SREE SIDDAGANGA COLLEGE
OF ARTS, SCIENCE and COMMERCE
B.H. ROAD, TUMKUR

(AFFILIATED TO TUMKUR UNIVERSITY)

BOTANY PAPER-VII

III BSC VI SEMESTER

SOLVED QUESTION BANK

Unit 1: Plant-water relations 6 Hrs
Importance of water, water potential and its components;
A brief account of absorption of water [actve and passive] and Ascent of sap[transpiration pull theory]
Transpiration: Structure of stomata, Stomatal mechanism (Steward and K- ion theory) Factors affecting transpiration; Anti-transpirants .

Unit2: Mineral nutrition 3 Hrs
Essential elements, macro and micronutrients; Role and deficiency symptoms of
Nitrogen, phosphorus, Potassium, Magnesium, Zinc, boron, and Molybdenum: Hydroponics

Unit 3: Photosynthesis 10 Hrs
Photosynthetic apparatus, Photosynthetic Pigments (Chl a, b, xanthophylls, carotene); Photosystem I and II, reaction centre, antenna molecules; Electron transport and mechanism of ATP synthesis; C3 , C4 and CAM pathways of carbon fixation**.**

Unit 4: Respiration 6 Hrs
Structure of mitochondrion, Glycolysis, anaerobic respiration, TCA cycle; Oxidative Phosphorylation, Pentose Phosphate Pathway**.**

Unit 5: Enzymes 5 Hrs
Structure, Nomenclature, Properties, classification; Mechanism of enzyme action and enzyme inhibition.

Unit 6: Nitrogen metabolism 4 Hrs
Biological nitrogen fixation; Nitrate Metabolism, Synthesis of amino acids, Reductive and Transamination.

Unit 7 Plant growth regulators 4 Hrs
Auxins, Gibberellins, Cytokinins, Ethylene ,ABA and their role in agriculture and horticulture.

Unit 8: Plant response to light and temperature 4 Hrs
Photoperiodism ,Phytochromes, Florigen concept, Vernalization.

Unit 9: Dormancy : a brief account of seed dormancy **1 Hour**

Unit 10: Plant movements: 2 Hrs
(phototropism, geotropism, hydrotropism and seismonasty)

Unit 1: Plant-water relations 6 Hrs

1.Draw a neat labeled diagram of Stomata. Diagram-1+ label-1

Stomata are minute pores present in the epidermis of leaves.it is bean shaped, bounded by two guard cells. In Dicot it is bean shaped, in monocots they are dumb-bell shaped.wall lining aperture is thick and its other side's wall is thin. Guard cell has vacuolated cytoplasm, nucleus, and number of chloroplasts. Guard cells are surrounded by subsidiary cells.

2.What is Transpiration? Mention its types. 1+1

Loss of water in the form of vapour is called Transpiration. It includes 3 types. Thet are Cuticular, Lenticular and Stomatal transpiration.

3.Define water potential. Mention its components. 1+1

Chemical potential of water is called water potential. In solvent system it represents difference between the chemical potential of water in that system and pure water .It is expressed by megapascals or bars and denoted by letter psi ( ). water potential of pure water is zero . In a plant water potential is sum total of 3 components .namely matric, solute and pressure potential.

4.Mention characters of Transpiration .1+1

Transpiration :- Loss of water in vapors form through Stomata, Cuticle or Lenticel during day time.Transpired water is pure, gives cooling effect in plants.

5.What are Antitranspirants? Give two examples. 1+1

Compounds sprayed on leaf to reduce rate of traspirationare called Antitranspirants. They are 1) colorless plastic, silicon oil, low viscosity waxes: These form thon film on the surface of leaves which can be negotiated by gases but not watr. Ex: Phenyl mercuric acetate:2) Absisic acid: 3) Carbon di oxide:

6.What is Ascent of sap? Mention its significance. 1+1

Upward movement of absorbed water molecules and mineral from root to shoot is called ascent of sap. it provides water for photosynthesis**.**

7.What is Hydroponics? Mention its significance. 1+1

The growth of plant in balanced nutrient solution is called 'Hydroponics' or 'Soilless growth', it is also called 'Solution culture 'as it involves the growth of plants by using nutrient solution.

significance of hydroponics:-

1. Hydroponics helps to cultivate commercial ornamental plants and Vegetables in areas under extremely cold and dry environment.
2. It helps to grow plants where soil is unsuitable for cultivation.
3. By this method essential elements can be identified and their deficiency symptoms are discovered.

5 MARKS QUESTIONS

1. **Explain water potential and its components. Definition-1, components-4**

   Chemical potential of water is called water potential. In solvent system it represents difference between the chemical potential of water in that system and pure water .It is expressed by megapascals or bars and denoted by letter psi (ψ)water potential of pure water is zero . In a plant water potential is sum total of 3 components .namely matric, solute and pressure potential.

   a) **Matric potential (ψm)**: matric potential is defined as the amount by which water potential of the cell sap is reduced due to adsorption of water molecules by hydrophilic colloids of protoplasm . It is not significant as it does not allow free movement of water molecules.

   b) **Solute potential (ψs)**: Solute potential is defined as the amount by which water potential of cell sap is reduced due to solute particles present in it. It represent negative numbers.

   c) Pressure potential (ψ_p): Pressure potential is defined as the amount by which water potential of the cell sap is reduced due to wall pressure (Pressure exerted by cell wall on cell contents) and Turgor pressure (equal pressure exerted by cell membrane on cell wall) . It represents positive sign.

2. Explain osmotic absorption of Water .

Absorption of water due toforce generated in root cells is called active absorption It takes place by 2 methods .They are :-1) Osmotic absorption. 2) Non osmotic absorption.

Osmotic absorption:-Atkins & Priestly proposed it. Absorption of water due to concentration gradient between cell sap & soil solution iscalled osmotic absorption. Water potential of cell sap has higher negative value than the soil solution , hence osmotic migration of the solvent takes place into the cell.Obj:- Cell sap conc. Is not always high ,Root pressure is not universal in plants.

3. Explain Non- osmotic absorption of Water .

Non osmotic absorption was proposed by Clark &supported by Thiamann,Bogen. Absorption of water against concentration gradient utilizing metabolic energy is called Non osmotic absorption. The

evidences that support it are as follows:- 1)Respiratory inhibitors like Malonate decrease water absorption.2)Poison like KCN which retard metabolic activities of root cells retard water absorption. 3) Growth hormones that increase metabolic activities of cells stimulate absorption.4) low temp. that retards rate of energy release during respiration reduces water absorption

4. Explain Passive absorption of water.

Absorption of waterthrough the root cells due to force generated in the leaf is called Passive absorption .High DPD in the mesophyll draws water from adjacent xylem vessels which develops tension in the cell sap .since water water is present in continous column from xylem of leaf to xylem of root, tension is developed in the upper part of xylem is to innermost cortical cels through apoplast pathway and to xylem through endodermis by symplast path way.Evidences like inhibition of transpiration inhibits absorption, rate of transpiration is equal to rate of absorption proves passive absorption.

5. Explain vital theories.

During Active absorption, root pressure is high, xylem of vein forces out water to Epithem. From Epithem it is released into Sub-stomatal cavity. When it is completely filled water flows out in the form of droplets through Hydathodes.Guttated water is impure, contains dissolved organic substances like sugar, amino acids, sodium, and carbonates, sulphates, chlorides etc.

1. <u>Vital theories of Ascent of sap.</u> <u>2+2</u>

Upward movement of water from root system to the shoot system is called "Ascent of sap".It takes place by several theories. According to Vital theory Ascent of sap is due to vital activities in the living cells of Xylem in stem. It includes 2 theories namely a) Relay pump theory b) Pulsatory theory.

a) **Relay pump theory**: - This theory was proposed by God lewski (1884). According to him water rises upward in xylem in stepwise manner due to Rhythmic change of osmotic pressure in vessels, parenchyma and medullary rays.

When osmotic pressure of living parenchyma is high, they draw water from lower vessel and osmotic pressure becomes low. Due to low osmotic pressure water from parenchyma is pumped into above vessel. This process is repeated. Thus water rises up. Objection: - This theory is disproved by Strasburger, and confirmed by Overton, mac dougal. They showed that Ascent of sap continued even after killing living cells by high temperature treatment or poison.

b) **Pulsatory theory:-**This theory was proposed by J.C. Bose. According to him Ascent of sap is due to pulsatory activity of living cells of the innermost cortical layer just outside endodermis. To explain pulsatory activity he invented Cresograph.It consists of an electric probe connected to Galvanometer. When needle of the electric probe was inserted into the stem slowlyneedle of the Galvanometer oscillate. when it reached inner cortical layer . It shows violent oscillations. According to him when cells absorb water they expand, after pushing water to xylem. They contract. This pulsatory activity helps in Ascent of sap. Objections:- 1) Shull, Mac , Dougal showed that there is no relationship between pulsatory activity and rate of translocation of water.2) Strasburger showed that the Ascent of sap continued even after killing of living parenchyma cells by Picric acid.

6. Explain the mechanism of Stomatal movement. Definition-1, stomata fig open, close -4, mechanism-3, merits-2.

Stomata are minute pores present in the epidermis of leaves.it is bean shaped, bounded by two guard cells. In Dicot it is bean shaped, in monocots they are dumb-bell shaped.wall lining aperture is thick and its other side's wall is thin. Guard cell has vacuolated cytoplasm, nucleus, and number of chloroplasts. Guard cells are surrounded by subsidiary cells.

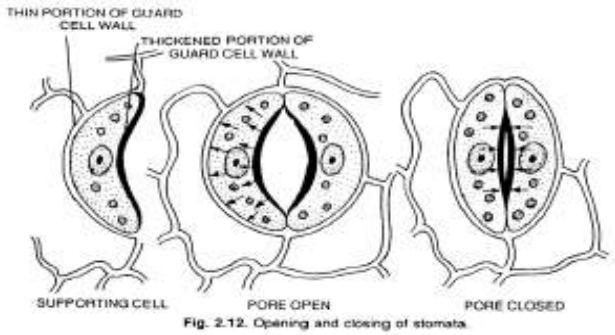


Fig. 2.12. Opening and closing of stomata

The mechanism of stomatal movement ie,. Opening and closing of stomata is responsible for stomatal transpiration. When Turgor pressure increases in the Guard cell, its thick wall lining the aperture bends inwards and thin wall stretches outside, become concave shape , thus stomata open.
When Tugor pressure decreases thick walls of Guard cells come closer to each other and stomata closes.During Day time Turgor pressure in the Guard cell increases , stomata opens, transpiration takes place . During night turgor pressure in Guard cell decreases , stomata closes, stomatal transpiration will not takes place.

7. Explain transpiration pull theory. Labelled Diagram-2,Expalnation-5,merits-1

Transpiration pull theory was proposed by Dixon &Jolley, supported by Renner, Curtis, Clark, Levitt. According to this theory 2 forces are responsible for ascent of sap. They are **a)** Cohesive & Adhesive properties of water to form water column. **b)** Transpiration pull exerted on this column.water molecules are held together tightly due to strong cohesive force. They also have Adhesive property ie strong attraction between water column and inner walls of xylem. Thus continuous water column is formed from leaf to root which cannot be broken. The water net has two terminals. Root tip near absorbing region and sub stomatal cavity in mesophyll. Transpiration creates DPD, resulting in flow of water from adjacent mesophyll cells; this DPD reaches cells abutting vasculature & xylem elements. Due to continuous transpiration, high DPD causes tension on the water column& it is transported down into root up to area of absorption .Thus water is pulled up due to suction force (Transpiration pull)due to transpiration.Objection: - Entry of air bubbles in the xylem disturb the continuity of water column water column.

8.Describe the factors affecting the rate of Transpiration. 6 to 8-½ each

The amount of water transpired per unit time from a plant is called "rate of transpiration".it is affected by various external and internal factors. **External factors: - a) Humidity:** increase in atmospheric humidity decrease the rate of transpiration. **b) Light: -** Light indirectly affect the rate of transpiration by controlling stomatal movement.**C) Temperature**: - The rate of transpiration increases with increase in temperature upto certain limit. At very high and low temperature and high temperature stomata are closed and transpiration stops.**D) Wind: -** High velocity of wind replaces humidity by dry air increasing the rate of transpiration.**E) Soil water**: - Less soil water causes partial or complete closure of stomata resulting in decrease of

transpiration.**F) Carbon di oxide concentration:-** High carbon di oxide concentration brings closure of stomata and retard transpiration. Decrease carbon do oxide concentration leads to stomatal opening and transpiration takes place**. Internal factors** : A) Deficiency of water in plants results in low rate of transpiration.B) Thick cuticle, Sunken stomata, Compact mesophyll, Less number of stomata decrease rate of transpiration.

9.Transpiration is a necessary evil. Discuss. 5 Points 1mark each

There are 2 conflicting views regarding the rate of transpiration. According to one view transpiration is Advantageous to plants; According to another view transpiration is disadvantageous and unavoidable process. Hence transpiration is considered as "Necessary evil´or "Unavoidable evil".

Advantages: - 1) Transpiration creates suction force to absorb water from soil. 2) It helps in Passive absorption of water and Ascent of sap by creating transpiration pull in the leaves.3) It helps in mineral uptake by developing suction force. 4) It removes excess of water from plant body. 5) It helps in translocation of solutes from one part of the plant body to another part.6) It brings down the temperature by allowing fresh water to flow through out the plant body 7) opening and closing of stomata during transpiration indirectly influence Respiration and Photosynthesis**. Disadvantages**: -
1) excess of transpiration cause scarcity of soil water.2) High rate of transpiration results in internal water deficit which retard growth.3) High rate of transpiration with low rate of water cause wilting of plants and structural adaptations in xerophytes. 5) Excess of transpiration induce formation of Abssisic acid that results in wilting of leaves.

