CO_2 to the atmosphere. Thus the great carbon cycle of nature, during which the carbon of CO_2 is used again and again by living things, goes on continuously.



Phosphorus Cycle

Phosphorus Cycle

Phosphorus is a key element in all living organisms. Phosphorus is an essential nutrient to biological systems. Its requirement is mainly seen in nucleic acids, cell membrane, phospholipids, NADP (Nicotinamide adenine dinucleotide phosphate), bones, teeth and adenosine triphosphate(ATP) as a universal fuel of living organisms.

The greatest reservoir of phosphates in the world lies in the relatively insoluble ferric and calcium phosphates in rocks. Erosion caused by rainfall and the runoff of streams remove phosphorus from phosphate rock. This results in a phosphorus supply in the soil which is available to plants. Animals obtain phosphorus from plants. After the death of living organisms, phosphorus returns to the water and soil from their bodies in the ion form and they recycle it in the ecosystem. Plants rapidly absorb them.

In most ecosystems, availability of phosphorus becomes a limiting factor. Some specific bacteria release phosphorus from the dead bodies as phosphate from organic phosphorous compounds. In higher plants, the symbiotic fungus (mycorriza) living on root systems helps in absorption of phosphate.

A modern source of phosphorus is the common household detergents which now enter waste water systems and are then released into streams, lakes and estuaries.

The phosphorus in the soil is dissolved in water, which in turn flows into bodies of water. Some of this phosphorus is used by plankton, which in turn is eaten by fish. These fishes are then consumed by sea birds. But the majority of phosphorus washed into the sea sinks to the ocean floor and is not recycled. The loss of phosphorus to the ocean has been greater than the gain to land.

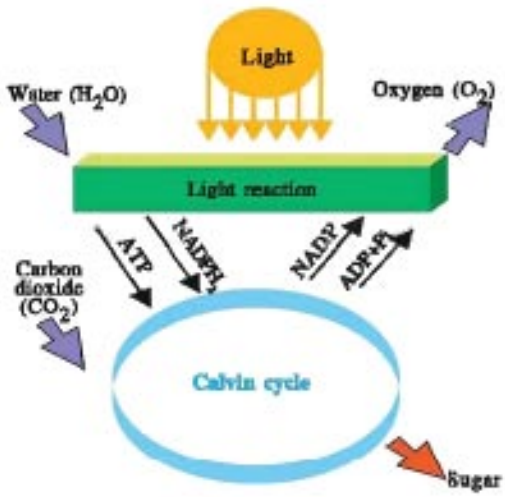
Carbon fixation

Carbon fixation is important for both animal and plant life. carbon fixation is the conversion of carbon dioxide into organic compounds during photosynthesis. it mostly refers to the processes found in autotrophs (producer), usually driven by photosynthesis, whereby carbon dioxide is changed into sugars.

Photosynthetic organisms use sunlight to create energy which is stored in the form of several chemical compounds. in the Calvin cycle, the energy is used to transform carbon dioxide into a sugar in a process which is sometimes referred to as carbon fixation.

The Calvin cycle is the most common biological method of carbon fixation. In plants, there are three ways of carbon fixation during photosynthesis:

C_3^- plants that use the Calvin cycle for the initial steps that incorporate CO_2 into organic matter, forming a 3-carbon compound as the first stable compound. This form of photosynthesis occurs in the majority of terrestrial species of plants.



C_4^- plants prefer the Calvin cycle with reactions that incorporate CO_2 into a 4-carbon compound. C_4 plants have a distinctive internal leaf anatomy. Examples, sugar cane and maize are C_4 plants.

CAM(Crassulacean Acid Metabolism)- plants that use Crassulacean acid metabolism as an adaptation for arid conditions. CO_2 enters through the stomata during the night and is converted into organic acids, which release CO_2 for use in the Calvin cycle during the day, when the stomata are closed.

Pollution free Oxygen

Oxygen is good for the healthy body and is our primary life-support. The air we breathe is so vital that without it we would rapidly die. Clean air is made up of several gases of which oxygen is the most important to us. Clean air contains 19%–21% oxygen. In ancient times people lived longer because the air was composed of 40% oxygen.

The generation and maintenance of all our body processes are supported by four basic life-support components: carbohydrates, water, proteins and energy. Most scientists agree that oxygen is actually the over-riding key ingredient in all four of these life-support components. 80% of all our metabolic energy production is created by oxygen!

All metabolic processes in the body are regulated by oxygen. Without oxygen — a crucial life-support — life ceases to exist in only minutes.

Facts about Oxygen

(1) Lack of oxygen in our universe is due to pollution, burning of fossil fuels and by- CFC(chloro floro carbon) overall destruction of the ozone layer.

(2) Everyday we breathe 20,000 times.

(3) Blood is the liquid carrier of oxygen that fuels all systems, stimulates chemical reactions and cleans itself of wastes and toxins.

(4) By mass, oxygen makes up 90% of the water molecule; water makes up 65-75% of the human body

(5) Cancer attacks every organ in our body, except the heart because of its abnormal supply of oxygen.

Summary

The ecosystem consists interacting system of biotic and abiotic components.

Different types of ecosystems may be natural and artificial. [1] Natural ecosystems : (i) Terrestrial -(a) forest (b) grassland (c) desert (ii) Aquatic - (a) Freshwater, which may be non stagnant (running-water as spring, stream, or rivers) or stagnant (standing-water as lake, pond, etc.). (b) Marine (an ocean and estuary). [2] Artificial ecosystems:These are maintained artificially by man where natural balance is disturbed regularly.

Abiotic components of ecosystem includes (i) inorganic substances (ii) organic materials (iii) environmental factors as - (a) the climatic factors and (b) the edaphic factors. Biotic component : This is the trophic structure of any ecosystem has two components:, (1) Autotrophic component. Members of the autotrophic component are known as producers. (2) Heterotrophic component. The organisms involved are known as consumers. The consumers are further categorised as : *(a) Macroconsumers.* These are herbivores, carnivores and omnivores. *(b) Microconsumers.* These are popularly known as decomposers.

Two important functions are carried out in every ecosystem – (i) Flow of energy(ii) Bio-geo-chemical cycling of materials.

The transfer of food energy from the producers, through a series of organisms (herbivores to carnivores to decomposers) with repeated eating and being eaten, is known as a food chain which may be - (1) Grazing food chain and (2) Detritus food chain. The individuals involved are also linked with food chains of other ecosystem. In this way, the animals are inter-dependent for food and they form a net which is termed as a food web.

The trophic structure of an ecosystem is kind of producer consumer arrangement, where each "food" level is known as trophic level. Ecological pyramids are of three general types - (1) Pyramid of Numbers (2) Pyramid of Biomass (3) Pyramid of Energy.

Energy is the capacity to do work. At each trophic level, the amount of available energy keeps decreasing, because heat is lost during the energy transformations. The energy that is captured by green plants does not revert back to the sun and the energy which passes to the herbivores does not come back to the autotrophs. The flow of energy in an ecosystem is always unidirectional.

'The amount of organic matter or biomass produced by an individual organism, population, community or ecosystem during a given period of time is called productivity'. Productivity is of the following types:1. Primary productivity. (a) Gross primary productivity. (b) Net primary productivity. 2. Secondary productivity. 3. Net productivity. Different ecosystems have different productivity. It is high in forests, medium in grasslands and low in deserts. In aquatic habitat also it decreases with the increasing depth.

Death and decomposition are important parts of all lives on the earth and they are essential for every ecosystem. The process by which dead or complex organic material is broken down into simpler forms of matter which resemble with the soil is called decomposition. Common decomposers are: bacteria, fungi. earthworms.There are three stages in the process of decomposition (1) fragmentation, (2) leaching and (3) catabolism.

The cyclic pathways through which chemical elements travel from the environment into the organisms and from the organisms into the environment regularly and continuously are called bio-geo-chemical cycles.There are two types of bio-geo-chemical cycles. (1) Gaseous cycle : Carbon cycle, Nitrogen cycle, Oxygen cycle, and (2) Sedimentary cycle : Phosphorus cycle, Sulphur cycle.

Carbon fixation is important for both animal and plant life. Carbon fixation is the conversion of carbon dioxide into organic compounds during photosynthesis. It mostly refers to the processes found in autotrophs (producer), usually driven by photosynthesis, whereby carbon dioxide is changed into sugars.

Oxygen is good for the healthy body and is our primary life-support. All metabolic processes in the body are regulated by oxygen. Without oxygen - a crucial life-support - life ceases to exist in only minutes. There is a defficiency of O_2 due to pollution.

Exercise

1. Select the proper option and write its number in circle :

(1) Abiotic component of Ecosystem is...

(a) Bacteria ○ (b) Inorganic substances ○

(c) Algae ○ (d) Fungi ○

(2) Producers are ...

(a) Heterotrophs ○ (b) Saprotrophs ○

(c) Autotrophs ○ (d) None of this ○

(3) Consumers are ...

(a) Heterotrophs ○ (b) Saprotrophs ○

(c) Autotrophs ○ (d) None of this ○

(4) Energy pyramid is always...

(a) Inverted ○ (b) Verticle ○

(c) Upright ○ (d) None of this ○

(5) Which is the main source of energy in ecosystem ?

(a) Soil ○ (b) Air ○ (c) Water ○ (d) Sun ○

(6) Name the first trophic level organisms in a terrestrial ecosystem.

(a) Decomposer ○ (b) Herbivorous ○

(c) Carnivorous ○ (d) Producer ○

(7) Which organisms are the first level consumer organisms ?

(a) Decomposer organisms ○ (b) Herbivorous organisms ○

(c) Carnivorous organisms ○ (d) Producer organisms ○

(8) Energy flow is always...

(a) Unidirectional ○ (b) Bidirectional ○

(c) Multidirectional ○ (d) Tridirectional ○

(9) Which cycle is the common biological method of carban fixation ?...

(a) Gaseous cycle ○ (b) Calvin cycle ○

(c) Nitrogen cycle ○ (d) Hydrological cycle ○

(10) Which nutrient cycle is sedimentary cycle in ecosystem ?

(a) Hydrogen cycle ○ (b) Phosphorus cycle ○

(c) Nitrogen cycle ○ (d) Oxygen cycle ○

2. Answer the following questions in short :

(1) What is an ecosystem ?

(2) Which organisms are known as a decomposers?

(3) From where does a grazing food chain begin ?

(4) Give names of the phases of decomposition.

(5) Mention the types of primary productivity.

(6) State the pathway of energy moves in ecosystem.

(7) Give the types of bio-geo-chemical cycle.

(8) Mention the three types of carbon fixations during photosynthesis.

3. Define :

(1) Gross Primary Production (2) Secondary Productivity

(3) Ecosystem (4) Decomposition

(5) Food chain (6) Food web

(7) Trophic level (8) Ecological Pyramids

(9) Biogeochemical Cycle.