Thus Transpiration is rather harmful than beneficial to plants. Even in such condition transpiration is unavoidable, due to presence of stomata which remain open for gaseous exchange during photosynthesis and respiration.Hence Curtis called Vital, Unavoidable phenomenon of plants the transpiration as **"Necessary Evil "** and Barns regarded it **as " Unavoidable evil".**

10.Give an account of Antitranspirants. Defination-1, types -4

Compounds sprayed on leaf to reduce rate of traspirationare called Antitranspirants. They are 1) colorless plastic, silicon oil, low viscosity waxes: These form thon film on the surface of leaves which can be negotiated by gases but not watr.2) Phenyl mercuric acetate: This when sprayed on leaves in a concentration of 10 M is non toxic to leaves, causes partial closure up to 2 weeks.3) Absisic acid: Natural growth regulator when sprayed cause partial closure of stomata.4) Carbon di oxide: raising carbon di oxide concentration from 0.3 %to 5% is known to cause closure of stomata. It is possible only in green houses.

11.Describe Stomatal mechanism.

The stomata are very minute apertures, found on the epidermis of the leaves. Each stoma is surrounded by two kidney-shaped special epidermal cells, known as guard cells.

The epidermal cells surrounding the guard cells of the stoma are known as accessory or subsidiary cells. The number of stomata may range from thousands to lacs per square centimeter on the surface of the leaf. Each stoma is surrounded by two guard cells. The kidney-shaped guard cells contain chloroplasts.

stomatal mechanism in plant cells.

The mechanism of the closing and opening of the stomata depends upon the presence of sugar and starch in the guard cells.

During day time or in the presence of light, the guard cells of the stomata contain sugar synthesized by their chloroplasts. The sugar is soluble and increases the concentration of the sap of guard cells. Due to higher concentration of the cytoplasm of guard cells, the water comes to them from the neighbouring cells by Endosmosis and they become turgid. With the result the stomata remain open.

In the night or in the absence of light the sugar present in guard cells converts into the starch. The starch is insoluble, and this way the cell sap of the guard cells remains of much lower concentration than those of neighbouring cells, and the neighbouring cells take out the water from the guard cells by Exosmosis making them flaccid and the stomata closed.

The conversion of sugar into starch during night and vice-versa in day time depends upon the acidity (pH) and alkalinity of the cell sap of guard cells.

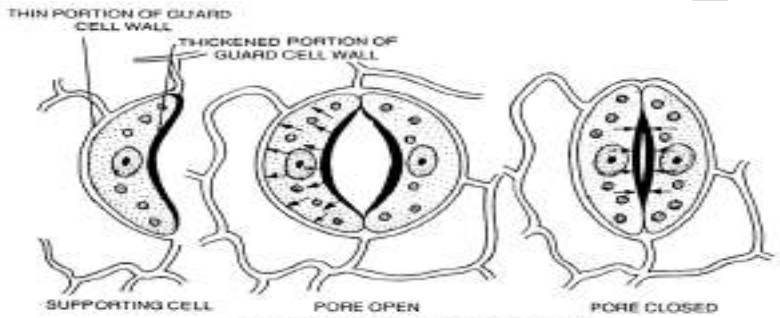


Fig. 2.12. Opening and closing of stomata

12.Explain Hydroponics.

Soil is required for terrestrial plants as a source of water and mineral nutrients, if the plant is provided with balanced nutrient and water, it can be grown even without the soil. In 1860 Julius von sachs , Geman Botanist demonstrated that Plants could be grown to maturity in a defined nutrient solution in absence of soil , and called this as Hydroponics.

The growth of plant in balanced nutrient solution is called 'Hydroponics' or 'Soilless growth', it is also called 'Solution culture 'as it involves the growth of plants by using nutrient solution.

All plants require certain inorganic mineral nutrients and water for their nutrition but not the soil. Seedling shows healthy growth and gives good crop yield as it gives when growth in soil.

Procedure for Hydroponics :-

- Take water containing balance inorganic micro and macro nutrients in a borosilicate bottle.
- Close the mouth of bottle with a lid containing two holed rubber cork.
- Introduce health herbaceous seedling into the bottle through one hole of the cork.
- Introduce a bent glass tube into the bottle through the other hole in cork, to provide aeration of solution. Allow the set for some days.

Significance of hydroponics:-

1. Hydroponics helps to cultivate commercial ornamental plants and Vegetables in areas under extremely cold and dry environment.
2. It helps to grow plants where soil is unsuitable for cultivation.
3. By this method essential elements can be identified and their deficiency symptoms are discovered.

10 MARKS QUESTIONS

1.Explain the mechanism of Water absorption.

Active absorption-5 (Osmotic-3, non-osmotic-2) Passive absorption -3

1)Active absorption:-.Absorption of water due to force generated in root cells is called active absorption It takes place by 2 methods .They are:-1) Osmotic and 2) Non osmotic

A)Osmotic absorption:-Atkins & Priestly proposed it. Absorption of water due to concentration gradient between cell sap & soil solution iscalled osmotic absorption. Water potential of cell sap has higher nega tive value than the soil solution, hence osmotic migration of the solvent takes place into the cell.Objection:- Cell sap conc. Is not always high, Root pressure is not universal in plants.

B)**Non osmotic absorption**:- It was proposed by Clark &supported by Thiamann, Bogen. Absorption of water against concentration gradient utilizing metabolic energy is called Non osmotic absorption. The evidences that support it are as follows: - 1) Respiratory inhibitors like Malonate decrease water bsorption. 2) Poison like KCN which retard metabolic activities of root cells retard water absorption. 3) Growth hormones that increase metabolic activities of cells stimulate absorption.4) low temp. that retards rate of energy release during respiration reduces water absorption.

2) Passive absorption: Absorption of waterthrough the root cells due to force generated in the leaf is called Passive absorption .High DPD in the mesophyll draws water from adjacent xylem vessels which develops tension in the cell sap .since water water is present in continous column from xylem of leaf to xylem of root, tension is developed in the upper part of xylem is to innermost cortical cels through apoplast pathway and to xylem through endodermis by symplast path way.Evidences like inhibition of transpiration inhibits absorption, rate of transpiration is equal to rate of absorption proves passive absorption.

2.Explain the active absorption of water.

Absorption of water due toforce generated in root cells is called active absorption It takes place by 2 methods .They are :-1) Osmotic absorption. 2) Non osmotic absorption. **1)Osmotic absorption**:-Atkins & Priestly proposed it. Absorption of water due to concentration gradient between cell sap & soil solution iscalled osmotic absorption. Water potential of cell sap has higher negative value than the soil solution , hence osmotic migration of the solvent takes place into the cell.Obj:- Cell sap conc. Is not always high ,Root pressure is not universal in plants.**2**)**Non osmotic absorption**:-It was proposed by Clark &supported by Thiamann,Bogen. Absorption of water against concentration gradient utilizing metabolic energy is called Non osmotic absorption. The evidences that support it are as follows:- 1)Respiratory inhibitors like Malonate decrease water absorption.2)Poison like KCN which retard metabolic activities of root cells retard water absorption. 3) Growth hormones that increase metabolic activities of cells stimulate absorption.4) low temp. that retards rate of energy release during respiration reduces water absorption **.**

3.Explain starch sugar interconversion hypothesis.

Starch Sugar interconversion theory was proposed by Sayrein1926, later modified by steward in1964. PH of the medium decides the interconversion of starch and sugar results in stomatal movement **.During Day** time carbon di oxide liberated by respiration is used by mesophyll for photosynthesis, PH increases,insoluble

starch is converted into Glucose -1.phosphate by phosphorylase,it isconverted into Glucose -6- phosphate by phosphoglucomutase which is further converted into soluble Glucose and phosphate.concentration of cell sap increases , osmotic pressure increases, water diffuses into guard cell from subsidiary cells , Guard cell become turgid and stomata opens.**During night** carbon di oxide accumulates, form carbonic acid , PH decreases , Glucose is converted into Glucose -1-phosphate using ATP inpresence of Hexokinase . It is converted into starch in presence of phosphorylase .Concentration of cell sap decreases, water diffuses out of guard cell , turgor pressure decreases , guard cell become flaccid , stomata close.**Objections** 1) Monocots do not have starch 2) No evidence to show presence of sugar when starch disappears 3) Stomata close at mid day without change in starch conversion.4) Stomatal movement do not require any energy.

4.Describe the structure of stomatal apparatus and stomatal movement with reference to Steward's hypothesis.

Stomata are minute pores present in the epidermis of leaves.it is bean shaped, bounded by two guard cells. In Dicot it is bean shaped, in monocots they are dumb-bell shaped.wall lining aperture is thick and its other side's wall is thin. Guard cell has vacuolated cytoplasm, nucleus, and number of chloroplasts. Guard cells are surrounded by subsidiary cells.Starch Sugar interconversion theory was proposed by Sayrein1926, later modified by steward in1964.

Starch Sugar Inter-conversion Theory:

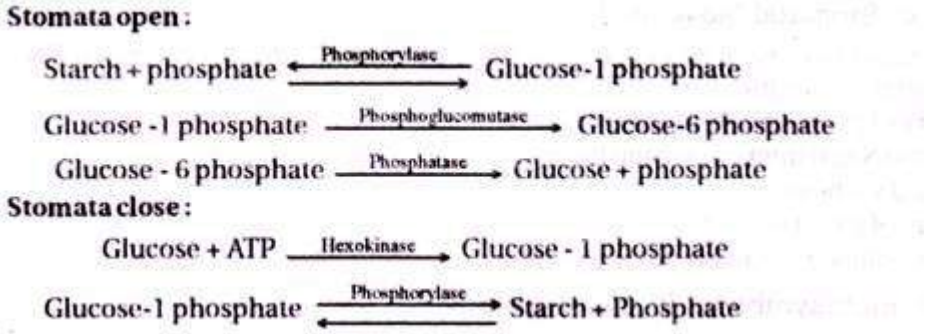
(i) According to **Lloyd** (1908) turgidity of guard cell depends on inter-conversion of starch and sugar. It was supported by Loft-field (1921). He found out that guard cells contain sugar during day time when they are open and starch during night when they are closed.

(ii) **Sayre** (1926) observed that during day time due to constant removal of carbon-dioxide by photosynthesis stomata open in neutral or alkaline pH, . Stomata remain closed during night when there is no photosynthesis and due to accumulation of carbon-dioxide, carbonic acid is formed that causes the pH to be acidic. It is supported by Scarth (1932) and Small et. al. (1942).

iii) Yin and Tung (1948) observed that during Day time starch is converted into glucose-1, phosphate in the presence of an enzyme phosphorylaseand stomata opens. dark phases (changing CO_2 concentration) control the changes in pH.

(iv) Steward's scheme:

Steward (1964) proposed modified scheme **of inter-conversion of starch and sugar for stomatal movement.** According to him conversion of starch to Glucose -1 phosphate is not sufficient. It should be converted to glucose to increase sufficient osmotic pressure. For this, ATP is also required through respiration in presence of oxygen. Guard cell carries enzymes like Phosphorylase, Phosphoglucomutase, Phosphatase and Phosphorylase. These enzymes help in opening and closing of the stomata.



Based on the above mentioned theory, process of opening and closing of stomata may be summarized as given below.

In Light: Photosynthesis takes place

(1) →Decreased CO_2Concentration in leaf cells

(2) →Increase in pH of guard cells

(3) → Hydrolysis of starch to sugar by enzymes

(4) → Increase of Osmotic Pressure of guard cells

(5) → Endosmosis of water in guard cells

(6) →Increase in T.R of guard cells

(7) →Aperture opens (Fig. 4.6)

Demerits of the starch-sugar inter-conversion theory:

Demerits of starch-sugar inter-conversion theory are as follows:-

1. In the presence of light when starch disappears from guard cells, malic acid appear and not the sugars.
2. Starch has not been reported in the guard cells of many monocots such as Iris, Amatyllis, Allium.
3. According to this theory O.P. of guard cells increases due to the formation of glucose-1- phosphate in guard cells but it is found that the presence of phosphate ions causes the development of same O.P as does the presence of glucose-phosphate.
4. Enzyme phosphorylase helps in conversion of starch to glucose-1-phosphate but not in the formation of starch from glucose-1-phosphate. This reaction is controlled by some other enzyme about which we do not know yet.

5.Explain the structure and mechanism of Stomatal movement with reference to Proton transport theory. Structure-2, mechanism day-3, night-3, merits-1, demerits-1.

The stomata are very minute apertures, found on the epidermis of the leaves. Each stoma is surrounded by two kidney-shaped special epidermal cells, known as guard cells.

The epidermal cells surrounding the guard cells of the stoma are known as accessory or subsidiary cells. The number of stomata may range from thousands to lacs per square centimeter on the surface of the leaf. Each stoma is surrounded by two guard cells. The kidney-shaped guard cells contain chloroplasts.

stomatal mechanism in plant cells: The mechanism of the closing and opening of the stomata depends upon the presence of sugar and starch in the guard cells.

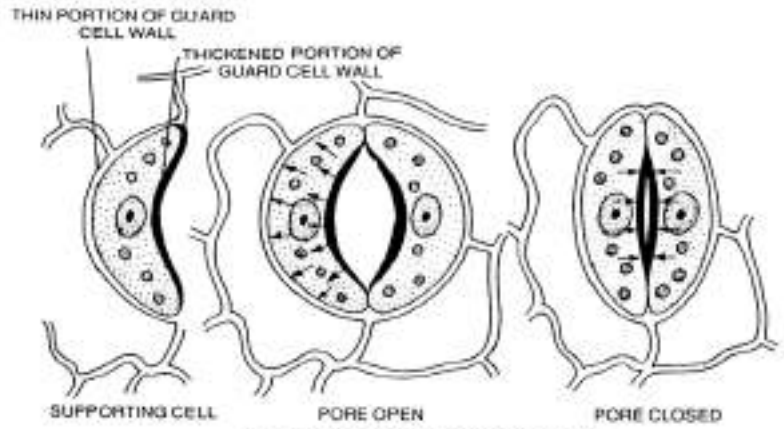


Fig. 2.12. Opening and closing of stomata

The important theories of stomatal movement are as follows: Many theories such as Theory of photosynthesis, Theory of glycolate metabolism **,** Starch Sugar inter-conversion theory **,** potassium transport ion **theory are put forward time to time to explain stomatal mechanism.**

Active K^+ Transport or Potassium Pump Theory and Role of Abscisic Acid: Or Active Potassium Pump Theory

The concept of K^+ ion transport was given by **Fujino** and supported, elaborated by **Levitt & Rashke** in 1975. It is an active mechanism which needs ATP. Mechanism is explained as follows.

Opening of Stomata during Daytime (in presence of light):

Opening of stomata depends upon following conditions:

(a) In Presence of light.
(b) Decrease in starch contents of guard cells.
(c) Increased concentration of malic acid in guard cells.
(d) Influx of K^+ ions into guard cells.
(e) Efflux of H^+ ions from guard cells.
(f) Intake of CI ions by guard cells.
(g) Low CO_2 concentration in an around guard cells.
(h) High pH (more than 7) in guard cells (hence, alkaline medium of the cell sap in guard cells).
(i) High Turgor Pressure in guard cells due to endosmosis, (turgidity of cells).
(j) And stomata open.

Explanation of Levitt Concept:This is explained as follows:

In the guard cells, starch are converted into malic acid in presence of light (during day time).Protons (H^+) thus formed are used by the guard cells for the uptake of K+ ions (in exchange for the protons H^+). This is an active ionic exchange and requires ATP energy and cytokinin (a plant hormone). The concentration of K^+ ions increases and the concentration of H+ ions decreases in guard cells. The pH of the cell sap in guard cells also increases (pH becomes more than 7 and the medium becomes alkaline).

There is also an increased uptake of CI" (anions) by the guard cells to maintain the electrical and ionic balance inside and outside the guard cells. The malate anions formed in the guard cells are neutralized by the K+ ions. This results in the formation of potassium malate.

Malate anions + K^+ →Potassium malate

Potassium malate enters the cell sap of the guard cells thereby reducing the water potential while increasing the osmotic concentration (and the O.P.) of the cell sap. Hence, endosmosis occurs, guard cells become turgid and kidney-shaped and the stomata opens.

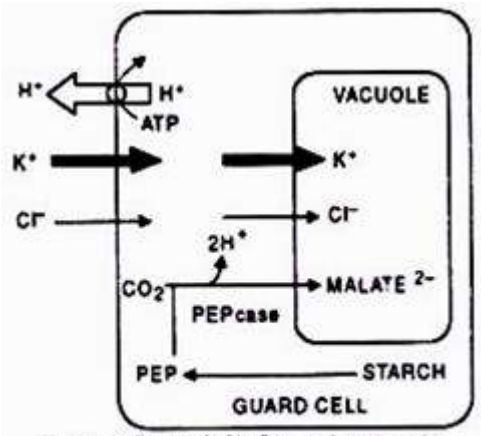


Fig. 4.7 Role of K^+, Cl^- and malate in increasing osmotic concentration (decreasing water potential) of guard cells.

It is also observed that the CO_2 concentration is low in and around guard ceils during day time. This is due to high photosynthetic utilization of CO_2. It helps in opening of stomata.

B. Closing of Stomata in Absence of Light (Darkness/Night Time):

Closing of stomata depends on following conditions:

(a) Absence of light.

(b) Decreased concentration of malic acid in guard cells.

(c) Efflux of K^+ ions from guard cells.

(d) Influx of H^+ ions in guard cells.

(e) Acidic medium of the cell sap in guard cells.

(f) Loss of Cl^- ions from guard cells.

(g) Increases CO_2 concentration in and around guard cell due to release of CO_2 in respiration combined with the absence of photosynthetic activity in dark.

(h) Presence of plant growth inhibiting hormone abscissic acid (ABA),

(i) Loss of turgidity and loss of kidney-shape by guard cells.

All these conditions represent the reversal of the daytime events. Under these conditions, the guard cells lose water by exosmosis and become flaccid. This causes closing of the stomata.

Unit2: Mineral nutrition 3 Hrs

1.Mention role and defiency symptoms of Nitrogen. 1 Role ,1 Symptom 1+1

Role: Building blocks of proteins, nucleic acids, biosynthesis of chlorophyll, growth, respiration, photosynthesis**.Symptoms**: inhibition of cell division, chlorosis, production of Anthocyanin,stunted growth, scenescence,suppress flowering,protein & starch are reduced, affects respiration

2.Mention the deficiency symptoms of Iron. Any 4 ½ each

Chlorosis, leaves turn yellow or brown in the margins between veins.

3.Mention defieciency symptoms of Boron and Molybdenum in plants. 1+1

deficiency symptoms of boron: deficiency causes death of shoot tip.2) Suppress flower formation.3)Leaves become coppery, Brittle, Curve inwards,Stunted root growth. **DEFICIENCY SYMPTOMS OF Mo**:-1) Mo deficiency causes Whiptail disease in Cauliflower.2)Chlorotic intervienal mottling of older leaves,Flower formation is retarded,In Cereals like Oats grain formation is reduced.

10 MARKS QUESTIONS

1.List out the Source,role,and deficiency symptoms of Phosphorus, Potassium and magnesium.

Definition,,Source,,Role,Deficiency symptoms-(3 each)

The essential elements which are required in large quantities by plants are called Major or macro nutrients .Ex: P ,K,Mg,Ca , S,O , N .

A) Phosphorous. Source-phosphates such as HPO ,HPO phosphate ions. **Role-** 1)It is vital component of Nucleic acids, ATP,NADPPhosphorylated compounds,phospholipids.2)Act as activator of enzymes 3) Healthy root growth,Translocation of carbohydrates**.DeficiencySymptoms-** 1)premature leaf fall, become purple due to accumulation of Anthocyanin.2)Root & shoot become short,slender, retard flowering. 3) accumulation of carbohydrates, soluble nitrogen compounds.4)Reduction in rate of protein synthesis .5) Growth is retarded with necrotic patches on leaves and fruits.

B)Potassium. Source: soil minerals such as Biolite, Muscovite , Illite .**Role:**1)' K' is an activator of enzymes such as DNA Polymerase, starch polymerase.2) It regulates stomatal movement. 3)Influence translocation and chlorophyll formation. 4) Maintain permeability and hydration. **DeficiencySymptoms;**1)shoot become thin, stunted growth, Leading to death of plant . 2) Interveinalchlorosis, Necrosis at tips & margins of leaves. 3) Reduction in flowering. 4) Reduced storage of carbohydrates in under ground stem and root.

C) Magnesium .Source: Mg occurs as silicates, carbonates in soil and minerals such as magnesite, dolomite,olvine.**Role ;**1) Mg is an important constituent of chlorophyll.2) play vital role in phosphorous metabolism.3) It is binding agent of ribosomal particles during protein synthesis .4) it acts as an activator for many enzymes like carboxylase, Hexokinase, Phosphorylase, dehydrogenasePeptidase(enzymes of carbohydrate metabolism & nucleic acid synthesis) **. DeficiencySymptoms** : 1)leaves develop Anthocyanin pigment & necrotic spots. 2) Petiole become slender and defoliation occurs.3) Reduction in size of the chloroplast .

2.What are Macro nutrients? Explain the role of N.P. 1+4+4.

Mineral which are required in large quantity for growth and development of the plant is called Macro nutrients**.**

1. NITROGEN : Availability:- Nitrogen from soil is absorbed in the form of Nitrates and Nitrites .Nitrogen from atmosphere is available to plants by nitrogen fixing bacteria and Blue green algae.
Physiological Role: 1. It is present in Macromolecules like Proteins, Nucleic acids. 2. It is also present in amino acids, Purine, Pyramidines, Porphyrines, and Coenzymes. Thus play an important role in metabolic reactions, Growth, Respiration, and Photosynthesis.
Deficiency symptoms:-1. Chlorosis (Yellowing) of leaves, older leaves is affected first. 2. Stem, Petiole, veins become colored due to formation of Anthocyanin . 3. Flowering is delayed or completely suppressed. 4. Protein content decreases.

2.PHOSPHOROUS: .Physiological Role:- 1)It is component of Nucleic acids, proteins, Phospholipids, Sugar phosphates, ATP, NADP, and phosphorylated compounds.2)Phospholipids along with proteins are important constituents of cell membranes.3)Through co enzymes NADP and ATP it plays an important role in oxidation reduction and energy transfer reactions of cell metabolism. Photosynthesis, Respiration etc. **Deficiency symptoms** :- 1)Disruption of general metabolism at the level of energy generation.2)Abnormalities in shape, size of the chloroplast.3)Anthocyanin pigmentation, Yellowing and Drying of lower leaves.4)Root and Shoot become short and slender.5)Promotes leaf fall and delays flowering.

3.POTASSIUM: Physiological Role:-1)Potassium is needed for Growth and development. A high amount is required for Protein synthesis.2)It acts as an activator of several enzymes, needed in change of sugar to Starch, Amino acids to protein, citric acid synthesis.3)It regulates movement of Stomata.4) It is essential in photosynthesis, Respiration, Translocation, Chlorophyll formation, Reduction of Nitrate.5)It maintains cellular organization, permeability and Hydration.**Deficiency symptoms**:-Mottled chlorosis of leaves. Necrosis at tips and margins of leaves.Stunted growth with short internodes.Reduction in flowering.Shortage of carbohydrate in underground stem and Root.

Unit 3: Photosynthesis 10 Hrs

1) What is photolysis of water? Mention its significance. 1+1

Splitting of watr molecule into H+ and OH- in presence of light is called 'Photolysis of water'. Significance: - evolution of oxygen.

2.What are thylakoids? Mention its role. 1+1

The Thylakoids are plate like membranous sacs arranged in compact bundles forming Grana. **Role: -** Inner surface of the chlorophyll contains photosynthetic units called 'Quantasomes' that involve in Light reaction.

3.Expand CAM.Mention its significance. 1+1

Crassulacean acid metabolism**.Significance:-**1) CAM plants refix the carbon di oxide which is released during respiration where as the other plant looses it.2) Stomata of CAM plants are closed during day time inorder to conserve water. Because most of CAM plants are xerophytes.

4.Draw neat labeled diagram of chloroplast. Fig-1+ label-1

Chloroplast is regarded as "Photosynthetic apparatus".A typical chloroplast is discoid in shape, bounded by 2 selectively permeable lipo-proteinmembrane with space between them called "periplastidialspace".The membrane encloses proteinaceous granular matrix called "stroma". Grana are membrane bounded flattened sacs derived from inner membrane. They are interconnected by stroma lamella or Fret channels. Each Granum consists of 2 to 40 flattened sacs called grana lamellae or Thallakoids. Membranes of grana lamella

and stroma lamella contain photosynthetic pigments namelygreen pigment chlorophyll and orange yellow pigment carotenoids.

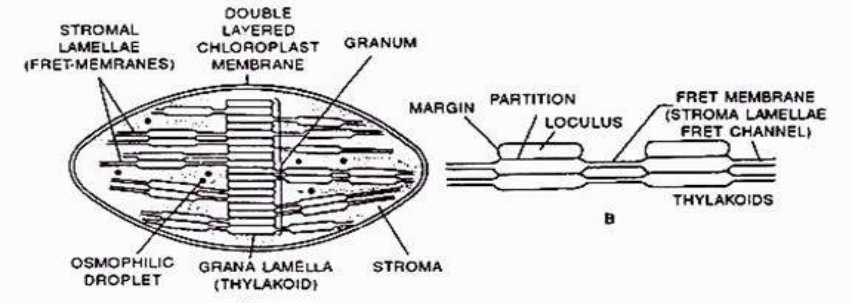


Fig. 6.2. (A) Internal structure of chloroplast (green plastid), (B) Enlarged thylakoids from two granna.

5 MARKS QUESTIONS

1.with a neat labeled diagram, explain structure of chloroplast. Fig-2, explanation-2 Chloroplast is regarded as "Photosynthetic apparatus".A typical chloroplast is discoid in shape, bounded by 2 selectively permeable lipo-proteinmembrane with space between them called "periplastidialspace".The membrane encloses proteinaceous granular matrix called "stroma". Grana are membrane bounded flattened sacs derived from inner membrane. They are interconnected by stroma lamella or Fret channels. Each Granum consists of 2 to 40 flattened sacs called grana lamellae or Thallakoids. Membranes of grana lamella and stroma lamella contain photosynthetic pigments namelygreen pigment chlorophyll and orange yellow pigment carotenoids.

2.Describe cyclic photophosphyrylation. Explain-3+ scheme-2

Light reaction or Hill reacton or Photochemical reaction is the first step part in the mechanism of photosynthesis.it is the light dependent process that takes place in the Grana part of the chloroplast.Robert Hill demonstrated the necessity of light for photo oxidation of water..It consists of 4 Light dependent reactions. They are:-) Photoexitation of Chlorophyll –a:- When the photon of light strikes pigment molecules all pigments absorb light energy and transfer it to reaction center molecules namely Chl-a 680,in PSII and Chl-a 700 in PSI.These molecules become excited and expel energy rich electrons to electron acceptors.

1) **Photo oxidation of water or photlysis of water**:-

Splitting up of water molecules into Hydrogen ions and Hydroyl ions in presence of light is known as Photolysis of water.Thus fromed Hydroxyl ions unite to form water, oxygen, and electrons. Oxygen is liberated as byproduct of photosynthesis. Electrons released are accepted by unknown compound z and are released inside the Thylakoid membrane.