4. Do as directed :

(1) Mention the kinds of ecosystem.

(2) Describe the types of food chains.

(3) Mention the structure of ecosystem.

(4) State the important functions of ecosystem.

(5) Describe the types of 'Ecological Pyramids'.

(6) State the role of Phosphorus in organisms.

(7) Describe the process of decomposition.

(8) State the sources of Phosphorus in nature.

5. Write short note on :

(1) Consumer organisms (2) Ecological pyramids

(3) Types of productivity (4) Carbon cycle

(5) Phosphorus cycle (6) Decomposition

(7) Carbon fixation (8) Pollution free oxygen

(9) Energy flow

6. Draw outline diagramme only :

(1) Single channel energy flow (2) Trophic level

(3) Calvin cycle pathway (4) Carbon cycle

12

Biodiversity and Its Conservation

In the entire biosphere, numerous kinds of microbs, plants and animals live. We can observe them in different regions. We also know that all organisms can not be found every where. They show diversity among many aspects like their shape, volume, size, colour, life style, and many other things. e.g. you have studied that *Sequoia sempervirens* (Gymnosperm) and *Eucalyptus* sp. (Angiosperm) having up to 400 and 100 meters height respectively. They are tallest trees. Where as *Zamia pygmea* (Gymnosperm) and *Wolffia globosa* (Angiosperms) are the smallest plants. Bacteria and Yeast are microscopic. Whales and Dolphins are the large sized aquatic mammals where as Elephant is terrestrial but Amoeba, Euglena are microscopic. Plasmodium is parasitic in its mode of life. Such examples indicate that there is a great variation in plants, animals and microbes. We are surprise when we hear that there are more than 20,000 species of ants, 300,000 species of beetles, 28,000 species of fishes and nearly 20,000 species of orchids. Man has been identifying them for the last two to three centuries. We determine their identity and classify them on the basis of their similarities and dissimilarities. Even variations can occur amongst the organisms of the same species.

(a) (b) (c)

(a) Sequoia sempervirens (b) Wolffia globosa (c) Wolffia globosa on the tips of fingers
Diversity found in size of plants

On what basis these variations are there ? For it, we have to refer its genetic aspect, species variety and different types of ecosystems. There can be genetic variations, species variations as well as ecosystem variations. Let us see these levels of Biodiversity.

Variation in mango species

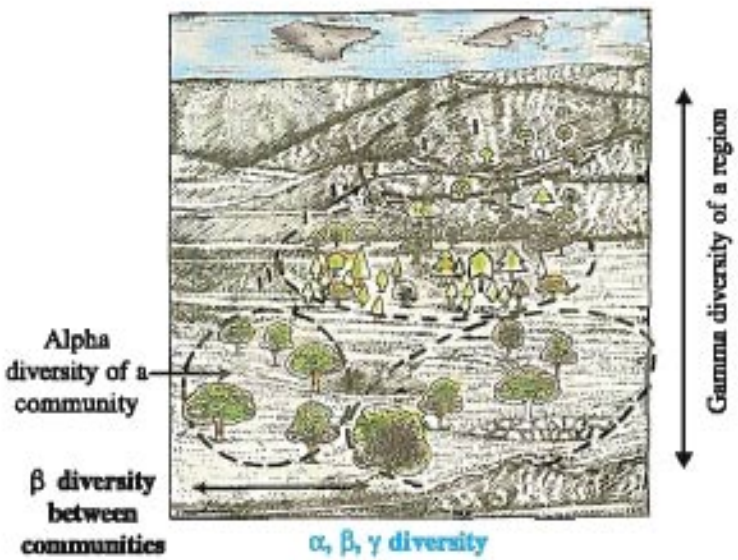
(1) Genetic Diversity : Organisms of each species possess genetic material. Genes of all organisms are made up of DNA. The number of genes and individuals of each species are fixed. India has unique genetical diversity. India has more than 50,000 genetically different strains of rice and 1000 verities of mango.

The variation in the constitution of genes is called species diversity of that species. There are alternative forms of a gene. i.e. Genetic diversity refers to totality of all inherited genetic variations within a population. A population is a group of similar individuals of same species. All genes of a population are called gene pool. Due to this genetic diversity that natural selection can operate in the process of evolution. Genetic diversity is basis of formation of new species.

(2) Species Diversity : The species diversity of any area is determined by various species which live there. The greater the number of species, the higher is the species diversity e.g. The sanctuary has 457 plant species, 140 species of birds, 40 species of mammals, 30 species of reptiles and 210 species of arthropods. The total number of these groups 877 constitute species diversity of the sanctuary. The another example is the Western Ghats have greater amphibian species diversity than the Eastern Ghats.

The species diversity also increases the genetic diversity of that area. It is very important for the normal functioning and sustainability of ecosystems. The measurement of species diversity of an area can be easily done through the number of species which live there. As the area increases the number of species living in it also increases. Over and above the presence of a species, the number of individuals of the species can also be taken into account. There may be more individuals of some species and less of some other species.

R. H. Whittaker (1965) has pointed three types of species diversity:



α, β, γ diversity

(1) α diversity (2) β diversity (3) γ diversity

α diversity : It is the relative richness of different species in an habitat i.e. the percentage of each and every species within a community.

β diversity : ß- diversity is the relative richness of different species along a gradient from one habitat to another habitat within the community. As an example, birds of pond and birds of agriculture area of the same grassland area.

γ diversity : γ – diversity refers to the richness of different species in a range of habitats within a geographical area. Bio diversity of a ocean, lakes, ponds, mountains, forests, etc. is the examples of γ – diversity.

(3) Ecosystem Diversity : The variation in species richness in different ecosystems of a geographical area is called ecosystem diversity. It contains a variety of plants, animals and environmental factors. They interact with each other. Each and every ecosystem has a particular set of environmental conditions and allows a particular group of plants and animals to grow there in. Therefore, species diversity differs from ecosystem to ecosystem.

Different classification systems exist to describe different types of biodiversity. Their levels are summarized in a table given below :

Table : The composition of biodiversity

Genetic diversity	Organization (species) diversity	Ecological Diversity
↓	↓	↓
Populations	Kingdoms	Biomes
↓	↓	↓
Species	Phyla	Ecosystems
↓	↓	↓
Chromosomes	Families	Habitats
↓	↓	↓
Genes	Genera	Niches
↓	↓	↓
Nucleotides	Species	Population
	↓	
	Sub species	
	↓	
	variety	

By above, now we can define the biodiversity easily. Biodiversity refers to the variety of microbes, plants and animals of an area. It indicates the degree of variety in nature. It indicates the totality of genes, species and ecosystems in a region. So it can be also defined as the biodiversity means "variety and variability of life."

In our life style in every event we think about role of biodiversity in our economy and development. Each and every organism is useful to each other directly or indirectly in a nature related to economy. A question can be arise that why should we learn biodiversity ? It has answer as below.

AIMS of biodiversity :

- The knowledge of biodiversity is very important for systematic studies of plants and animals.
- Identification of hot spots.
- Ecosystem studies.

- Biogeographic studies.
- Proposing advance conservation programmes.
- Enriching quality of resources.
- Conservation of global ethics.

We always think that we acquire to gain from nature for benefit. Gandhiji had wrote that, "The nature has capacity to satisfy the need of man, but not his greed."

Patterns of Biodiversity

Latitudinal gradients : The diversity of plants and animals is not uniform throughout the world and shows an uneven distribution. Generally, there is an increase in biodiversity from polar region to the equator (tropics latitudinal range of 23.5^0 N to 23.5^0S). Thus localities at lower latitudes have more species than localities at higher latitudes. This is often referred to as the latitudinal gradient in species diversity. for examples; Colombia located near the equator has nearly 1400 species of birds while New York at 41^0 N has 105 species and Greenland at 71^0N (North) only 56 species. India, with much of its land area in the tropical latitudes, has more than 1200 species of birds. A forest in a tropical region like Equadar has up to 10 times as many species of vascular plants as a forest of equal area in temperate region like the Midwest of the USA. The largely tropical Amazonian rain forest in south America has the greatest biodiversity on earth. It comprises more than 40,000 species of plants, 3000 of fishes, 1300 of birds, 427 of mammals, 427 of amphibians, 378 of reptiles and of more than 1,25,000 invertebrates. Scientists estimated that in this rain forest there might be at least two million insect species waiting to be discovered and named.

High biodiversity in tropics

Ecologists and evolutionary biologists have proposed various hypotheses for greater biodiversity in tropics. Some of these are :

(a) Speciation : Speciation is the formation of new and distinct species in the course of evolution. It is time consuming process. Unlike temperate regions subjected to frequent glaciations in the past, tropical latitudes have remained relatively undisturbed for millions of years and thus, had a long evolutionary time for species diversification.

(b) Effect of environment : Tropical environments, unlike temperate ones, are less seasonal, relatively more constant and predictable. Such constant environments promote niche specialization and lead to a greater species diversity and (c) species-energy hypothesis: There is more solar energy available in the tropics, which contributes to higher productivity. This, is in turn might contribute indirectly to greater diversity.

(c) Species-Area relationships : Species Area relation is a relationship between the area of habitat or part of a habitat and the number of species found within that area. According to German naturalist and geographer Alexander von Humboldt the number of species increases as the size of a geographical area increases but only up to a limit. In fact, the relation between species richness and area for a wide variety of taxa (angiosperms plants, birds, bats, freshwater fishes) turns out to be a rectangular hyperbola.

Importance of Biodiversity

Biodiversity is useful to man in several ways. Uses are direct or indirect. They are described below :

(1) Food : It provides food for man and their pets. Plants are consumed by animals as food. It is the consumptive value of biodiversity. Rice, wheat, corn, cereals, vegetables, fruits, milk, egg, meat, fish, etc. are supplied by our valuable biodiversity.

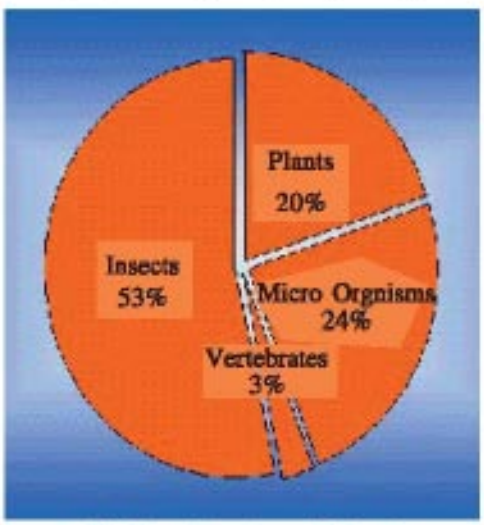
(2) Productive use value : The marketable items of biodiversity form the productive use value. e.g. timber, agricultural products, aqua food like fish, animal husbandry produces milk, egg and meat, silk, pearl, drugs, cotton, papers, pesticides (like Neem tree). Antibiotics are synthesized by microbes e.g. Penicillin from fungus, etc.