2) **Photoreduction of NADP**:-

NADP is an hydrogen acceptor. It accepts hydrogen ions released during photolysis of water and electrons from reducing agent NADP + H+.

3) **Photophosphorylation of ADP**:-

The process of formation of ATP from ADP and inorganic phosphate under the influence of light during light reaction is called 'Photophosphorylation'.it was studied by Daniel Arnon. ATP is formed in 2 methods in chloroplast. They are: - photophosphorylation B) Non- cyclic photophosphorylation.

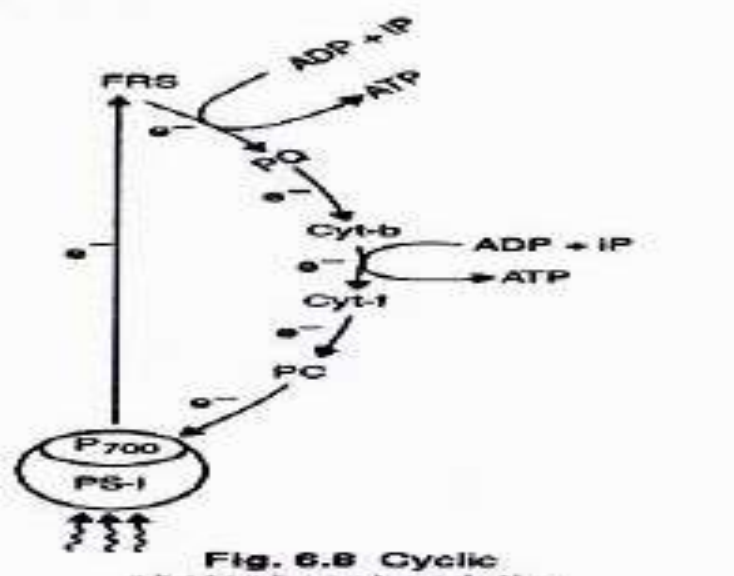


Fig. 6.8 Cyclic photophosphorylation

A) **Cyclic photophosphorylation: -**

Synthesis of ATP during Cyclic transfer of energy rich electrons is known a 'Cyclic photophosphorylation".

- When photon of light strikes PS-I, pigment molecules absorb light energy, transfer it to Chl-700. It becomes exicited and ejects energy rich electrons.
- Electrons pass through electron carriers like FRS(Ferrodoxin reducing substance – unknown protein) Fd(Ferrodoxin) Cyt-b6 (Cytochrome b-6) Cyt-f(Cytochrome-f) PC(Plastocyanin). And cycled back to Chl-700 .This is called as cyclic electron transfer.
- It involves only PS I.free energy lost from electrons during cyclic journey of electrons is utilized for synthesis of ATP at 2 places ie. Between FD and Cyt – b6, and also Cyt b6 and Cyt- f.
- Thus at the end of cyclic photophosphorylation 2 molecules of ATP are sysnthesised.

3.Differentiate between C3 and C4 plants. Four differences 1 mark each.

Sl.no	C3 path way	C4 path way
1	C3 path way takes place in majority of plants	C4 path way take place in members of graminae with Kranz anatomy
2	Only one type of chloroplast is involved	2 types of chloplasts ie, Chloroplast present in mesophyll and bundle sheath are involved
3	RUBP is the primary acceptor of CO2.	PEP(Phospho enol pyruvic acid) is the primary acceptor of CO2.
4	First stable product is phosphor glyceric acid	First stable compound is Oxalo acetic acid.
5	In each chloroplast 2 pigment system are present ie,. PS-I and PS-II	In bundle sheath cell Chloroplast PS-II is absent. they depend on chloroplastof Mesophyll for NADPH+ and H+.

4.Explain Non cyclic Photophosphorylation. Explanation-3+ chart-2

An unidirectional flow of electrons leading to the formation of ATP from ADP an pi, reduction of NADP and photolysis pf water under the influence of Light energy is called **'Non cyclic photo phosphorylation'. Z scheme model of Hill and Bendal Significance: -** Formation of NADP, ATP and release of oxygen to atmosphere.

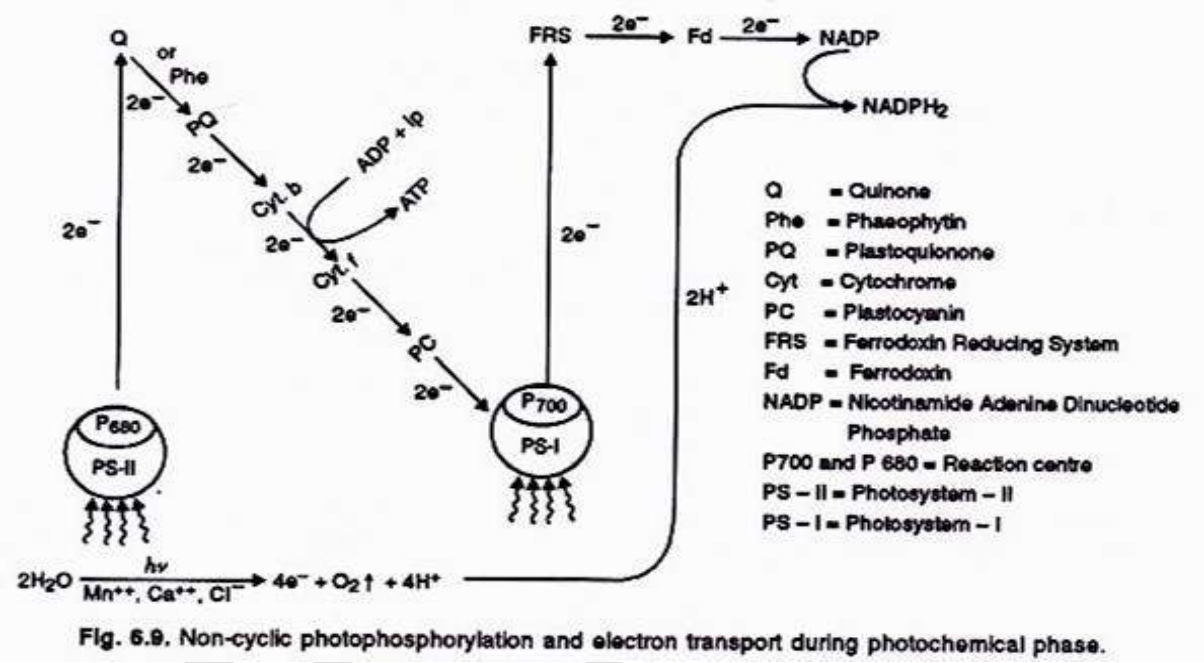


Fig. 6.9. Non-cyclic photophosphorylation and electron transport during photochemical phase.

- It is the major path way of light reaction that involves PSI where Chl-700 is hre reaction Chl-a 680 is the reaction center.
- Electrons expelled from PSI and PSII are not cycled back.
- Whenphoton of light strikes pigment molecules of PSII, light energy is absorbed and transferred to Chl- 680.
- Loss of electrons from Chl-680 is companisiated from electrons released during photo oxidation of water.
- Similar to PSII, when Photon of light strikes pigment molecules of PS-I, light energy is absorbed by pigment molecules and transferred to Chl- 700. It becomes excited and ejects energy rich electrons.
- The expelled electron from PS II is accepted by primary electron acceptor Pp(Pheophytin) and then passed to PQ (Plastoqunone) , Later electrons move through different electrons carriers likr Cyt-b6, Cyt—f, PC, and finally PSI and from there through FRS and Fd.
- Finally electrons from FD are utilized in the formation of reducing agent NADPH2.
- During this Non-cyclic journey of electrons one ATP molecule is synthesized at the Junction of Cyt-b6 and Cyt- f.

Conclusion- At the end of light reaction assimilatory powers like strong reducing agent NADPH2 and high chemical enrgy compound ATP are formed with the liberaton of oxygen.
12 H2o + 12 NADP + 18 ADP + 18 Pi ---------- 12 NADPH2 + 18 ATP + 6 O_2

5.Explain CAM pathway. Definition- 1, fig-1, explain-3

The plants which fix carbon do oxide in dark display diurnal pattern of organic acid formation. This was first observed in plants belonging to family Crssulaceae. Hence this is called "Crassilucean acid metabolism". Such plants are called CAM plants. Ex: Bryophyllum. It is also reported from members belonging to family Orchidaceae, Euphorbiaceae, Asclepiadaceae etc.

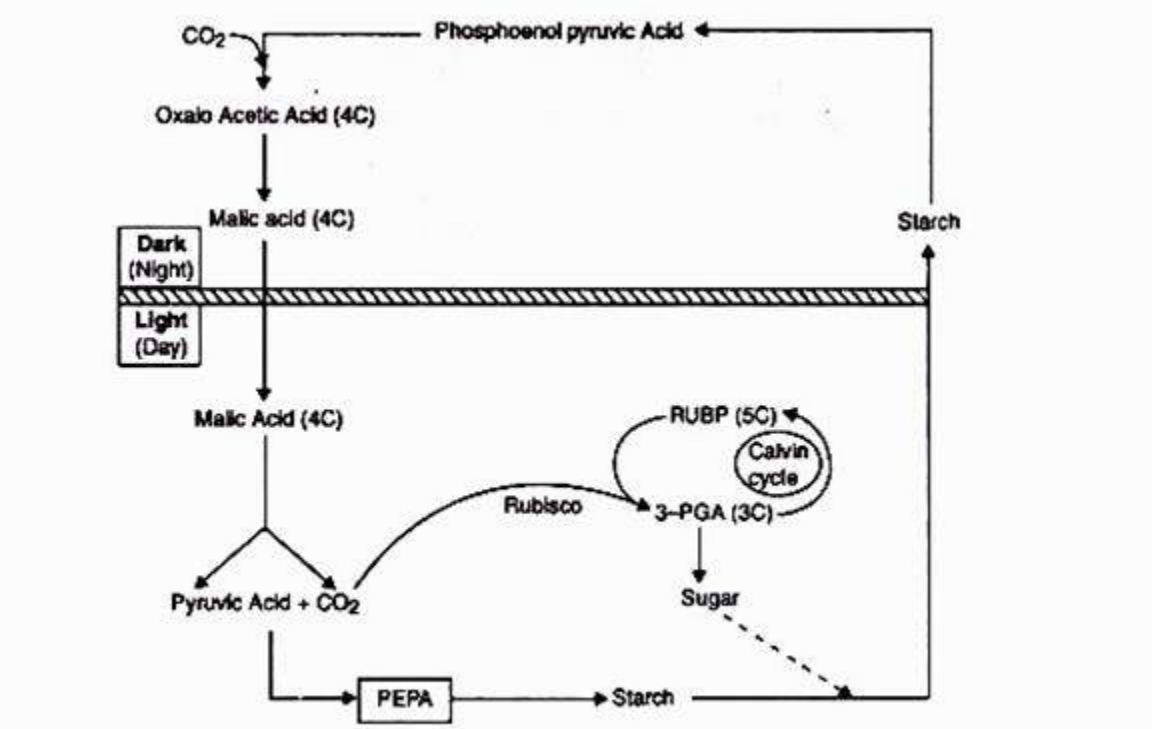


Fig. 6.15. Mechanism of Crassulacean acid metabolism (CAM) showing CO_2 uptake from outside during night and its utilisation in photosynthesis during daytime.

- In CAM plants stomata open in night and closed in day light. During night when stomata open phosphor enol pyruvic acid absorb carbon di oxide, form oxaloacetic acid. It is converted into Malic acid. This increases acid content (Acidification).pH decreases.
- During day time when stomata close Malic acid is converted into Pyruvic acid. This decreases acid content and pH increases, carbo di oxide released enters Calvin cycle.

Acidification: - In darkness stored carbohydrates are converted into phosphoenol pyruvic acid by the process of glycolysis. In CAM plants Stomata open in dark, fix CO2, phosphor enol pyruvic acid is converted into Oxaloacetic acid in presence of PEP carboxylase.

PEP + CO2+ H2O ----------OAA + H3PO4

OAA is reduced to Malic acid in presence of Malic dehydrogenase, it requires NADP
OAA+ NADPH + H+ ----------Malic acid + NADP+
Malic acid produced in dark as a result of acidification is stored in Vacuole.

Deacidification:- In Light, Malic acid is converted into Pyruvic acid in presenc of Malic enzyme or PEP carboxylase . One molecule of NADP is reduced.

Malic acid + NADP+ ---------- Pyruvic acid + NADPH + H+ + CO2.
Carbon dioxide released is used by Calvin cycle and photosynthesis continues, pyruvic acid is utilized for regeneration of phosphor enol pyruvic acid.
Significance: - 1) CAM path way in succulents helps to perform photosynthesis under extremely dry condition.2) During Day time when Stomata are closed CO2 can not enter, CO2 from deacidification provides free carbon di oxide to dark rection.

6.Explain Hatch –Slack Pathway Explanation-2, cycle-1, significance-1

Hatch and Slack investigated the complete pathway for carbon di oxide, where first stable product fromed is 4 carbon compound Oxalo acetic acid.Hence it is also called as C4 path way. It is composed of 2 carboxyl compound; hence it is called as 'Dicarboxylic acid cycle'. It occurs in some tropical plants having Kranz anatomy. In leaves of C4 plants vascular elements are surrounded by bundle sheath which contains large chloroplast without Grana, but mesophyll surrounding this contains small chloroplast with grana. C4 path way in chloroplast of mesophyll and another in chloroplast of bundle sheath.
A) In Mesophyll :- Fixation of CO2 :- Phospho enol pyruvic acid (PEP) found in mesophyll fix atmospheric CO2 and form 4 'C' compound Oxalo acetic acid.in presence of carboxylase.