(3) Aesthetic and Cultural Benefits : Biodiversity also has great aesthetic value. Examples of it include ecotourism, bird-watching, wildlife, pet keeping, gardening, etc. Throughout human history people have related biodiversity, to the very existence of human race through cultural and religious believes. In a majority of Indian villages and towns, people like *Oscimum sanctum* (Tulsi), *Calotropis procera* (Akdo) *Polyalthia longifolia* (Asopalav), *Ficus religiosa* (Pipal) and *Prosopis cineraria* (Khejdo) and various other trees are planted, which are considered sacred and worshipped by the people. Several birds and even snake have been considered sacred. Today we continue to recognize plants and animals as symbols of national pride and cultural heritage. Tiger and peacock have been declared as national animal and bird respectively in India. Asiatic lion, Flamingo (bird), Indian laburnum (wild flower) and Neem (tree) are the list of symbols of Gujarat state.

(4) Ecosystem Services : Biodiversity is important in the maintenance of biosphere and its ecosystems. Forests are the main mechanism for the conservation of carbon dioxide into carbon and oxygen. Various aspects like green house effect, maintenance of global temperature, oceanic currents and winds for maintenance of climate, regulation of rain fall maintained by forests conservation of soil, pollinations of plants and purification of groundwater are made possible due to biodiversity. The ecosystem services have been valued in the range of 16 to 54 trillion (10^{12}) US dollar per year.

Biodiversity at World, National and Gujarat levels

(a) Biodiversity at World Level : Previously in semester 1, it was mentioned that, estimated species may be approximately 50 lacs to 5 crores. Public interest in protecting the world's plant and animal species has identified during the last 20 to 30 years. Approximately about 1.7 to 1.8 millions species are identified till today. These include 300000 species of angiospermic plants, 800,000 species of insects, 40,000 species of vertebrates, and 3,60,000 species of microorganisms etc. Among plants, Angiosperms constitute the largest number of species in the world and in the animal kingdom arthropods are dominant. According to some recent estimates the number of insects alone may be as high as 10 millions. The tropical forests are regarded as the richest in animal and plant diversity. More than half of the species on the earth live in moist tropical forests which are only 7% of the total land surface. Both, scientists and general public have realized that we are living in a time of unprecedented mass extinction. Around the globe, biological communities that took millions of years to develop and being devastated by human activity.



Biodiversity at world level

(b) Biodiversity at National level : India is one of the twelve mega biodiversity countries of the world. The richness of biodiversity in India is mainly due to the wide variety of climatic and altitudinal conditional characteristics of this country. The climate varies from humid topical area (Western Ghats) to icy mountains (Trans-Himalaya) via hot desert (Thar) and plains. The ten biogeographical regions of our country form a wide variety of ecological habitat which give shelter to so many kinds of plants and animals.

India covers only 2.4% of the total area of the world, but it has 11% of the world's total biota, i.e. 45,500 member of species of plants and 86,874 species of animals. India has more than 7% of the total animal species in the world.

A significance feature of Indian flora is the confluence of flora from the surrounding countries like Malaya, China, Tibet, Japan and Europe and even from distant countries like America, Africa and Australia. About 5000 species of flowering plants belonging to 141 genera of 47 families had originated in India. Indian flora is extremely varies in exert composition and endemism. There are hundreds of species of grasses. We are equally rich in insect, amphibian, reptile, bird and mammalian species of great economics potential. India is a source of traditional crop varieties ranking first amongst the 12 regions of diversity of crop plants and seventh so far in the contribution of agricultural species. India is the origin place of 166 species of crop plants, and 320 species of wild relatives of cultivated crops. At present 30,000 – 50,000 varieties of cultivated plants are found in India.

Out of the total number of plant species known in India, there are more than 4000 species used in medicines, about 3000 for food, about 500 yield fibre, 400 as fodder, 300 yield gum and about 100 species are used to extract essential oils and scents. India has been primary centre for domestication of rice, sugarcane, banana, tea, mango, cucumber, citrus, beans, jute, cardamom, black pepper, ginger, turmeric, yam, bamboo and jack fruit and secondary centre for domestication of potato, tomato, maize, sesamum and soyabean.

India is rich in marine biodiversity among the coastline of 7500 km, supporting the most productive ecosystems such as mangroves, coral reefs, estuaries, lagoon etc. There are about 45 species of mangrove plants and over 341 species of coral reefs.

The occurrence of a taxa in a small area and no where else, is called endemism. As endemic species of both plants and animals are mostly found in North-East, Western Ghats and Andaman and Nicobar Islands. Birds representing about 14% of global avian fauna show relatively high endemism. Nilgiri pipit, Nilgiri wood pigeon, Malbar parakeet, Rofous babbler are endemic birds. The species which is distributed only in a small restricted area is known as endemic species.

(a) Nilgiri wood pegion (b) Nilgir pipit (c) Malbar parakeet

(c) Biodiversity of Gujarat : Gujarat is rich in diversity of species, habitats and ecosystems. Gujarat is home of nearly 7000 species of plants and animals. Its geographic location is characterized by mountain ranges and longest coast line. It is famous for its unique saline desert, called Rann of Kachchh. Gujarat also has several district biogeographic zones reflecting a wide range of ecological diversity. The coral reefs in the Gulf of Kachchh as widely admired for their amazing beauty and spectacular diversity. Species diversity is also high: in Gujarat as seen in the 4320 species of plants. There are 2198 species of higher plants belonging to 901 genera and 155 families. There are 2,728 species of animals. The state harbors 14% of fish, 9% amphibians, 19% reptiles, 37% of birds and 25 % of mammals. Gujarat has unique ecosystems where world's threated species of plants and animals get shelter.

Flamingo city : This area between Khadir and Paccham islands in the great Rann of Kachchh, is the largest breeding ground of flamingos, a migratory species.

The great Rann of Kachchh, and the little Rann of Kachchh are the worlds only saline desert spread in 25,000 sq km. Its high residual salinity level provide a rare and unique type of ecosystem. The Wild Ass Sanctuary is a unique habitat of Indian Wild Ass, the remnant gene pool in the world.

Flamingo City

Bhal region (The arid and saline area) is known for its indigenous varities of "Bhalia" and "Rata" wheat. Painted frog (rare and endangered sp.) is found in Vansada National Park (Valsad District). Safed Musli is available from Vijaynagar forest (Sabarkantha District) and (Danta forest of Banaskantha district). Velavedar Black buck National Park (Bhavnagar District) has dense population of Blackbucks. Girnar forest (Junagadh District) is a home of Asiatic Lion. Narayan Sarovar chinkara sanctuary (Kachchh District) is a rich ecosystem in arid region of Gujarat and is abode of many rare and endangered species such as Guggal among plants and Chinkara, Lesser-Florican, Spring Tailed Lizard among animals. Ratanmahal Sloth Bear Sanctuary (Panchmahal District) is important habitat for sloth bear. Giant flying squirrel is found in Shool paneshwar Wild life Sanctuary.

Branches of Guggal

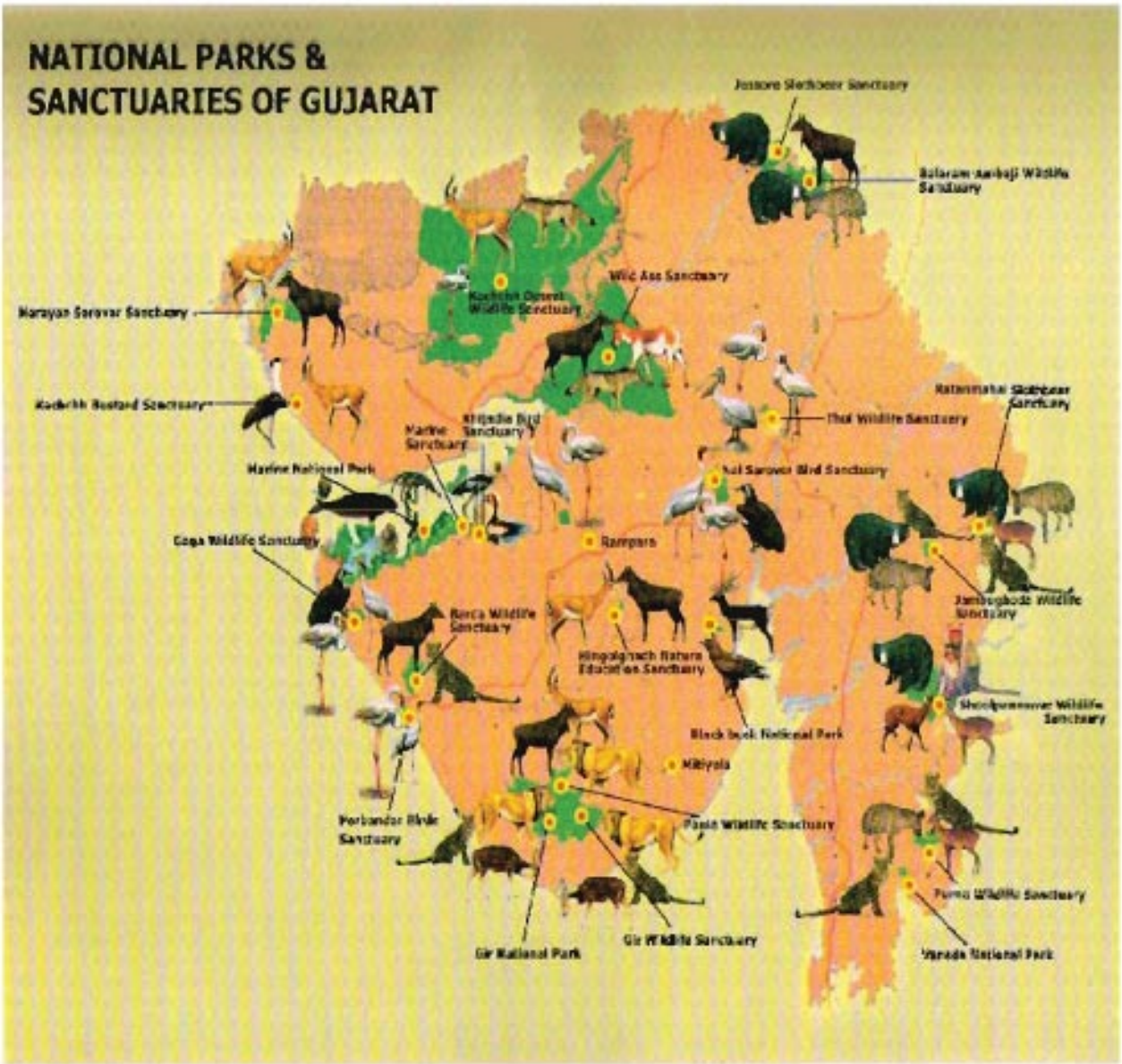
Secretion of Guggal from stem of Guggal

Giant flying squirrel

Spring tailed lizard

Marine Wild life Sanctuary and National Park is famous for its rich coral, marine algae and mangrove diversity. Many migratory and local migratory large number of birds take visit to Nal sarovar Bird sanctuary as well as Thol Bird Sanctuary.

There are four categories of forest in Gujarat. Tropical moist deciduous forest, Tropical dry deciduous forests, Tropical thorn forests and the Littoral forests. The major plants are *Tectona, Terminlia, Madhuca, Bamboo, Boswellia, Acacia, Zizyphus,* Mangroves etc.



National Parks and Santuaries of Gujarat (only for information)

Loss of Biodiversity

The biological wealth has been declining rapidly. The **IUCN (International Union for Conservation of Nature and natural resources)** Red List (2004) documents the extinction of 784 species in the last 500 years. Some examples of recent extinctions include the Dodo (Mauritius), Guagga (Africa), Steller's sea cow (Russia) and three subspecies of tiger i.e. Bali, Javan and Caspian. The last twenty years alone have witnessed disappearance of 27 species. The current rate of extinction is 1000 to 10,000 times higher than the past rate of extinction. Ecologists warn that if the present trends continues by the end of twenty first century, there will be a reduction by 50 % in the biodiversity of the earth.

(a) Dodo (Maurithus)

(b) Guagga (Africa)

(c) Steller's sea cow (Russia)

Causes of Biodiversity losses

Important factors leading to extinction of species and consequent loss of biodiversity are as follows.

(1) Habitat loss and fragmentation : This is the most important cause driving animals and plants to extinct. The disturbance of habitat of living organisms is called habitat loss. Quarrying, laying new railway tracks, constructing dams, felling of trees, cleaning of land for agriculture, deforestation are the major causes for habitat loss. Its well known example came from tropical rain forests. It was covering more than 14% of the earth's land surface, but now these rain forests cover not more than 6 percent. They are being destroyed speedily. The Amazon rain forest (known as lungs of the planet) is being cut and cleared for cultivating soyabeans. Bignonia and Habanera are plants mainly living on rocks of the Western Ghats. They formed luxuriant growth before quarrying the rocks with dynamine. As quarrying continues, these rocky species were forced to extinction. In the southern part of Western Ghats, lion tailed macaque were once found in large numbers. It has become endangered due to loss of habitat. Of the 370 butterfly species available here, up to 70 are on the average of extinction

Lion tailed macaque

(2) Over-exploitation : Human uses the natural resources for food and other purposes, but when 'need' turns to "greed", it leads to over-exploitation of natural resources. For instance, excessive harvesting of marine organism such as fish, molluscs, crustaceans, sea cows and sea turtles has resulted in extinction of these animals.

Since prehistoric time, man has been hunting wild animals for food and clothing. Commercially wild animals are hunted for their products like tusks, hides, skin, meat, horns, claws, perfumes, cosmetics, pharmaceuticals and decoration purposes. Elephants, rhinoceros, tigers, musk deer, crocodiles, spiny tail lizards are the victims for it. Now, these species are going to be extinct. Passenger pigeon of North America was killed for food as a result before 500 years this species has been at the stage of extinction. All over the world large number of animals are collected for laboratory study, dissections, research point of view. Frog is the well know example for it. Rabbits and monkey are also used.

Sea turtles

Passenger Pigeon

Eichornia

(3) Alien species invasions : New species entering a geographical region are called alien species. Introduction of such invasive species may cause disappearance of native species. A few examples are:, (1) The purposely or accidentally introduced species like carrot grass (*Parthenium*), gandhari (*Lantana*) and water hyacinth (*Eicchornia*) have lead to the extinction of many local species as well as adversely affected human health. (2) The recent illegal introduction of the African catfish *Clarias gariepinus* for aquaculture purposes is posing a threat to the indigenous catfishes in our rivers.

(4) Co-extinctions : When a species becomes extinct, the plant and animal species associated with it in an obligatory way also become extinct. When a host fish species becomes extinct, its unique assemblage of parasites also meets the same fate.

Biodiversity Conservation

Why should we conserve Biodiversity ?

Now man is aware of the conservation of environment. Conservation of biodiversity means the conservation of gene complexes, species and ecosystems. Conservation of biosphere is our moral responsibility. We must conserve our biosphere as it is not a better one, for our descendants. Thus biodiversity has to be conserved to keep an ecological equilibrium necessary for maintaining a sustainable environment for future generation. The future depends on the decision which we take, as individuals, as a society and as a nation.

We have to think that the benefits that we gain from biodiversity go beyond the mere provisions of raw materials. Our food and energy security strongly depends on biodiversity. Biodiversity is essential to global food security and nutrition and also serves a safety-net to poor householders during times of crisis.

How do we conserve Biodiversity ?

The maintenance and preservation of biodiversity is called biodiversity conservation. The conservations of biodiversity one of two types. They are:

(1) In – situ conservation (on site).

(2) Ex – situ conservation (off site).

(1) In – situ conservation : The conservation of genetic resources (different species) in their natural habitat is called in –situ conservation. It refers to the conservation of biological diversity in their natural habitats through protection of total ecosystem. The in-situ approach includes protection of a group of typical ecosystem through a network of protected areas. The areas which provide protection to the biological diversity include: Protected areas, Biosphere reserves etc. The protected areas are managed through authorized bodies. Proper laws are framed. National parks and Wild life sanctuaries are the examples of protected areas. As a September 2002, India has 581 protected areas (89 national parks and 492 wild life sanctuaries). Forests, grasslands and oceanic regions are identified in the concerned state or the country for the purpose of conservation of biodiversity and declared- "protected areas".

Benefits of Protected Areas

(1) Maintain viable populations of all native species and sub-species.

(2) Maintain the number and distribution of communities and habitats, and conserve the genetic diversity of all the present species.

(3) Prevent man made introduction of alien species.

The area which is rich in plant and animal species, of which many are endemic and endangered is called biodiversity hot spot. Initially 25 biodiversity hotspots are marked out in the entire world but subsequently nine more have been added to the list, bringing the total number of biodiversity hotspots in the world to 34. For example : Western Ghats, Srilanka, Indo-Burma and Eastern Himalayan region in India. Western Ghats has a total of 310 endemic vertebrates among the total of 32,678 species in the world.

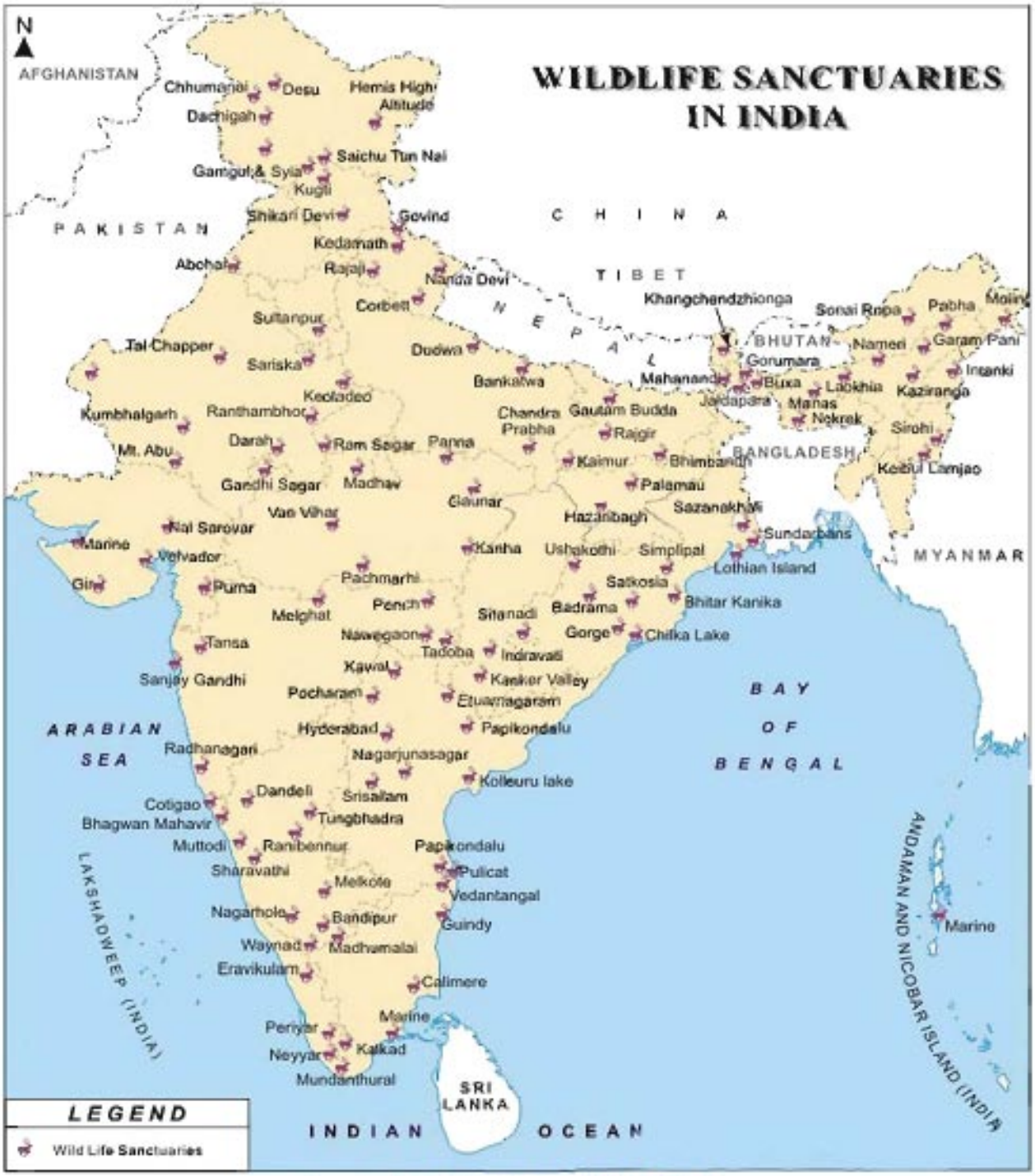
National Parks :

A national park is an area which is strictly reserved for the welfare of wild life and where activities such as forestry, grazing or cultivation are not allowed. Some important national parks of India are: Kaziranga National Park (Asam), Sundarbans (Tiger Reserves, West Bengal), Hazaribagh National Park (Bihar), Corbett National Park(Uttar Pardesh), Gir National Park(Gujarat, district Junagadh), Kanha Patiala Park (Madhya Pradesh), Tandoba National Park (Maharashtra), Bandipur National Park (Karnataka). In our state there is a marine national park near Jamnagar. Gujarat has 4 National Parks.