PEP + CO2 + H2O ----carboxylase -------Oxaloacetic acid.

Formation of Malic acid:- oxalo acetic acid is converted into Malic acid in presence of Dehydrogenase and NADPH2. OAA -----Dehydrogenase-------malic acid.

B)In Bundle sheath:-Malic acid from chloroplast of mesophyll is transferred to chloroplast of bundle sheath. Malic acid is converted into pyruvic acid in presence of Decarboxylase.

Malic acid ------decarboxylase ----------Pyruvic acid.

Pyruvic acid is transported back to chlorophyll of mesophyll, where it is converted into phosphor enol pyruvate in presence of Pyruvate, phosphate dikinase and ATP.

Significance:- 1) C4 plants absorb CO2 from very low CO2 concentration in the atmosphere . Thus they perform high rate of photosynthesis. 2) C4 plants have greater rate of CO2 fixation. It needs 5 ATP and 2 molecules of reduced NADPH + H+ to fix one molecule of CO2. Thus C4 plants have more yields when compared to C3 plants.3) C4 plants are better adopted in tropics and deserts.

7.Explain Pentose Phosphate pathway. Define- 1+ process-2+ Significance-1

Oxidation of Glucose -6 –phosphate into Pentose phosphate without entering Glycosis is known as Pentose path way. It was described by Warburg and Dickens. It takes place as follows**:-**

1) Glucose-6 –phosphate is oxidized into Gluconate -6 –phosphate, accompanied by reduction of co enzyme NADP+ to NADP + H+.

2) Gluconate -6-Phosphate is oxidatively decarboxylated into Ribulose -5-phosphate. NADP + is reduced to NADPH + H+, one molecule of carbon-di-oxide is released.

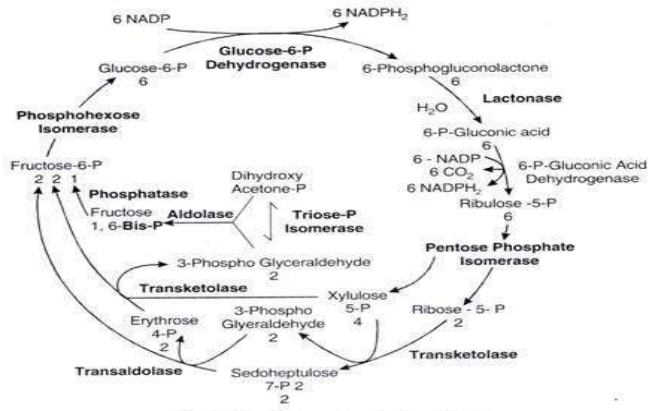


Fig. 16.18. Pentose phosphate pathway.

3) Ribulose-5- phosphate undergoes isomerisation to form either Ribulose -5- phosphate or Xylulose -5-phosphate,

4) a molecule of Ribose 5 phosphate with a molecule of Xylulose 5 phosphate form Sedoheptulose -7-phosphate and Glyceraldehyde 3 Phosphate.

5) Sedoheptulose – 7- phosphate and Glyceraldehyde-3-phosphate combine to produce Fructose -6 –phosphate and Erythrose -6 – phosphate.

6) Erythrose -4- phosphate and a molecule of xylulose-5 –phosphate combine to form Fructose-6-phosphate and Glyceraldehyde -3- phosphate.

7) The molecules of Fructose -6- phosphate are isomerised to Glucose 6 phosphate.

8) Glyceraldehyde 3 phosphate is broken down into to Pyruvic acid in Glycolysis.

Significance:-1) Pentose path way provides a) Co enzyme NADAP + H+ for some synthetic process.b) Ribose sugar for Nucleic acid synthesis.c) Erythrose for Lignin and other aromatic compounds. D) Carbon di oxide for fixation in photosynthesis.e) It Provides alternative route for carbohydrate break down.

10 MARKS QUESTIONS

1.Describe Light reaction. Explain- 4+ reaction-6

Light reaction or Hill reacton or Photochemical reaction is the first step part in the mechanism of photosynthesis.it is the light dependent process that takes place in the Grana part of the chloroplast.Robert Hill demonstrated the necessity of light for photo oxidation of water.Hence Light reaction is also called Hil reaction.It consists of 4 Light dependent reactions. They are:- 1) Photoexitation of Chlorophyll –a:- When the photon of light strikes pigment molecules all pigments absorb light energy and transfer it to reaction center molecules namely Chl-a 680,in PSII and Chl-a 700 in PSI.These molecules become excited and expel energy rich electrons to electron acceptors.

4) Photo oxidation of water or photlysis of water:- Splitting up of water molecules into Hydrogen ions and Hydroyl ions in presence of light is known as Photolysis of water.Thus fromed Hydroxyl ions unite to form water, oxygen, and electrons. Oxygen is liberated as

byproduct of photosynthesis. This reaction is associated with PSII. Mn++ and Cl- ions act as CO factors. Electrons released are accepted by unknown compound z and are released inside the Thylakoid membrane.

5) Photoreduction of NADP:- NADP is an hydrogen acceptor. It accepts hydrogen ions released during photolysis of water and electrons from reducing agent NADP + H+.

6) Photophosphorylation of ADP:- The process of formation of ATP from ADP and inorganic phosphate under the influence of light during light reaction is called 'Photophosphorylation'.it was studied by Daniel Arnon. ATP is formed in 2 methods in chloroplast. They are: - photophosphorylation B) Non- cyclic photophosphorylation.

B) **Cyclic photophosphorylation: -** Synthesis of ATP during Cyclic transfer of energy rich electrons is known a 'Cyclic photophosphorylation".

- When photon of light strikes PS-I, pigment molecules absorb light energy, transfer it to Chl-700. It becomes exicited and ejects energy rich electrons.
- Electrons pass through electron carriers like FRS(Ferrodoxin reducing substance – unknown protein) Fd(Ferrodoxin) Cyt-b6 (Cytochrome b-6) Cyt-f(Cytochrome-f) PC(Plastocyanin). And cycled back to Chl-700 .This is called as cyclic electron transfer.
- It involves only PS I.free energy lost from electrons during cyclic journey of electrons is utilized for synthesis of ATP at 2 places ie. Between FD and Cyt – b6, and also Cyt b6 and Cyt- f.
- Thus at the end of cyclic photophosphorylation 2 molecules of ATP are sysnthesised.

C) **Noncyclic photophosphorylation; -** Synthesis of ATP during non-cyclic journey of electrons of the chlorophyll molecule is called "Non-cyclic photophosphorylation".This is also called 'Z' scheme electron transport, because electrons travel in Zig-Zag manner through the electron carriers.

- It is the major path way of light reaction that involves PSI where Chl-700 is hre reaction Chl-a 680 is the reaction center.
- Electrons expelled from PSI and PSII are not cycled back.
- Whenphoton of light strikes pigment molecules of PSII, light energy is absorbed and transferred to Chl- 680.
- Loss of electrons from Chl-680 is companisiated from electrons released during photo oxidation of water.
- Similar to PSII, when Photon of light strikes pigment molecules of PS-I, light energy is absorbed by pigment molecules and transferred to Chl- 700. It becomes excited and ejects energy rich electrons.
- The expelled electron from PS II is accepted by primary electron acceptor Pp(Pheophytin) and then passed to PQ (Plastoqunone) , Later electrons move through different electrons carriers likr Cyt-b6, Cyt—f, PC, and finally PSI and from there through FRS and Fd.
- Finally electrons from FD are utilized in the formation of reducing agent NADPH2.

- During this Non-cyclic journey of electrons one ATP molecule is synthesized at the Junction of Cyt-b6 and Cyt- f.

  Conclusion- At the end of light reaction assimilatory powers like strong reducing agent NADPH2 and high chemical enrgy compound ATP are formed with the liberaton of oxygen.

  12 H2o + 12 NADP + 18 ADP + 18 Pi ---------- 12 NADPH2 + 18 ATP + 6 o2.

2.Describe C 3 cycles. Cycle-4, explanation-6marks.

Dark reaction or Thermochemical reaction or carbon assimilation reaction is the second part of mechanism of photosynthesis. It is not light dependent process. It takes place in stroma part of the chloroplast. In 1905 Blackman demonstrated thermochemical reduction of carbon di oxide into carbohydrate.Hence it is also called 'Blakmann reaction". It takes place as follows;-**C3 path way or Calvin cycle**:-This is the major Path way of carbo di oxide fixation in green plants. During Dark reaction using products of Light reaction carbo di oxide is reduced to carbohydrate in a cyclic manner. It was explained by Calvin et al. for which he was awarded Nobel prize.in 1961.hence this is also called Calvin cycle. During this cycle the first stable product is 3 carbon compound phosphoglyceric acid . Hence it is also called C3 cycle. It consists of 4 main steps:-

1. **Fixation of carbon di oxide:-** Ribulose 1,5- biphosphate is a 5 carbon sugar found in stroma of the chloroplast. 6 molecules of RUBP absorb 6 molecules of carbon di oxide to from 6 molecules of unstable 6 'C' compound in presence of an enzyme RUBP carboxylase , breaks up into 12 molecules of Triose phosphate called 'Phosphoglyceric acid'.
   6 RUBP + 6 CO2 --RUBP carboxylase----6 molecule of unstable compound Rubisco—12 PGA
2. **Reduction of phosphoglyceric acid:-**Posphoglyceric acid is reduced to Phosphoglyceraldehyde in presence of assimilatory powers ATP and NADPH2 in presence of Kinase and dehydrogenase.
   12 PGA + 12 ATP -----kinase -------12 Di PGA + ADP
   12 Di PGA + 12 NADPH + + H+ ----PGA dehydrogenase ----12 PGAL + 12 NADP

3. **Formation of simple sugar:-**12 molecules of PGAL participate in different reactions as follows:- one PGAL molecule undergo isomerisation to from Dihydroxyacetone phosphate(DHAP). This combines with another PGAL molecule to from fructose 1, 6-Diphosphate in presence of Aldolase.
   PGAL---Isomerase----------DHAP
   DHAP + PGAL --------Aldolase---------Fructose 1, 6-Diphosphate.
   Fructose 1, 6- diphosphate is converted into Fructose 6 phosphate in presence of phosphotase.some of it is tapped off from Calvin cycle and is converted into hexose sugar which is end product of photosynthesis**.**
   Fructose 1,6 –diphosphotase -------Phosphotase----------Fructose 6 phosphate.

4. **Regeneration of RUBP:- T**he remaining 10 PGAL molecules are subjected to several reactions to regenerate 6 molecules of RUBP to complete the Cycle . This can be represented as follows:-
   A) PGAL+Fructose 6 phosphate----Transketolase----------Erythrose 4 phosphate + Zylulose 4 phosphate
   B) Erythrose 4 phosphate + Dihydroxy Acetone phosphate------sedoheptulose 1, 7 Phosphate

A) Sedoheptulose 1,7 diphosphate –phosphotase-----sedoheptulose 7 phosphate

B) Sedoheptulose 7 phosphate +PGAL ---Transketolase---xylose 5 phosphate+ Ribose 5 phosphate

E) Xylulose 5 phosphate -------Epimerase --------Ribulose 5 phosphate

F) Ribose 5 phosphate ---------Isomerase---------Ribulose 5 phosphate

G) Ribose 5 phosphate ------ Kinase ----------Ribulose 1,5 –Diphosphate+ ATP

6 RUBP + 6co2 + 12 NADPH2 + 18 ATP -----6 RUBP + FDP + 12 NADP + 12 ADP + 18 Pi.

3.With schematic representation describe C3 pathway. Cycle-4, description-6 marks

Dark reaction or Thermochemical reaction or carbon assimilation reaction is the second part of mechanism of photosynthesis. It is not light dependent process. It takes place in stroma part of the chloroplast. In 1905 Blackman demonstrated thermochemical reduction of carbon di oxide into carbohydrate.Hence it is also called 'Blakmann reaction". It takes place as follows;-**C3 path way or Calvin cycle**:-This is the major Path way of carbo di oxide fixation in green plants. During Dark reaction using products of Light reaction carbo di oxide is reduced to carbohydrate in a cyclic manner. It was explained by Calvin et al. for which he was awarded Nobel prize.in 1961.hence this is also called Calvin cycle. During this cycle the first stable product is 3 carbon compound phosphoglyceric acid . Hence it is also called C3 cycle. It consists of 4 main steps:-

- **Fixation of carbon di oxide:-** Ribulose 1,5- biphosphate is a 5 carbon sugar found in stroma of the chloroplast. 6 molecules of RUBP absorb 6 molecules of carbon di oxide to from 6 molecules of unstable 6 'C' compound in presence of an enzyme RUBP carboxylase , breaks up into 12 molecules of Triose phosphate called 'Phosphoglyceric acid'.

6 RUBP + 6 CO2 --RUBP carboxylase----6 molecule of unstable compound Rubisco—12 PGA

- **Reduction of phosphoglyceric acid:-**Posphoglyceric acid is reduced to Phosphoglyceraldehyde in presence of assimilatory powers ATP and NADPH2 in presence of Kinase and dehydrogenase.

12 PGA + 12 ATP -----kinase -------12 Di PGA + ADP

12 Di PGA + 12 NADPH + + H+ ----PGA dehydrogenase ----12 PGAL + 12 NADP

- **Formation of simple sugar:-**12 molecules of PGAL participate in different reactions as follows:- one PGAL molecule undergo isomerisation to from Dihydroxyacetone phosphate(DHAP). This combines with another PGAL molecule to from fructose 1, 6-Diphosphate in presence of Aldolase.

PGAL---Isomerase----------DHAP

DHAP + PGAL --------Aldolase---------Fructose 1, 6-Diphosphate.