Important National Parks of India (Only for information)

Sanctuaries : A sanctuary is an area, which is reserved for the conservation of animals only. Operations such as harvesting of the timber, collection of minor forest products and

private ownership rights are allowed with the condition that they do not affect the animals adversely. Wild life sanctuaries in India attract people from all over the world. Some important wild life sanctuaries of India are: Annamali Sanctuary (Tamilnadu), Jaldapara Sanctuary (West Begal), Keoladeo Ghana Bird Sanctuary (Bharatpur-Rajasthan), Sultanpur Lake Bird Sanctuary (Hariyana), Shikari Devi Sanctuary (Himachal Pradesh), Dachigam Sanctuary, Srinagar (Jammu & Kashmir), Madumalai Sagar Sanctuary (Andhra Pradesh), Chilka Lake Bird Sanctuary (Orissa), Periyar Sanctuary (Kerala), Manas Wild life Sanctuary (Asam), Gujarat has Nalsarovar Bird Sanctuary, and Thol Bird Sanctuary. Gujarat has 21 Sanctuaries.



Sanctuaries of India (Only for information)

Biosphere Reserves

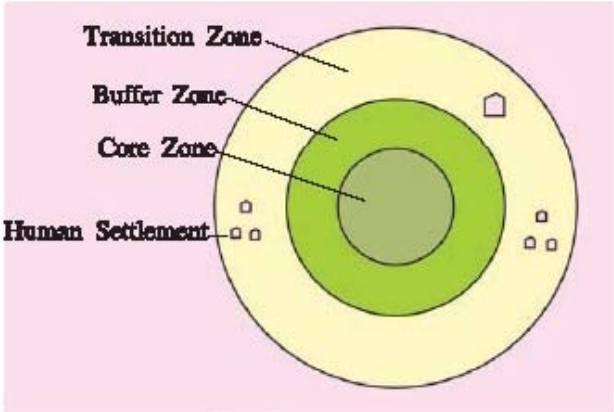
The man and Biosphere (MAB) programme of UNESCO formulated the concept of biosphere reserves in 1975. The biosphere reserves are the special category for protected area of land or coastal environments, wherein people are integral components of the system. At present there are 14 biosphere reserves in India. Some of them are Nanda Devi, Manas, Sundarbans, Great Nicobar, Gulf of Mannar etc.

A biosphere reserve consists of three zones: core, buffer and transitional Zones.

(1) Core Zone : It comprises an undisturbed and legally protected ecosystem.

(2) Buffer Zone : It surrounds the core area and is managed to use for research and educational activities.

(3) Transitional Zone : It is the outermost part of the biosphere reserve. It serves as an area of as an area of active cooperation between reserve management and the local people, wherein certain activities are allowed with conservation goals.



Biosphere reserves

Some special projects are also established in a special case e.g. Project tiger, Gir lion project. Crocodile breeding project, Rhinos conservation, Snow-leopard project, Project elephant.

(2) Ex-situ conservation : It is the conservation of genetic resources out side their natural habitat. Plant, animal and microbial species are preserved in ex-situ conservation systems. They includes : Botanical Gardens, Arboreta, Herbal Gardens (for plants), Zoos (for animals), seed bank, gene bank, Biotechnology use (Tissue culture, genetic engineering, etc.) and Culture collection (for micro-organisms).

There are 1500 or more botanical gardens in the world. About 80,000 species are maintained in these gardens. Of these nearly 800 important gardens are documented in the international Association of Botanical Garden (IABG). You have studied it in semester-I. There are more than 800 zoos in the world. Animals are maintained here and official reproduction is also tried out in captivity. In our state, the Vaghai Botanical Garden maintains many medicinal plants.

Seed bank : Seed bank can be developed through botanical garden. In a seed bank seeds are stored for long duration. It is practiced through cold storage in seed bank. Germ plasm of primitive cultivars or land races and other cultivars are kept in seed bank. The seed of those plants which have a possibility of extinction is stored in seed bank. The fact that seed samples are often not large enough to cover the whole spectrum of variations and bound to be shrinkage of breeding groups and finally the gene pools. This will result in some of genetic variation adaptation being lost. After germ plasm is introduced in to conservation programme, it can be saved

Seed bank

The seed bank is a fairly good way of conserving diversity and seed has to be stored for many years, with a minimum loss of viability. Many forests and fruit species requires some different ways for the storage involving three fold strategy: Dry storage, Cryogenic storage and Storage of fully or practically hydrated seeds at ambient temperature.

Gene bank : Gene bank can be developed for conservation of rare genes. It includes genetic resource centers. Gene banks have become particularly important for conservation of crop varieties and wild genetic resources, because of their utility in future crop improvement and a forestation programmes. Collection and preservation of genetic resources is done through the National Bureau of Plant Genetic Resources, Delhi for the wild relatives of crop plants. The National Bureau of Animal Genetic Resources, Karnal for the domesticated animals and the National Bureau of Fish Genetic Resources, Allahabad, for the economically valuable fish species. These bureaus are assigned the task of collecting germ plasm from within and outside the country and also to supply them on request to Indian and foreign agencies for research purpose.

In India several varieties of Rice have been preserved in gene-banks. However, this is very expensive and risky. Encouraging farmers to continue to grow several traditional varieties is, thus, an important concern for the future of mankind. At present, gene-bank collections have over 34,000 cereals and 22,000 pulses.

In recent years ex-situ conservation has advances beyond keeping gametes of threatened species in enclosures. The reproductive units of plants and reproductive cells of animals can be deep frozen at a very low temperature and thus conserved for future use. This method of conservation at -196° C in liquid nitrogen is called cryopreservation, and its bank is called cryobank. Eggs can be fertilized *in vitro* (In Laboratory condition) and plants can be propagated using tissue culture method.

Gene Bank

The world conservation union (WCU) and the world wildlife fund (WWF) are active in biodiversity conservation all over the world. Environmental Education (EE) is given first priority to youth, if we have to save our wealth of nature i.e. biodiversity. The objectives should be awareness, knowledge, attitude, skill, evaluation ability and participation.

Summary

Biodiversity refers to the variety of microbes, plants and animals of an area. It is the degree of variety in nature. It is the totality of genes, species and ecosystems. Thus it can be defined as the variety and variability of life. There is lot off variations amongst organisms. There can be genetic variations, species variations as well as ecosystems variation. On the basis of it, there are three levels of biodiversity - genetic, species and ecosystems biodiversity. Species diversity can be categories as - α - diversity ß-index diversity and γ - index diversity.

Knowledge of biodiversity is important for systematic study of organisms, Ecosystem studies, and Biogeography studies etc. It provides food, marketable items, etc. It has social and aesthetic

value. Information of biodiversity at world level, national level and state level is important. The main causes of biodiversity loss are: (1) Habitat loss and fragmentation. (2) Over-exploitation, (3) Alien species invasions and (4) Co-extinctions.

Conservation of biodiversity means the conservation of gene complexes, species and ecosystems. Biodiversity is essential to global food security and nutrition. The conservations of biodiversity are of two types: (1) In-situ conservation and (2) Ex-situ conservation. In-situ conservation is possible through to declare protected areas, biosphere reserves, national parks and sanctuaries. Ex-situ conservation can be done through botanical gardens, zoos, gene bank, pollen bank, seed bank tissue culture and cryopreservation.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Which is the tallest tree in Gymnosperms ?

(a) Sequoia ○ (b) Zamia ○

(c) Wolfia ○ (d) Eucalyptus ○

(2) In India, how many genetically different strains of rice are there ?

(a) 50,000 ○ (b) 1000 ○

(c) 40,000 ○ (d) 20,000 ○

(3) The Western Ghats have grater ..... species diversity than the Eastern Ghats.

(a) Mammals ○ (b) Birds ○

(c) Amphibian ○ (d) Arthropods ○

(4) As we move from the polar region towards the equator, the biodiversity gradually..... .

(a) Decreases ○ (b) Increases ○

(c) Increases and decreases ○ (d) All the given ○

(5) How many birds found in Colombia located near the Equator ?

(a) 1200 ○ (b) 1400 ○ (c) 56 ○ (d) 1300 ○

(6) Who gave species area relation hypothesis ?

(a) Humboldt ○ (b) Whittaker ○

(c) Raven ○ (d) Mendal ○

(7) Which is our National animal ?

(a) Lion ○ (b) Tiger ○

(c) Peacock ○ (d) Solth bear ○

(8) How many species are identified till today at world level ?

(a) 1.6 to 1.8 millions ○ (b) 1.6 to 1.8 trillions ○

(c) 1.7 to 1.8 millions ○ (d) 1.7 to 1.8 trillions ○

(9) What is current rate of extinction of a species than that in the past ?

(a) 1000 to 2000 times higher ○ (b) 2000 to 3000 times higher ○

(c) 1000 to 10,000 times higher ○ (d) 100 times higher ○

(10) Which are the approaches to be considered for conservation of biodiversity ?

(a) in-situ ○ (b) ex-situ ○

(c) Both a and b ○ (d) a or b ○

(11) Which kind of National park is located near Jamnagar ?

(a) Sundarvans ○ (b) Gir Sanctuary ○

(c) Wild Ass Sanctuary ○ (d) Marine National Park ○

(12) Where is ex-situ Conservation carried out ?

(a) Sanctuaries ○ (b) Zoo ○

(c) National Park ○ (d) None ○

(13) How many National Parks are there in India ?

(a) 79 ○ (b) 89 ○ (c) 69 ○ (d) 59 ○

(14) How many hot spots exist in India?

(a) 25 ○ (b) 34 ○ (c) 3 ○ (d) 581 ○

(15) Which region of Gujarat has botanical garden for many medicinal plants ?

(a) Ahmedabad ○ (b) Vaghai

(c) Rajpipla ○ (d) Veraval

(16) Sundarbans National park is found in..... .

(a) Asam ○ (b) West Bengal ○

(c) Madhya Pardesh ○ (d) Bihar ○

(17) This provides a temperature of - 196°C for cryopreservation.

(a) Liquid CO_2 ○ (b) Gaseous Nitrogen ○

(c) Solid CO_2 ○ (d) Liquid Nitrogen ○

(18) Gujarat has ..... Sanctuaries.

(a) 21 ○ (b) 12 ○ (c) 32 ○ (d) 19 ○

(19) Gir Sanctuary is famous for ?

(a) Asiatic Lion ○ (b) Chittah ○

(c) Wild Ass ○ (d) Tiger ○

(20) MAB means

(a) Man and Bacteria ○ (b) Man and Botany ○

(c) Man and Biotic community ○ (d) Man and Biosphere ○

(21) Which sub region of biosphere reserve is legally protected ecosystem ?

(a) Core ○ (b) Buffer ○

(c) Transitional ○ (d) a and c ○

(22) Which institutes are actively involved in maintenance of biodiversity ?

(a) Word Conservation Union ○ (b) World wild life fund (WWF) ○

(c) WHO ○ (d) a and b ○

2. Answer the following question in short :

(1) Which is the tallest gymnosperm ?

(2) Which is the smallest angiosperm ?

(3) Which is genetic material ?

(4) What is ecosystem diversity ?

(5) Give full forms of : WWF, WCU, MAB

(6) The value of ecosystem service is ..... .

(7) India has more than ..... percent of the total animal species in the world.

(8) How many species disappeared in last twenty years ?

(9) Give the name of any one alien species introduced in India.

(10) Gujarat has ..... National parks.

3. Explain the term :

(1) Biodiversity (2) Species diversity (3) Ecosystem diversity

(4) Hot spot (5) National park (6) Sanctuary

(7) gene pool

4. Give short notes :

(1) Species diversity (2) Ecosystem diversity

(3) Loss of biodiversity (4) Species area relationship

(5) α, β and γ and index diversity (6) Over exploitation

(7) Alien species invasions (8) Seed bank

(9) Gene bank (10) Sanctuary

(11) Zones of Biosphere reserves

5. Answer the following questions in detail :

(1) Describe Levels of Biodiversity.

(2) Describe biodiversity at global, National and state level.

(3) Describe patterns of biodiversity.

(4) Describe importance of biodiversity.

(5) Describe any three causes of biodiversity loss.

(6) Describe ex-situ conservation of biodiversity.

(7) Describe in-situ conservation of biodiversity.

13

Environmental Issues

As the human population continues to increase, the space available for natural ecosystems to live in, continuous to decrease. As a result, their capacity of disposal of waste materials generated in the biosphere decreases. Such materials accumulate and act as pollutants. Substances which are harmful to organisms of biosphere are called pollutants and any undesirable change in physical, chemical or biological characteristics of air, land, water or soil is called pollution. In order to control environmental pollution, the Government of India has passed the Environment (protection) act, 1986. In this chapter we will study the different types of pollutions, their effects and control.

Air Pollution and its control

As all living organisms depend on air for their respiration, air pollution is dangerous to them. Air pollution reduces the growth and yield of crops and causes premature death of plants. It also affects the respiratory system of human and animals.

There are many sources of air pollution but the obvious ones are two – fuel consumption and vehicular exhaust. The sources of air pollution are natural as well as anthropogenic. Suspended particles in air, pollen of plants, smoke substances spread during volcanic eruption etc can be considered natural air pollutants. Amongst anthropogenic pressure, smoke from the chimneys of industrial establishment, thermal power stations, vehicles and domestic usage can be considered.

Air pollution due to industries

Several industries have become important sources of air pollution. Mainly, petroleum refineries and fertilizer factories are responsible for the emission of SO_2 and NO_2 in air. The smelting factories, paper mills, sugar factories and the units associated with manufacture of cotton and cloths and rubber factories are other major sources of air pollution. Stone quarries, cement industry and asbestos factories also cause pollution.

Control of Air pollution

To control air pollution, the photochemical smog should be eliminated as far as possible. Photochemical smog is the product of automobiles. All automobiles can not be removed from the roads hence, the alternative is to develop transport of a different kind, perhaps electrical and solar operated cars and two wheelers rather than those burning the petrol. Even proper maintenance of automobiles along with use of lead- free petrol or diesel can reduce the pollutants they emit.

Particulate matter which is produced by industries and thermal power plants can be control by scrubbers, electrostatic precipitators and filters. In Electrostatic precipitator's electric charge is generated on the particles in the smoke and they are down towards electrodes and removed. Around 99 percent particulate matter present in the smoke and exhaust from a thermal power plant can be removed by electrostatic precipitators. A scrubber can remove gases like sulphur dioxide. In a scrubber, the exhaust is passed through a spray of water or lime. Recently it has been researched out by Central Pollution Control Board (CPCB) that particles which are having size of 2.5 Micrometers or less in diameter are responsible for causing greatest harm to human health. Inhalation of such particles damage the lungs and responsible for premature death.

In India, the Air (Prevention and control of pollution) act came into force in 1981, but was amended in 1987 to include noise as an air pollutant. Noise is usually referred to as unwanted sound which is usually unpleasant. The sources of noise pollution are high intensity of sound, generally 150 db (decibels) or more, produced by machines, air craft, rockets, motor cars, scooters, crackers etc. These sources are disturbing the man and also cause permanent damage to hearing. Even chronic exposure to a relatively lower noise level of cities may permanently damage hearing ability of humans. Noise pollution can be controlled by as follows :

- Using machines which do not produce sound
- Installing sound producing machines in the sound proof halls
- Plugging ears by cotton wool
- Establishing factories away from residential areas
- Putting ban on blowing horn in normal circumstances.

Air pollution due to vehicles: a case study of Gujarat

The transport sector is the fastest growing energy consumers in the our State, using mostly diesel, petrol and CNG. As per the report of Gujarat Ecological Commission and pollution control board, every year about 4,50,000 vehicles are added to the roads of the State. Hence the problem of vehicular pollution is increasing day by day. The following table clearly indicates that in last four years there is a notable increase in the levels of suspended particulate matter sulphur dioxide and oxides of nitrogen in the Sabarmati area of Ahmedabad.

(Report of Gujarat Pollution Control Board, Gandhinagar)

Year	Suspended Particulate Matter(SPM)	Sulphur dioxide	Oxides of Nitrogen
2007-08	155	06	25
2008-09	143	05	15
2009-2010	257	23	21.33
2010-2011	275	23.3	24

(All the Parameters are in Microgram Per Cubic Meter)

Based on the analysis of ambient pollutant levels, the study estimated that nearly 21 percent of the city's population is exposed to emission levels with the more severe consequences. Clinical examination of shop keepers and traffic policemen indicated that by evening 18 percent in the exposed group had increased Carbon mono-oxide (CO). A NIOH (National Institute of Occupational Health, Ahmedabad) study observed that problems of air pollution at street junctions in the cities of Ahmedabad, Vadodara, Surat and Bhavnagar are quite high. SPM has exceeded the safe level. About 20 percent of the children living near these junctions suffered from cough and congestions.

In order to put check on transport system in the state, the state government has established the "Commissionerate of Transport". It has initiated the **"Pollution Under Control System"** within state in 1995 and such checks are being performed on vehicles in all major cities of the state. Similarly, the **EURO-III** norm, newly labeled as **BHARAT-III** has been implemented in Ahmebadad and Surat with effect from April 1, 2005. Whereas, **Bharat-II** norms have been adopted in the rest of the state. All new vehicles registered are to be either BHARAT-III or Bharat–II compliant. Measures to minimize delays at junctions through time depicting signalization, and stricter enforcement of traffic rules are being undertaken methodically in Ahmedabad, Vadodara and other cities.

In all the large cities of Gujarat most of the city buses and auto rickshaws are now running on CNG mode. The CNG burns more efficiently, unlike petrol and diesel, in the automobiles and and very little of it is left unburnt. It does not produce any visible smoke or odur and cannot be adulterated easily. CNG being lighter than air, it escapes into the atmosphere immediately, reducing the risk of fire. CNG is also non carcinogenic and non corrosive.

In Gujarat, **Gujarat Gas Company Ltd. (GGCL)** is providing CNG in Surat and Ankleshwar, and **Gas Authority of India Ltd.(GAIL)** is providing it in Vadodara, while Gujarat Adani Energy Ltd. is providing CNG in Ahmedabad. Both the **Ahmedabad Muncipal Transport Service (AMTS)** and **Gujarat State Road Transport Corporation (GSRTC)** have started operating buses with CNG on a regular bases. The CNG programme in major cities of Gujarat has gained momentum and considerable numbers of vehicles are now running on CNG mode reducing air pollution.

Water pollution and its control

When any undesirable substance mixes with water then water becomes contaminated. This results in water pollution. Due to pollution water becomes unfit for use. Water pollution is caused by disposing industrial waste, city sewage, domestic waste, chlorinated hydrocarbons etc. in water. They greatly affect the life of aquatic animals and plants. Moreover, the said pollutants ultimately go to the ocean along with river water and thus, marine water pollutaion takes place which affects marine life.

Fresh water pollution is most dangerous environmental problem of the world. Water pollution causes diseases like typhoid, hepatitis, jaundice, cholera, diarrhoea, dysentery etc. Realising the importance of maintaining the cleanliness of the water bodies, the Government of India has passed the water (Prevention and control of pollution) Act, 1974 to safeguard our water resources.

Domestic sewage and Industrial effluents

We use water in our homes for various purposes like bathing, washing etc. This used water and waste substances that are produced by human bodies is known as sewage. Have you ever thought where the sewage that comes out of our houses go ? If it is poured into the river then it will be proved dangerous to animals, plants and even human being. A mere 0.1 percent impurities make domestic sewage unfit for human use.

Domestic sewage mostly contains biodegradable organic matter, which readily decomposes by microorganisms. It is possible to estimate the amount of the biodegradable organic matter in sewage water by measuring **Biochemical Oxygen Demand (BOD).** The measurement of the amount of the oxygen required for the decomposition of biodegradable substances is done through BOD. Microorganism involved in biodegradation of organic matter consume a lot of oxygen, resulting into a sharp decline in dissolved oxygen in water body. Thus as the amount of dissolved oxygen in water decreases, the BOD increases.

Eutrophication

Eutrophication

Eutrophication means an easy availability of nutrients in an aquatic habitat. When organic and inorganic substances are added to water, the availability of nutrients increases. When sewage, fertilizers, animal excreta and detergents become added to water, the amount of ammonia, nitrates, nitrites and phosphorous increases and hence, the growth of microorganisms and aquatic vegetation is stimulated. Algae and particularly blue green algae virtually under go population explosion forming algal bloom. They completely spread over the entire water surface and generate a foul smell and toxic taste –spoiling substances due to which a large number of fishes die. Increased amount of nutrients also stimulate the growth of many kinds of aquatic plants. For example water hyacinth *(Eichhornia crassipes)*, the world 's most problematic aquatic weed, also called **"Terror of Bengal"**. They grow abundantly in eutrophic water bodies. Over the centuries, as silt and organic debris pile up, the water body becomes shallow and finally it is converted into land.

Depending on climate, size of lake and other factors, the natural ageing of a lake may span thousands of years. However, pollutants from man's activities like effluents from the industries and homes can accelerate the aging process. This phenomenon has been called Cultural or Accelerated Eutrophication.

Industrial effluents from industries like petroleum, paper manufacturing, metal extraction and processing, chemical manufacturing etc. often contain toxic substances which are nondegradable and can undergo **biological magnification** in the aquatic food chain.

Biological magnification :

Biological magnification means increasing concentration of some toxic substances at various trophic levels of a food chain of organisms. This happens because a toxic substance accumulated by an organism can not be metabolized or excreted, and thus passed on to the next higher trophic level. This phenomenon is well known for mercury and DDT. DDT is sprinkled on water to destroy mosquitoes. From water, it enters into plant bodies and from there it enters into herbivores and then into carnivores along with food. It becomes concentrated in the fatty tissues of the body and causes lethal effects on higher level carnivore animals. Figure indicates that the concentration of DDT starts at 0.003 ppb (Parts per billion) in water and it can ultimately reach 25 ppm (parts per million) in fish eating birds through biomagnification.