Fructose 1, 6- diphosphate is converted into Fructose 6 phosphate in presence of phosphotase.some of it is tapped off from Calvin cycle and is converted into hexose sugar which is end product of photosynthesis**.**

Fructose 1,6 –diphosphotase -------Phosphotase----------Fructose 6 phosphate.

- **Regeneration of RUBP:- T**he remaining 10 PGAL molecules are subjected to several reactions to regenerate 6 molecules of RUBP to complete the Cycle . This can be represented as follows:-

A) PGAL+Fructose 6 phosphate----Transketolase----------Erythrose 4 phosphate + Zylulose 4 phosphate

B) Erythrose 4 phosphate + Dihydroxy Acetone phosphate------sedoheptulose 1, 7 Phosphate

C) Sedoheptulose 1,7 diphosphate –phosphotase-----sedoheptulose 7 phosphate

D) Sedoheptulose 7 phosphate +PGAL ---Transketolase---xylose 5 phosphate+ Ribose 5 phosphate

E) Xylulose 5 phosphate -------Epimerase --------Ribulose 5 phosphate

F) Ribose 5 phosphate ---------Isomerase---------Ribulose 5 phosphate

G) Ribose 5 phosphate ------ Kinase ----------Ribulose 1,5 –Diphosphate+ ATP

6 RUBP + 6co2 + 12 NADPH2 + 18 ATP -----6 RUBP + FDP + 12 NADP + 12 ADP + 18 Pi.

Unit 4: Respiration 6 Hrs

1. Draw a neat labeled diagram of Mitochondrion. Fig-1+ label-1 mark

Typical Mitochondrion is Rod shaped bounded by 2 layered Lipoprotein membranes enclosing proteinaceous granular Mitochondrial matrix which is composed of DNA, RNA, Ribosomes, proteins and enzymesthat takes place in Kreb's cycle.Space between 2 layers is called Perichondrial space.outer membrane smooth , inner membrane is convoluted forming inflodings called Cristae. On the surface of Cristae knob like stalked particles called 'Rackers particles" or 'Oxysoms' or 'Elementary particles.each particle has Base , stalk and spherical head.base has an intergral membrane protein complex Fo and Head has membrane protein complex F1 for ATP synthesis during oxidative phosphorylation. Function: Mitichondria are power house of Eukaryotuc cells as they take part in ATP generation during Aerobic respiration.

2.What is oxidative phosporylation? Mention its significance. 1+1

Oxidative phosphorylation or Electron transport system is the final step of mechanism of Aerobic respiration. It takes place in 'F' particles or 'Oxisomes' of cristae in Mitochondria.The Oxidation of reduced Co enzymes like NADH+ + H and FADH + H+ by atmospheric oxygen is known as ' **Terminal oxidation'**.

3.Mention the events of Aerobic respiration. 1+1

Absorption of carbon di oxide.2) Formation of water 3) Elevation of carbon di oxide.4) Liberation of heat 5) Liberation of energy.

4.What is RQ? Mention the RQ value of proteins. 1+1

The ratio between the volume of carbon di oxide out and oxygen taken in simultaneously by given weight of the tissue in a given period at standard temperature and Pressure is called RQ.

5.What is RQ? Mention the RQ value of fat. 1+1

The ratio between the volume of carbon di oxide out and oxygen taken in simultaneously by given weight of the tissue in a given period at standard temperature and Pressure is called RQ. RQ Value of Fat is less than one.

6.What is Oxidative phosphorylation? Where does it occur? 1+1

Oxidation of reduced Co- enzymes coupled with phosphorylation of ADP into ATP. It occurs in the Oxisomes of Mitochondria.

7.Give the energy budget of aerobic respiration. 1+1

2+2 =4 ATP at substrate level, 6+6+ 22 = 34 ATP at terminal oxidation level. Energy budget of Aerobic respiration in total is 38 ATP (4+ 34).

8.Define RQ. Mention the RQ value of carbohydrates. 1+1 The ratio between the volume of carbon di oxide out and oxygen taken in simultaneously by given weight of the tissue in a given period at standard temperature and Pressure is called RQ.

9.What is Glycolysis? Mention end products. 1+1

Oxidation of one molecule of Glucose into 2 molecules of Pyruvic acid is called 'Glycolysis'.End product is Pyruvic acid.

5MARKS QUESTIONS

1.Explain Glycolytic pathway. Explanation-3 marks , Flow chart-2

Glycolysis is the first prt of the mechanism of Aerobic respiration that takes place in cytoplasm. 2) The oxidation of one molecules of pyruvic acid is known as Glycolysis.3) German Biochemists Emdem, Mayer, parnas explained the stepwise break down of Glucose into Pyruvic acid. Hence Glycolysis is also called **EMP pathway**.4). Glycosis oxygen is not utilized fro oxidation. It is brought about by dehydrogenation hence; Glycolysis is common path Way for aerobic and anaerobic respiration. Glycolysis takes place in following 3 main steps:-

A) Formation of fructose Di phosphate:-

- **Phosphorylation**: - Glucose is phosphorylated by ATP to from Glucose 6 phosphate in presence hexokinase and Mg ++ as co factor.
- **Isomerisation: -** Glucose 6 phosphate is isomerised to fructose 6 phosphate in presence of an enzyme Phospho gluco isomerase.
- **Second phosphorylation**: - Fructose 6 phosphate is phosphorylated by ATP to from 1, 6 di-phophate in presence of Phospho gluco kinase.

B)Formation of triose phosphate:-

- **Cleavage; -** Fructos 6 phosphate unergo cleavage into 2 molecules of Triose phosphate PGAL and DHAP in presence of Aldolase.

- **Isomerisation:** - DHAP is converted into PGAL in presence of isomerase.

C)Formation of Pyruvic acid:-

- **Phosphorylation and oxidative dehydrogenation: -** Phosphoglycerldehyde is phosphorylated by phosphoric acid to form 1, 3 – diphosphoglyceraldehyde. Simultaneously dehydrogenated to from 1, 3-diphospho glyseric acid. NAD is reduced to NADH2 in presence of dehydrogenase (PGAL release 2 electrons and protons. Electrons provide energy for linking inorganic phosphate protons are accepted by NAD).
- **ATP generation**: - 1, 3 phosphoglyceric acid is converted into 3 phosphoglycericacid in presence of phosphoglyceric kinase and Mg++ as co factor. Molecule of ATP is generated from ADP.
- **Isomerisation:** - 3 PGA is isomerised into 2 PGA in presence of phosphoglyceric mutase.

2.Explain Alcoholic fermentation. Path way-2, expalnaton-3 marks.

Incomplete oxidation of organic substances like Glucose in the living cells without utilizing oxygen to release energy is known as "Anaerobic respiration". $C_6H_{12}O_6$ ---------$2CO_2 + 2C_2H_5OH$ + 56 K.cal. energy.

Mechanism of anaerobic respiration:-Anaerobic oxidation takes place in 3 main steps. They are as follows:- Formation of Pyruvic acid:-Glucose is oxidized by dehydrogenation into 2 molecules of pyruvic acid .

2NAD 2NADH + H+

Glucose ---------- 2 Pyruvic acid

GLYCOLYSIS

2ADP + 2Pi 2 ATP

- Formation of Acetaldehyde: - Pyruvic acid under anaerobic condition undergoes decarboxylation to from Acetaldehyde.
- Formation of Ethyl alcohol: - Acetaldehyde is reduced to ethyl alcohol using NADH 2 produced during Glycolysis.

2 NADH+ H+ NAD

2Acetaldehyde ----------2 Ethyl alcohol

Dehydrogenase

- Overall reactions can be represented as

Glucose + 2 ADP + 2 Pi ---------- 2 CO_2 + 2 Ethyl alcohol + 2 ATP.

Conclusion:- At the end of Anaerobic respiration oxidation of one molecule of CO_2 , 2 molecules of Ethyl alcohol and 2 Molecules of ATP are formed

3.Explain Oxidative phosphorylation. Definition-1, explanation-6,fig-3

Oxidative phosphorylation or Electron transport system is the final step of mechanism of Aerobic respiration. It takes place in 'F' particles or 'Oxisomes' of cristae in Mitochondria.

The Oxidation of reduced Co enzymes like NADH+ + H and FADH + H+ by atmospheric oxygen is known as ' **Terminal oxidation'**.During this hydrogen ions pass into perichondrial space. Energy rich electrons of hydrogen atoms passes through various electron carriers present in inner membrane of mitochondrion by Redox process. These electron carriers constitute **'Electron transport system'. (ETS**). During this process some amount of energy will be released at oxidation level of electron carriers. This energy is utilissed for the synthesis of ATP from ADP & Pi. This process is called as **"Oxidative phosphorylation**". Mechanism is as follows:-

1. NADH2 transfer 2 electrons and 2 Hydrogen ions to Flavin Monophosphate (FMN). NADH2 is oxidized to NAD and FMN is reduced to FMNH2.
2. Co-Q H2 accepts H2 atoms from FMNH2 or FADH2 and become reduced into Co-QH2.
3. Co-QH2 transfer 2 electrons of cytochrome –b and release 2 hydrogen ions.
4. Hydrogen ions move along proton gradient. Electron passes from cyt-b to cyt-c, cyt-a, cyt-a3 by redox process.
5. Finally Hydorgen from the medium and electrons from cyt-a3 are assepted by oxygen to form one molecule of water. This is called 'Terminal oxidation".

During electron transport, Phosphorylation of ADP tp ATP takes place utilizing free energy released at oxidation of electron carriers at 3 sites. These are between NADH and FAD, between cyt-b and cyt-c, between cyt-a and cyt-a3. This is called 'Oxidative phosphorylation".

4. **Explain EMP pathway. Definition-1,Expalnation-6, Flow chart-3.**

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- **Isomerisation:** - 3 PGA is isomerised into 2 PGA in presence of phosphoglyceric mutase.

5.Explain Krebs cycle. Schematic cycle-4 , explanation-6 marks,

1)Kreb's cycle takes place in the **mitochondrial matrix**.

2) In 1937 H.A. Krebs proposed cyclic reactions to explain aerobic oxidation of Pyruvic acid into carbon di oxide and water.

3)CItric acid cycle"The first **intermediate compound compound is citric acid**. Hence Krebs called it as "Citric acid cycle".

4)Citric acid and Iso citric acid have **3 carboxyl groups**. Hence this path way is also called as "Tricarboxylic acid cycle. (TCA Cycle).

5) Acetyl Co-A formed by oxidative decarboxylation of Pyruvic acid enters Krebs cycle, combines with Oxalo acetic acid to from Citric acid . It is subjected to series of enzymatic reactions which end up with formation of Oxalic acid.

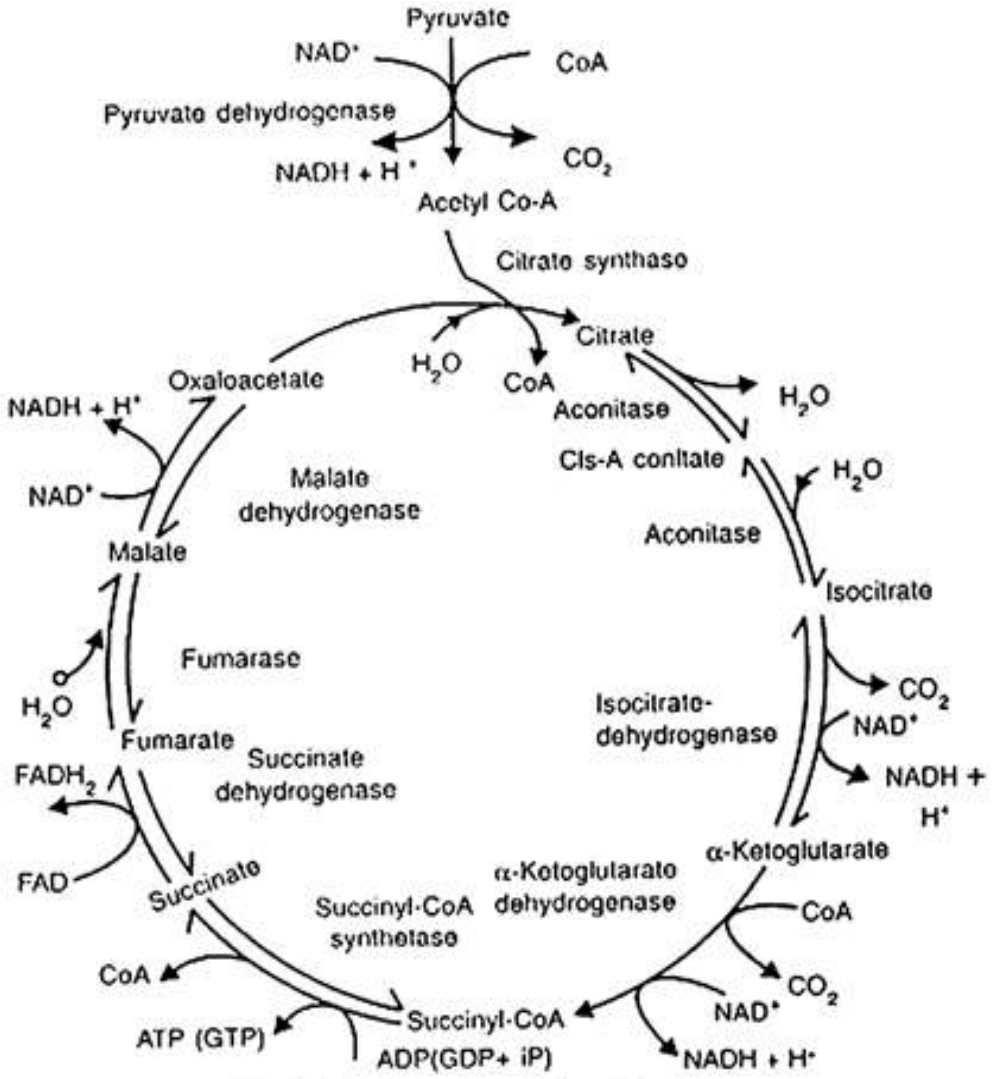

Fig. 4.3. Krebs cycle or citric acid cycle.

1 Reactions involved are as follows:-1) Hydration:-Cis- aconotic acid reacts with one molecule of water to form Iso citric acid in presence of Aconitase. 2) Dehydration:-Iso citric acid is oxidized to Oxalo succinic acid in presence of Iso citric dehydrogenase. NAD is reduced to NADH+ + H +.

Conclusion: - At the end of Kre's cycle for oxidation of 2 molecules of Pyruvic acid following end products are formed. A) 2+6 = 8 molecules of NADH2. B) 2 molecules of FADH2 3) 2+ 4=6 molecules of Carbon di oxide. 4) 2 moleclules of ATP.

6.Describe Tricarboxylic acid cycle. Cycle representation- 4+ explain-6

1. Kreb's cycle takes place in the mitochondrial matrix.
2. In 1937 H.A. Krebs proposed cyclic reactions to explain aerobic oxidation of Pyruvic acid into carbon di oxide and water.
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Acetyl Co-A formed by oxidative decarboxylation of Pyruvic acid enters Krebs cycle, combines with Oxalo acetic acid to from Citric acid . It is subjected to series of enzymatic reactions which end up with formation of Oxalic acid. Reactions involved are as follows:

1. Codensation:- 2 'C' Acetyl Cp-A reacts with 4 'C' oxalo acetic acid to form 6 'C' citric acid in presence of condensing enzyme 'Citric synthetase'.
2. Dehydration:- Citric acid loses a molecule of water to form Cis- aconitic acid in presence of Aconitase and Fe++.
3. Hydration:-Cis- aconotic acid reacts with one molecule of water to form Iso citric acid in presence of Aconitase.
4. Dehydration:-Iso citric acid is oxidized to Oxalo succinic acid in presence of Iso citric dehydrogenase. NAD is reduced to NADH+ + H +.

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Unit 5: Enzymes 5 Hrs

1.What is transamination? Give an example. 1+1

The transfer of amino group from one compound to othr is called 'Transamination'.
Ex: Glutamic acid+ Pyruvic acid ---------→ alpha keto glutaric acid+ Alanine.

2.Mention the theories of mechanism of enzyme action. 1+1

Lock and Key Theory, Double displacement theory(Ping pong theory), Induced fit theory.

3.Differentiate between prosthetic group and co-enzyme. 1+1

The non protein part of the enzyme is tightly bound to the protein part and it is called **prosthetic group.** If the non protein part of the enzyme is loosely bound to the protein part it is called **Coenzyme.**

4.What are enzyme inhibitors? Give an example. 1+1

The organic substances which inhibit the enzymes activity on the substrate molecules by blocking active sites of enzymes are called "Enzyme inhibitors".Ex: Enzyme Succinic dehydrogenase catalyses conversion of succinic acid to fumaric acid. Due to structural similarity between Malonic acid succinic acid reaction does not takes place.

5.Mention any four properties of enzymes. ½ each.

Colloidal in nature, have catalytic property, Thermoliable or het sensitive, exhibit specificity in their action.

6.Briefly explain Ping pong reaction. Definition-1 example-1

In Bisubstrate reaction, substrate molecule alternately binds to an Enzyme, releases the product and free enzyme. This mechanism is called "Ping pong reaction". Ex: Transamination.

5 MARKS QUESTIONS

1.Explain lock and Key theory of enzyme action. Fig-1, explanation-3 marks

To explain mechanism of enzyme action many theories have been proposed. They are: -
1) Lock and Key and mechanism:- This theory has been propsed by Fischer in 1898. According to this theory all enzymes have rigid, active, unfolded surface called as **Active site.** It can fix to particular substrate molecule to form **Enzyme substrate complex.**Rapid reaction takes place, product is released from the enzyme and the enzyme become free without any change. This theory explains the specificity of the enzymes as particular lock can be opened by a particular key which is specially designed to open it.

2.Give an account of enzyme classification. 6 types 4 marks

According to "Commission on Enzyme of international union of Biochemistry, the features of enzyme classification is as follws:-

1. All enzymes are grouped in 6 Major classes.
2. Each Major class has been divided into many sub classes.
3. Each sub class is further subdivided into sub sub classes.
4. Each enzyme has specific code number of 4 digits. First digit indicates Major class, second digit indicates sub class, third digit indicates sub sub class and fourth digit denotes specific name of enzyme in which first part indicates name of substrate and second part indicates type of reaction.
   6 major classes are as follows:-

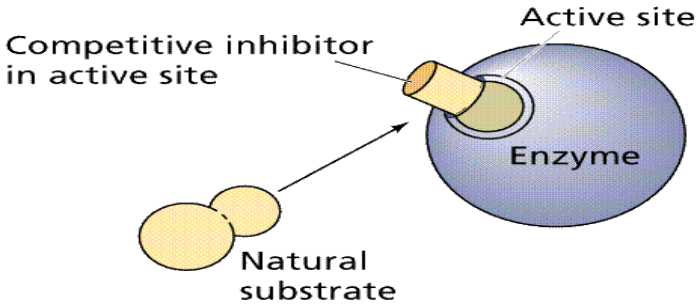
1. **Oxido reductases**: - It catalyses oxidation reduction reactions.
2. **Transferases:** - It catalyses reactions that involve group transfer. Ex: Transketolase, Transaminase, Transaldolase, Transphosphorylase, Transcarboxylase etc.
3. **Hydrolases;** - It catalyses hydrolytic reactions like Carbohydrases, Lipases.
4. **Lyases: -** It catalyses removal of group from substrate without addition of water.
5. **Isomerases**:-It catalyses isomerisation reactions.
6. **Ligases:** - It catalysesreactions in which 2 molecules are coupled by breaking of pyrophosphate bond by ATP.

3.Write a note on Enzyme inhibitors

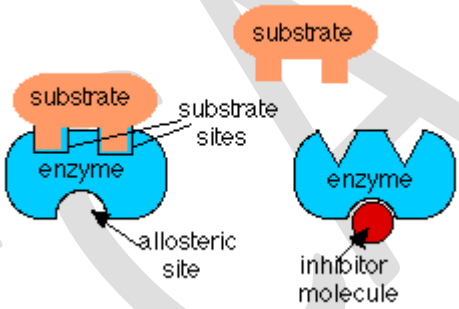
Enzyme inhibition:-When active sites of enzymes are blocked, it becomes inactivated. The chemical compound that inactivates the enzyme is called '**Enzyme poison**".

The organic substances which inhibit the enzyme activity on the substrate molecule by blocking Active sites of enzymes are **called enzyme inhibitors. There are 2 types of inhibitors, Namely** Competative **inhibitors Non competitive inhibitors and Allosteric inhibitors (End product inhibitors).**

1. **Competative inhibitors: - In Competitive type** the organic substances are structurally similar to the substrate molecule, compete with substrate to occupy active site, they pre occupy the active site, substrate will be unable to bind, enzyme activity is inhibited. Ex: Enzyme Succinic acid dehydrogenase catalyses conversion of Succinic acid to Fumaric acid. Due to structural similarity between Succinic acid and Malonic acid reaction does not takes place.



2. **Non competitive inhibitors:-** **In Non competitive** type the organic substances which are not structurally similar to the substrates, do not occupy Active site and do not compete with the substrate , But inhibit enzyme activity by destroying the structure of an enzyme protein or alter reactive group of an enzyme such as –COOH, -NH_2 group etc.
3. **Allosteric inhibitors (End product inhibitors or Feed back inhibition):-** when series of reactions are catalysed by number of enzymes in sequence, the **accumulation of final end product** may **cause inhibition in the activity** of the first enzyme of the series. This inhibition due to final end product which is different in structure from the Substrate of the enzyme is called **"Allosteric or Feed back inhibition.**
Allosteric enzyme has 2 types of sites for enzyme action. They are**: Active site and Allosteric site.**
Fig



Allosteric site is present away from the active site. When final end product fits in the Allosteric site, it changes the shape of an enzyme and makes it unfit to form Enzyme substrate complex. Allosteric inhibition is **reversible.** When the **concentration of final end product falls,** it leaves allosteric site and **activity of an enzyme starts.**

4.Factors affecting Enzyme action. Any four factors 1 mark each.

Enzyme activity on the substrate is affected by number of factors as follows:-

- **Enzyme concentration:** - Increase in concentration of enzymes will increase the rate of reaction catalysed by it in presence of enough concentration of substrate.
- **Substrate concentration:** - Decrease in concentration of substrate molecules lower than rate of reaction, as many active sitesof enzymes are unoccupied.
- **Temperature:-**Activity of the enzymes is minimum at low temperature ie,.0 degree C. It is optimum at normal temperature; maximum at 45 degree C. Beyond 60 degreeC enzyme activity is retarded.

- **PH: -** Enzymes function efficiently at particular hydrogen ion concentration. Pepsin require low PH, Trypsin require high PH. Beyond its own optimum range they show reduced activity.
- **Water:-**Enzymes are active when supplied with sufficient water. In absence of water activity of enzyme is suppressed.
- **Enzyme inhibitors:-** The organic substances which inhibit the enzyme activity on the substrate molecule by blocking Active sites of enzymes are **called enzyme inhibitors.**It may be **Competative** where the organic substance are structurally similar to the substrate molecule, compete with substrate to occupy active site.they pre occupy the active site, substrate will be unable to bind, enzyme activity is inhibited.or **Non competative** The organic substances which are not structurally similar to the substrates, do not occupy Active site and do not compete with the substrate , But inhibit enzyme activity by destroying the structure of an enzyme protein or alter reactive group of an enzyme.

5.Mention the properties of enzymes. 6 to 8 points-4 marks.

Enzymes shows following properties:-

- **Catalytic properties:-**All enzymes are Bio catalysts required in vey small quantities. They accelerate the pace of reaction and remain unchanged, do not disturb the euillibrium of the reaction.
- **Reversibility of reaction: -** Enzymes accelerate the pace of reaction in both directions. Depending upon the reuuirements of the cell and factors present at that particular time.Ex: Starch phosphorylase during day time hydrolase starch to sugar. During night synthesis of starch takes place, light and PH decides the direction of enzymes.
- **Specificity:-** Enzymes are highly specific in their action. A particular enzyme catalyses particular kind of reaction.Ex; Malic dehydrogenase removes hydrogen atom from Malic acid and from any other keto acid.
- **Colloidal nature:-** Enzymes are dispersed in the protoplasm and show colloidal properties. They cannot pass through membrane of colloidon.
- **Heat sensitivity:-** Enzymes are active at normal temperature but denatured at high temperature, in dried condition they are stable.
- **PH sensitivity:-** Enzymes are active at limited range of pH . They are denatured by strong acids or alkali.

10 MARKS QUESTIONS

1.Explain the mechanism of enzyme action. 3 theories 3 marks each ,1

To explain mechanism of enzyme action many theories have been proposed. They are: -

1) Lock and Key and mechanism: - This theory has been propsed by Fischer in 1898. According to this theory all enzymes have rigid, active, unfolded surface called as **Active site.** It can fix to particular substrate molecule to form **Enzyme substrate complex.**Rapid reaction takes place, product is released from the enzyme and the enzyme become free without any change. This theory explains the specificity of the enzymes as particular lock can be opened by a particular key which is specially designed to open it.

1) **Induced fit theory**: - This theory was proposed by Koshland in 1969.According to this theory Active site of the enzyme is not rigid and it has 2 groups. These are A) Substrate supporting catalytic groups.and 2) Substrate breaking group.The substrate interacts strongly with the enzyme; alter the active site so that perfect fitting with the substrate takes place to carry out reaction.
2) **Ping pong theory or Double displacement theory**:-In Bisubstrate reaction, substrate molecule alternately binds to an enzyme, releases the product and free enzyme. This mechanism is called as "Ping pong mechanism. EX: Transamination reaction.

In a reaction involving Glutamic acid and Oxalo acetic acid as substrate, the enzyme is transaminase, has Pyridoxyl phosphate as prosthetic group. In the first step Glutamic acid bind with the prosthetic of enzyme donates amino group and released as a product Alpha keto Glutaric acid. In the second step Oxalo acetic acid binds to the enzyme which has amino group bound to it from first substrate. Now substrate accepts amino group transferred from the first substrate and releases Aspartic acid as product.

Unit 6: Nitrogen metabolism 4 Hrs

1.What is Nitrification? Mention the Bacteria responsible for it. 1+1

Microbes which are responsible for conversion of unusable form of nitrogen to usable form by plants are called 'Nitrifiction'. Ex: Rhizobium, Nitrosomonas, Nitrococcus.

2.What are 'nif' genes? Mention their significance. 1+1

The Nitrogen fixing genes found close to Histone region of DNA are called**'Nif' genes.** They regulate the activity of Nitrogenase enzyme.

3.Differentiate between nitrification and denitrification. 1+1

Nitrification - Conversion of Ammonia into Nitrite and then into Nitrate by Nitrifying bacteria.
Denitrification- Breaking of Nitrates and Ammonium compounds into molecular Nitrifying bacyeria.

4.What are Symbiotic bacteria? Give an example. 1+1

Bactreia which live in association with other plants where both the partners are mutually benifited are called' Symbiotic Bacteria'. Ex: Rhizobium in roots of leguminous plants**.**

5 MARKS QUESTIONS

1.Describe the Nitrogen cycle. Cycle-2, explanation-3marks.