Biological magnification (1 PPM = 1000ppb)

Waste water treatment

Waste water treatment is the process of removing contaminants from waste water. It includes physical, chemical and biological processes to remove physical, chemical and biological contaminants. Waste water including sewage can be treated in three phases. In the primary phase large suspended substances are filtered out and made harmless. This material can also be used as manure. In the second phase organic waste is induced to decompose using bacterial activity and airflow and water is chlorinated. In the third phase nitrates, phosphates etc. are removed from water and pure water is obtained.

Like sewage, human waste i.e. excreta does not require water if can be recycled into natural fertilizer which reduces the need of chemical fertilizers. There are working 'EcoSan' toilets in many areas of Kerala and Srilanka.

Solid waste

Solid waste refers to everything that goes out in trash. Solid waste is commonly known as garbage, and it is a waste type consisting of everyday items we consume and discard. It predominantly includes food wastes, yard wastes, containers and product packaging, and other miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources. Examples of inorganic wastes are appliances, newspapers, clothing, food scrapes, boxes, disposable tableware, office and classroom paper, furniture, wood pallets, rubber tires, and cafeteria wastes. Municipal solid waste does not include industrial wastes, agricultural wastes, and sewage sludge. The collection is performed by the municipality within a given area. They are in either solid or semisolid form. The term residual waste relates to waste left from household sources containing materials that have not been separated out or sent for reprocessing. Following are the different types of wastes.

Biodegradable waste : food and kitchen waste, green waste, paper (can also be recycled).

Recyclable material : paper, glass, bottles, cans, metals, certain plastics, etc.

Inert waste : construction and demolition waste, dirt, rocks, debris.

Composite wastes : waste clothing, tetra packs, waste plastics such as toys.

Domestic hazardous waste (also called "household hazardous waste") and toxic waste

Solid Waste

Hospital generated hazardous waste that includes disinfectants and other harmful chemicals, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, shoe polish.

Irreparable computers and other electronic goods are known as electronic waste (e- waste). More than 50 % of the e-waste generated by the developed countries is exported to developing countries like China, India and Pakistan. These countries remove metals like copper, iron, silicon nickel and gold during recycling process from e-waste. Recycling in developing countries often involves manual participation thus exposing workers to toxic substances present in e-waste.

Use of plastic waste :

Polymer modified bitumen is emerging as one of the important construction materials for flexible pavements. Use of plastic waste in the construction of flexible pavement is gaining importance because of the several reasons. The polymer modified bitumen shows better properties for road construction & plastics waste, otherwise considered to be a pollution menace, can find its use in this process and this can help solving the problem of pollution because most of the plastic waste is polymers.

Plastic waste

The plastic waste (bags, cups, Thermocol) are separated from the waste, cleaned if needed and shredded to small pieces (passing through 4.35mm sieve) The aggregate (granite) is heated to 170°C in the "Mini hot mix plant" and the shredded plastic waste is added, it gets softened and coated over the aggregate. Immediately the hot Bitumen (160°C) is added and mixed well. As the polymer and the bitumen are is the molten state (liquid state) they get mixed and the blend is formed at surface of the aggregate. The mixture is transferred to the road and the road is laid. This technique is extended to "Central Mixing Plant" too.

Salient features of the polymer-waste-bitumen mix Road

- Road strength is twice stronger than normal roads.
- Resistance towards water stagnation i.e. no potholes are formed.
- Less bleeding during summer.
- Burning of plastics waste could be avoided.
- It doesn't involve any extra machinery.
- It doesn't increase cost of road construction.
- It helps to reduce the consumption of bituminous mix vis-a-vis reduce cost.

Agrochemicals and their effects

As a part of green revolution the use of herbicides, pesticides and fungicides has increased tremendously in order to get more production. These chemicals are toxic to non target organisms, which are important components of soil ecosystem. These chemical substances accumulate in the soil and pass in the different trophic levels of an ecosystem. These substances can also biomagnified in the terrestrial ecosystem.

Case study of organic farming

Organic farming is the form of agriculture that relies on techniques such as crop rotation, green manure, compost and biological pest control to maintain crop productivity and control pest on farm. Organic farming excludes the use of manufactured fertilizers, pesticides, plant growth hormones etc.

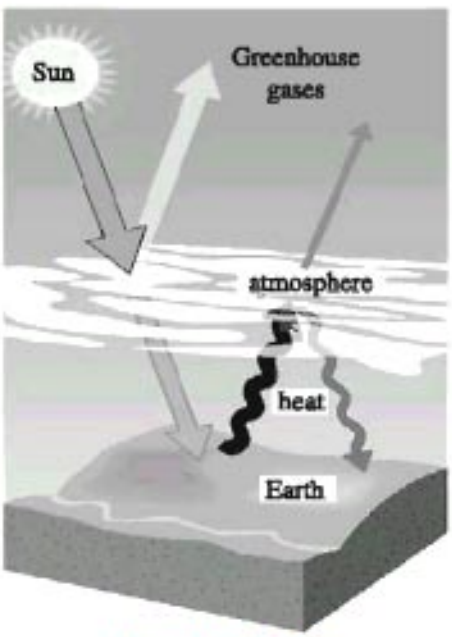
Ramesh Chandra Dagar, a farmer in Sonipat, Hariyana is making use of organic farming. He includes bee-keeping, dairy management, water harvesting, composting and agriculture in a chain of processes, which support each other and allow an extremely economical and sustainable venture. He uses cattle excreta as chemical fertilisers for crops. Crop waste is used to make compost, which can be used as natural fertilizer or can be used to generate bio gas for satisfying the energy needs of the farm. Dagar has created the 'Haryana Kisan Welfare Club', with a current membership of 5000 farmers.

Radioactive waste

Radioactive wastes are wastes that contain radioactive material. Radioactive wastes are usually by-products of nuclear power generation and other applications of nuclear fission or nuclear technology, such as research and medicine. Initially nuclear power generation was considered as non polluting way of generating electricity. Later on it was realized that use of nuclear energy has very serious two inherent problems. The first is accidental leakage, as occurred in the Three Mile Island and Chernobyl incidents and second is disposal of radioactive waste.

Radioactive waste

Radioactive waste is hazardous to human health and the environment. Radiations which are emitting from the radioactive waste cause mutation in living organisms. It creates various disorders and cancer in human beings. It is recommended that storage of radioactive waste after pretreatment should be done in suitably shielded containers buried within the rocks, about 500 mt deep below the earth's surface.



Greenhouse Effects

Greenhouse Effects and Global warming

An atmosphere envelops the earth. Sunlight passes through this atmosphere and reaches the surface of the earth. Under the influence of this light, the atmosphere and the surface of the earth get heated. The rays which get reflected from the surface of the earth have to pass through this atmosphere to get dissipated in the space. The CO_2 present in the atmosphere absorbs the long wavelength infrared rays and reflects them back towards the earth. As a result the earth and its surrounding atmosphere remain warm. This effect is called **greenhouse effect** and the CO_2 which induces such

an effect is known as **green house gas**. The glasshouse constructed for the maintenance of warm temperature is also designed on the same principle. This is the reason this effect is known by the same name.

It is obvious that as the concentration of CO_2 increases, the greenhouse effect also increases and the temperature of the earth is affected by it. Since the industrial revolution and its progress from around the year 1750, the amount of CO_2 in the atmosphere is on an increase.

CO_2 itself is not a pollutant. Moreover, other green house gases are also added to the atmosphere. Amongst them, methane, nitrous oxide, hydroflurocarbon (HFC), chloro-flurocarbon(CFC) etc. can be considered the main ones.

Increase in the level of green house gases has led to considerable heating of earth leading to global warming. Earth's average temperature is around 15° C. During the twentieth century it has increased by about 0.6° C. It is estimated to rise by 0.5° C between the years 1950 and 2020. However, some authoritative sources expect this rise to be of nearly 5° C by the year 2050. This rise in the temperature is leading to deleterious changes in the environment and resulting in odd climate changes, thus leading to increased melting of polar ice caps as well as of other places like the Himalayan snow caps. Over many years, this will result in a rise in sea level that can submerge many costal areas.

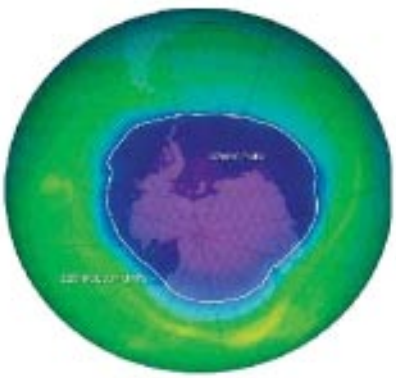
The following steps can be taken to control global warming

- A drastic and immediate reduction in the consumption of fossil fuel can be made.
- Use of natural gases as an alternative source of energy should be encouraged.
- Alternative energy resources like solar energy, geothermal energy as well as atomic energy should be put to a greater use.
- Reduction in deforestation and plantation should be promoted.

Ozone depletion in the stratosphere

The atmosphere of the earth is stratified. The nearest to the earth is troposphere. At the height of about 50 kms in the stratosphere, the ozone layer is located. The thickness of the ozone in a column of air from the ground to the top of the atmosphere is measured in terms of Dobson unit (DU). The ozone layer absorbs UV radiation emitting from the sunlight and prevents it from reaching the earth.

Ozone gas is continuously formed by the action of UV rays on molecular oxygen and also degraded into molecular oxygen in the stratosphere. There should be a balance between production and degradation of ozone in the stratosphere. But due to continuous addition of Cl^- in the atmosphere the balance is getting disturbed leading to depletion in ozone layer. Sources of Cl^- are chloroflurocarbon (CFC). One such substance, Freon, is used in refrigerators and air conditioners. The chlorine atom reacts with ozone and removes the atoms of ozone one by one. One atom of chlorine can decompose 1,00,000 molecules of ozone in this fashion and after many years it can return to earth as chloride.



Ozone hole

Although ozone depletion is occurring widely in the stratosphere, the depletion is particularly marked over the Antarctic region. This has resulted in the formation of a large area of thinned ozone layer, commonly called as **the ozone hole.**

It is noted in one study that depletion of 10 % in ozone layer can cause a 26 % increase in incidence of skin cancer and cataract. This would mean that there will be 3,00,000 more cases of skin cancer and 17.5 million more cases of cataract every year. High dose of UV also causes inflammation of cornea, called **snow-blindness.**

Degradation by improper resource utilization and maintenance

It is important to note that the degradation of natural resources not only occur due to the action of pollutants but also due to improper resource utilization practices.

Soil erosion and desertification

The formation of the fertile top soil layer takes hundreds of year. But due to human activities like over cultivation, unrestricted grazing, deforestation and poor irrigation practices it can be lost very easily forming arid patches of land. When such large patches extend and meet over a time, a desert is created.

Water logging and soil salinity

Irrigation without proper drainage of water leads water logging in the soil. This not only effects the crops but also draws salt to the surface of soil. The salt then is deposited as a thin crust on the land surface and inhibits the growth of crops. Waterlogging and soil salinity are some of the problems that have come in the wake of the Green revolution.

Deforestation

Forest cover of world is rapidly depleting. The present scenario of deforestation is particularly grim in India. At the beginning of the twentieth century, forest covered about 30 % of the land of India. By the end of the century, it shrunk to 19.4 %, whereas the National Forest Policy (1988) of India has recommended 33 % forest cover for the plains and 67 % for the hills.

The reasons for the deforestation are – rapidly increasing population, the resulting increase in demand on agriculture, increased use of timber and fuel wood and increasing industrialization and urbanization. Slash and burn agriculture, commonly called as Jhum cultivation in the north-eastern states of India has also contributed to deforestation. In slash and burn agriculture, the farmers cut down the trees of the forest and burn the plant remains. The ash is used as fertilizer and the land is used for farming or cattle grazing.

Deforestation has serious effects. Deforestation includes changes in the regional and global climate. Due to deforestation the rainfall decreases. Loss of forest cover causes increased soil erosion decreasing soil fertility. Amount of CO_2 increases in the atmosphere causing increase in temperature. This leads to greenhouse effects. The ecosystem balance is disturbed due to deforestation and irregularities arise in the running of biogeochemical cycles. Many organisms lose their natural habitats and become endangered or extinct.

Reforestation is the process of restoring the forest that once existed but was removed at some point of time in the past. Reforestation may occur naturally in a deforested area. However, it can be speed up by planting the trees.

People's participation in conservation of forest

The forests play an important role in well being of seven billion inhabitants of the world, of which 1.6 billion directly depend on forest for their livelihood. In recent years, however, it has become much harder for forest-dependent people to use local forests and their products, owing to deforestation, logging, population pressure or legal initiatives such as the declaration of state forests, national parks or wildlife reserves. In many countries, plans to protect forest ecosystems have failed to address the needs and knowledge of local forest-dependent communities. Participation by local people is essential to any conservation effort.

About half of the states in India have endorsed a strategy of **'joint forest management'** (JFM), in which forestry departments and communities jointly manage forests and share rights and responsibilities. The idea of JFM originated from the management of sal (*Shorea robusta*) forests in West Bengal. Here, community involvement had a remarkable effect on the rehabilitation of degraded sal forests. Landscape images have shown that the area of closed sal forest increased from 11% to 20% in Midnapore District alone, and that many square kilometres of degraded scrub forest have been restored to open forest.

Encouraged by this success, the Indian government expanded the programme during the 1990s. Under JFM, the ownership of the land remains with the government. Village committees, who are the co-managers, are entitled to the benefits from forest products. Forest protection committees control access to jointly managed forests. These local institutions are demonstrably more effective in protecting forests than the state forest departments.

Study of three beneficial environmental issues

(1) In 1731, the king of Jodhpur, Rajasthan asked his minister to arrange wood for construction of a new palace. The minister along with soldiers went to forest near a village, inhabited by Bishnois, to cut down trees. The **Bishnois** are known as the conservationists to whom the preservation of animals and vegetation life is a religion and has been so from the early 15th century. The effort to cut down trees by the king was thwarted by the Bishnois. A Bishnoi women Amrita Devi showed exemplary courage and stood in the way. She explained to the soldiers the importance of trees to their faith and survival. Then she argued. A crowd soon gathered and joined her in dissuading the soldiers. When everything failed and the solders began their preparations, Amrita Devi hugged a tree and asked them to cut her before they cut the tree! And so, it was done! A shocked and outraged crowd, was roused to action. One by one, they followed Amrita Devi, hugged a tree, dared the king's men and were cut dead. The carnage continued; an unending line of Bishnois choosing to die for their love of trees and nature. When a bewildered king finally arrived at the scene and stopped his men, 363 lay dead. Silence enveloped the moment with eloquence. There is probably no parallel to this, in the history of conservation.

The Government of India has recently instituted the Amrita Devi Bishnoi Wildlife Protection Award for individuals or communities from rural areas that have shown extraordinary courage and dedication in protecting wildlife.

(2) You have already studied Chipko movement of Garhwal Himalayas. In 1974, local women showed enormous bravery in protecting trees from the axe of contractors by hugging them. People from all over the country have acclaimed the Chipko movement. The movement spread to Himachal Pradesh in the north, Karnataka in the south, Rajasthan in the west, Bihar in the east and to the Vindhyans in central India. In addition to the ban in Uttar Pradesh, the movement succeeded in halting clear felling in the Western Ghats and the Vindhyas, as well as generating pressure for a natural resources policy more sensitive to people's needs and environmental factors. The Chipko Movement was the result of hundreds of decentralised and locally autonomous initiatives. Its leaders and activists have primarily been village women, acting to save their means of subsistence and their communities. Men have been involved, too, however, and some of them have given wider leadership to the movement. One of the most prominent leaders has been Sunderlal Bahuguna, a Gandhian activist and philosopher, whose appeal to Mrs Gandhi resulted in the given wider leadership to the movement.

Chipko movement

(3) In 1980, the Government of India has introduced the concept of Joint Management Program (JFM) so as to work closely with the local communities for protecting and managing forest. In return, communities are benefited by various forest products like fruits, gum, rubber, medicine etc.

Summary

Substances which are harmful to organisms of biosphere are called pollutants and any undesirable change in physical, chemical or biological characteristics of air, land, water or soil is called pollution.

There are many sources of air pollution but the obvious ones are two – fuel consumption and vehicular exhaust. The sources of air pollution are natural as well as anthropogenic. Particulate matter which is produced by industries and thermal power plants can be control by scrubbers, electrostatic precipitators and filters.

Noise is usually referred to as unwanted sound which is usually unpleasant. Noise pollution can be controlled by reducing high intensity of sound.

When any undesirable substance mixes with water then water becomes contaminated. This results in water pollution. Water pollution causes diseases like typhoid, hepatitis, jaundice, cholera, diarrhoea, dysentery etc.

Eutrophication means an easy availability of nutrients in an aquatic habitat. Due to easy availability of these nutrients the growth of microorganisms and aquatic vegetation is stimulated. They completely spread over the entire water surface and generate a foul smell and toxic taste – spoiling substances due to which a large number of fishes die.

Biological magnification means increasing concentration of some toxic substances at various trophic levels of a food chain of organisms. This happens because a toxic substance accumulated by an organism can not be metabolized or excreted, and thus passed on to the next higher trophic level.

Waste water treatment is the process of removing contaminants from waste water. It includes physical, chemical and biological processes to remove physical, chemical and biological contaminants.

Solid waste are the different types like : Biodegradable waste, Recyclable material, waste, Inert waste, Composite wastes and Domestic hazardous waste. Use of plastic waste in the construction of flexible pavement is gaining importance because of the several reasons. The polymer modified bitumen show better properties for road construction. Radioactive wastes are usually by-products of nuclear power generation and other applications of nuclear fission or nuclear technology, such as research and medicine. Radioactive waste is hazardous to human health and the environment. Radiations which are emitting from the radioactive waste cause mutation in living organisms.

The CO_2 present in the atmosphere absorbs the long wavelength infrared rays and reflects them back towards the earth. As a result the earth and its surrounding atmosphere remain warm. This effect is called greenhouse effect and the CO_2 which induces such an effect is known as green house gas.

The reasons for the deforestation are – rapidly increasing population, the resulting increase in demand on agriculture, increased use of timber and fuel wood and increasing industrialization and urbanization.

Participation by local people is essential to the conservation of forest. About half of the states in India have endorsed a strategy of joint forest management (JFM), in which forestry departments and communities jointly manage forests and share rights and responsibilities.

Exercise

1. Put a dark colourin a given circle for correct answer :

(1) Which type of pollution reduces the growth and causes premature death of plants :

(a) Water Pollution ○ (b) Noise pollution ○

(c) Air pollution ○ (d) Soil pollution ○

(2) In the electrostatic precipitators electric charge is generated on...

(a) Soil particles ○ (b) Particles in the smoke ○

(c) Particles of photochemical smog ○ (d) Particles in water ○

(3) Which type of gas can be removed by a scrubber ?

(a) Nitrous oxide ○ (b) Carbon dioxide ○

(c) Sulphur dioxide ○ (d) Oxygen ○

(4) What is ful form of CPCB ?

(a) Central Province Control Board ○

(b) Centralized Pollution and Chemical Board ○

(c) Central Pollution Control Board ○

(d) Centre for Pollution and Chemical Board ○

(5) Easy availability of nutrients in aquatic habitat may lead to....

(a) Biomagnification ○ (b) Eutrophication ○

(c) Mutation ○ (d) Greenhouse effect ○

(6) Which chemical is emerging as one of the important construction materials for flexible pavement ?

(a) Butanol ○ (b) Ethanol ○

(c) Bitumen ○ (d) Aceton ○

(7) The ozone hole is resulted in...

(a) Tropical region ○ (b) Antarctic region ○

(c) Subtropical region ○ (d) Temperate region ○

(8) Slash and burn agriculture means :

(a) Agriculture on desert land ○ (b) Jhum cultivation ○

(c) Cultivation on hills ○ (d) Reforestation ○

(9) Which gas is responsible for causing increase in the temperature ?

(a) Oxygen ○ (b) Carbon dioxide ○

(c) Sulphur dioxide ○ (d) Carbon monoxide ○

(10) Which of the following is associated with Chipko Andolan ?

(a) Amrita Devi ○ (b) Bishnoi ○

(c) Sunderlal Bahuguna ○ (d) Medha Patkar ○

2. Answer the following questions in short :

(1) What are the sources of air pollution

(2) Define pollution.

(3) What are the sources of emission of SO_2 and NO_2 ?

(4) What is the unit of measurement of Sound ?

(5) Name the diseases which are caused by water pollution.

(6) Give full form and define BOD.

(7) What is Accelerated Eutrophication ?

(8) Mention the different types of solid wastes.

(9) Give examples of e-waste.

(10) Give examples of Greenhouse gases.

3. Do as directed :

(1) How noise pollution can be controlled ?

(2) Write a note on radioactive waste.

(3) Write salient features of polymer-waste-bitumen road.

(4) What steps can be taken to control global warming ?

(5) Write a note on Chipko Andolan.

4. Answer the following questions in detail :

(1) Explain in detail-Eutrophication

(2) Describe the phenomenon of Biological magnification.

(3) Explain how plastic waste can be used in construction of flexible pavement ?

(4) Describe the causes and consequences of greenhouse effect.

(5) Describe the causes of depletion of ozone layer in stratosphere.