The cyclic movement of Nitrogen between organic and inorganic form to maintain its balance in nature is called" Nitrogen cycle".Nitrogen cycle involves fallowing steps :

1. Air is a reservoir for nitrogen. It is made avilablefor plants during lightning and rain fall by physical means and through soil microbes by biological nitrogen fixation.
2. Nitrates are utilized by green plants to synthesisenutrients .[proteins].
3. Animals feed on plants , Nutrients are passed to animals . These excrete nitrogenous wastes. These are converted into Nitrites by Ammonification.
4. Dead bodies of plants and Animals are decomposed into nitrogenous wastes.
5. Nitrites are converted into nitrates by nitrification.
6. Nitrates are converted into gaseous nitrogen by denitrification[bacteria pseudomonas denitrificans , Thiobacillus bring about Denitrification].
7. Gaseous Nitrogen is made available for plants throughnitrogen fixation by physical and biological methods.

Thus Nitrogen cycle goes on continuously in nature.

2.Describe Nodulation in Legumes. Definition-1, explanation-3+ fig-1.

. I Symbiotic Nitrogen fixation The process of conversion of atmospheric nitrogen to usable forms by Micro organisms when they are present in symbiotic association is called ymbiotic Nitrogen fixation.Ex : Nitrogen fixation by bacteria Rhizobium when present in Leguminous root nodules.

Mechanism of Nodule formation: Nodules are small ,knob like protruberances formed by species of Rhizobium . Bejernick isolated it first from Roots of leguminous plants . Prasmukifirst studied mechanism of nodule formation . It involves fallowing steps:-

1)Specific Leguminous root stimulate specific Rhizobium to develop symbiotic association.EX: Pea stimulates Rhizobium leguminosarum , Bean roots stimulates Rhizobium phaseolietc .

2)Rhizobium secrete growth harmone IAA which induce curling of root hair that help in attachment of Rhizobium to binding site of Root hair.

3)Rhizobium secretes Cystase enzyme which help in entry of Rhizobium into Root hair.

4)Root hair develops infection thread . It carries the bacteria ,grow across cortical cell , reaches innermost cortical cell releases rhizobium into il.

5)Rhizobial cell induce cortical cell to proliferate. Thus root nodules are formed. Rhizobium divide ,loose cell wall,become vacuolated ,bulged ,branched cells called bacteriods. These fix nitrogen as plant matures.

Mechanism of symbiotic Nitrogen fixation:symbiotic Nitrogen fixation Rhizobium in root nodules of leguminous plants requires fallowing factors:-

- **6 electrons** :-Ferrodoxin of Photosynthetic electron transport chain donates electrons.
- **6 Hydrogen atoms +12ATP** :- Pyruvic acid metabolism donates Hydrogen atoms and ATP molecules ,Respiratory metabolites also supply ATP.
- **Nitrogenaseenzyme** :-**'NIF'** gene of Rhizobium codes for it..

N+ 6e +6H +12 ATP---------Rhizobium----------2 NH+12ADP+ 12Pi

The process of symbiotic nitrogen fixation takes place as fallows :-

- Reduced Ferrodoxin donates electrons to oxidized Fe- protein complex ,then this complex become reduced.
- Reuduced Fe protein complex reacts with ATP and become ATP activated Fe- protein complex . It donates electrons to MO-Fe protein complex.
- Mo-Fe Protein complex receives electrons from ATP activated Fe- protein Complex and reduced. It transfer electrons to nitrogen.
- Nitrogen combines with hydrogen to form free Ammonia . It get converted into Amino acids in the root nodules . Amino acids diffuses into soil and become available for the plants.

In RhizobiumNitrogenase enzyme needs anaerobic condition to fix molecular Nitrogen .Leg haemoglobin in the root nodule absorbs oxygen and keeps Rhizobium in oxygen free state.
[Leghaemoglobin is a protein produced by symbiotic interaction of rhizobium and Legume Root].
Haeme component of protein is formed by Rhizobium globulin by legume root].

10 MARKS QUESTIONS

1.Give an account on Biological Nitrogen fixation. Fig-2, symbiotic- 6+non symbiotic 2

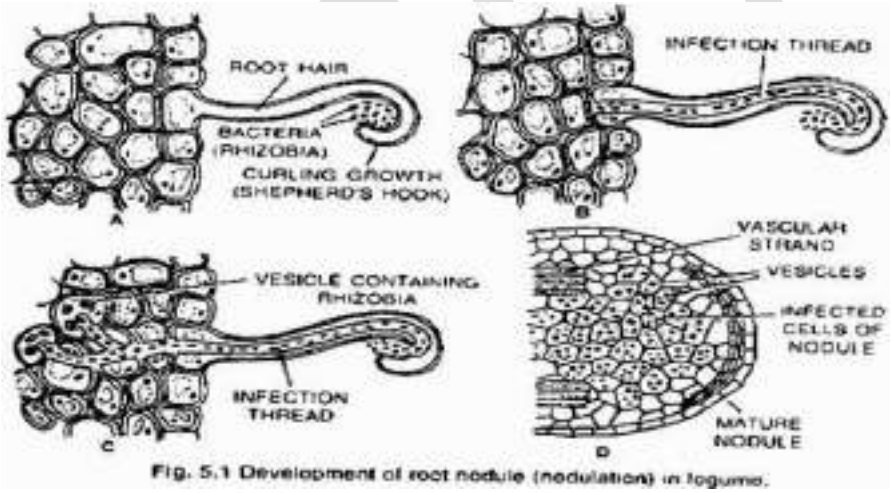


Fig. 5.1 Development of root nodule (nodulation) in legume.

The Process of conversion of atmospheric nitrogen into usable form by soil micro organisms is called Biological nitrogen fixation.It takes place by 3 methods as fallows**:- 1. Symbiotic Nitrogen fixation2. Non-symbiotic Nitrogen fixation.3.Associative Nitrogen fixation.**

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3)Mo-Fe Protein complex receives electrons from ATP activated Fe- protein Complex and reduced. It transfer electrons to nitrogen.

4)Nitrogen combines with hydrogen to form free Ammonia . It get converted into Amino acids in the root nodules . Amino acids diffuses into soil and become available for the plants.

In RhizobiumNitrogenase enzyme needs anaerobic condition to fix molecular Nitrogen .Leg haemoglobin in the root nodule absorbs oxygen and keeps Rhizobium in oxygen free state.[Leghaemoglobin is a protein produced by symbiotic interaction of rhizobium and Legume Root]. Haeme component of protein is formed by Rhizobium globulin by legume root].

II Non symbiotic Nitrogen fixation: The process of conversion of molecular Nitrogen of the atmosphere into free Ammonium ions by free living bacteria is known **as Non symbiotic nitrogen** fixation.EX; Azatobacter ,clostridium, Pseudomonas, Chlorobium , Rhodospirullumetc .

III Associative Nitrogen fixation:-The process of conversion of molecular nitrogen of the atmosphere into free Ammonium ionsby free living bacteria when present in intimate association with roots of higher plants is known as **" Associative Nitrogen fixation."**

It is an association between bacteria and roots of cereals , grasses without development of nodule like structure. In this type bacteria live in Rhizosphere[transition zone between soil & root] .the bacteria fix Nitrogen and supply to root, in return roots provide carbon di oxide , & carbohydrates to bacteria.
Ex: Beijerinckia ----Roots of Sugar cane ,
Azospirullum -------Roots of cereals
Azatobacterpaspali---------Roots of tropical grass.

Unit 7 Plant growth regulators 4 Hrs

1.Mention any two physiological effects of Gibberlins. 1+1

1)Break dormancy2) Elongation of internode3) Elongation of condensed intrnode toeffect flowering .It is called 'Bolting'.4) Induce Parthenocarpy 5) Activate cell-division and synthesise Enzyme.

2.What is Richmond Lang effect? Mention harmone responsible for it. 1+1

Delayed leaf Senescence (growing old) and other organs of plants are called "Richmand lang effect". It retards the aging process of plant parts keeping them productive longer. It retards chlorophyll degradation and mobilizing nutrients and has an effect on protein synthesis. Phytoharmone cytokinin is responsible for it.

3.Mention any four applications of ABA. 1+1

1)ABA inhibits the growth by retarding cell division and cell elongation.2) Inhibts seed germination. 3) Functions as stress harmone and induces closing of stomata during water stress.4) Induces development of Absission layer and results in abscission of leaves, flowers and fruits.5) Induces bud and seed dormancy.

4)Contribution of Kurusova and M.K. Chailakhyan. 1+1

Kurusova- In 1926 he discovered Gibberlins in paddy seedlings.**M.K Chalakyan-**

5 MARKS QUESTIONS

1.Gibberlins Role-3, applications-2 marks..

Gibberlins: - Gibberlins are growth promoting harmones produced in the meristematic regions of plants.Kurasova discovered it in paddy seedlings. Yabuta isolated it from fungus Gibberella fujikoroi.**Role:-**

1) Seed which do not sprout when soaked in water is called seed dormancy.gibberlins break seed dormancy and induce germination.
2) Gibberlins spray break genetical dwarfness and promote elongation of stem.

3) They bring about elongation of condensed internode to affect flowering. This is called 'Bolting.
4) Gibberlins induce parthenocarpy in Pome and stone fruits.
5) Gibberlins activate cell division in vascular cambium during secondary growth
6) Gibberlins synthesise enzyme Amylase in Aleurone layer of endosperm in cereals during germination.
Application of Gibberlins: - 1) Gibberlins enhance seed germination**. 2)** Expansion of leaf area in commercial crops**. 3)** Reversal of genetic dwarfism**.4) I**ncrease length of the peduncle between flowers resulting in less crowding and larger fruits due to available place.

2.Describe four physiological effects of Auxins. Four to six effects 1 mark each. Auxins are growth promoting phyto harmones.Role is:-

1. **Cell division and cell elongation: -** Auxins stimulate cell division in Vascular cambium and responsible fro secondary growth in dicots. High concentration of Auxin in shoot tips promotes cell division, in root tip it inhibits cell division**.**
2. **Apical dominance:** The phenomenon of inhibition of growth of lateral buds by apical buds in plant sis called 'Apical dominance'**.**
3. **Root formation:-** Low concentration of Auxins induce root formation . High concentration of Auxins inhibits Root growth**.**
4. **Parthenocarpy:-** Spraying of Auxins on flowers induces Parthenocarpic fruits.
5. **Xylem differentiation; -** Auxins induce differentiation of xylem elements**.**
6. **Prevention of Abscisson layer: -** Auxins prevent formation of Abscission payer causing premature shedding of leaves, flowers and fruits.
7. It induces synthesis of m-RNA fro specific enzyme invoved in cell wall enlargement. Stimulates respiration**.**

   Applications: - 1) Seeds are soaked in auxin solution to reduce dormancy and induce quick seed germination**.2)** In Horticulture Auxins are used to used to induce root formation in stem cuttings**.3)** Auxins are used to development of parthenocarpic fruits**.4)** Prevents premature fruit fall, to induce vascular differentiation in callus, synthetic auxin 2, 4 D (2, 4 dichlorophenoxy acetic acid). It is a selective weed killer.

10 MARKS QUESTIONS

1.Explain the role and applications of Cytokinin and Gibberlins. Any 4 Role -2 marks+ any 4 Applications-2 marks each for auxin and Gibberlins.

Cytokinins are plant growth substancesthat promote cell division in plant root and shoot they are involved in cell growth and differentiation, but also affect apical dominance, axillary bud growth, and leaf senescence. Folke skoog discovered their effects using coconut milk in1940.

There are 2 ytpes of cytokinins; -1) Adenine type cytokinins represented by **Kinetin, Zeatin and 6-Benzyl amino purine and 2) Phenyl urea type** cytokiins like **Diphenylurea and Thidiazuron (TDZ).**
Physiological effects of Cytokinins:-

1. Cytokinin induces cell division in both meristematic and non meristematic tissues in plants.

2. These induce cell enlargement in leaves and cotyledons.Ex: Pumpkin cotyledon, leaves of Phaseolus vulgaris.
3. These induce interfascucular cambiumfrom permanent tissues during secondary growth.
4. It cause morphogenetic changes in undifferentiated callus.The Tobacco pithcallus can be mde to develop into buds or roots by changing concentration of Kinetin
5. They break dormancy and induce seed germination.
6. They promote lateral bud formation in dicots.
7. Aeging of leaves due to loss of chlorophyll and break down of proteins called "Scencescence".
8. Cytokinins application retard break down of chlorophyll in leaves and delay scenescence. This is called "**Richmond lang effect".**

Gibberlins: - Gibberlins are growth promoting harmones produced in the meristematic regions of plants.Kurasova discovered it in paddy seedlings. Yabuta isolated it from fungus Gibberella fujikoroi.

Role of Gibberlins :-

1) Seed which do not sprout when soaked in water is called seed dormancy.gibberlins break seed dormancy and induce germination. 2) Gibberlins spray break genetical dwarfness and promote elongation of stem. 3) They bring about elongation of condensed internode to affect flowering. This is called 'Bolting.

4) Gibberlins induce parthenocarpy in Pome and stone fruits.

5) Gibberlins activate cell division in vascular cambium during secondary growth

6) Gibberlins synthesise enzyme Amylase in Aleurone layer of endosperm in cereals during germination.

Application of Gibberlins: - 1) Gibberlins enhance seed germination**. 2)** Expansion of leaf area in commercial crops**. 3)** Reversal of genetic dwarfism**.4) I**ncrease length of the peduncle between flowers resulting in less crowding and larger fruits due to available place.

2.Give an account of physiological role and applications of Auxin .5+5

Auxins are growth promoting phyto harmones.Role is:-

1. **Cell division and cell elongation: -** Auxins stimulate cell division in Vascular cambium and responsible fro secondary growth in dicots. High concentration of Auxin in shoot tips promotes cell division, in root tip it inhibits cell division**.**
2. **Apical dominance:** The phenomenon of inhibition of growth of lateral buds by apical buds in plant sis called 'Apical dominance'**.**
3. **Root formation:-** Low concentration of Auxins induce root formation . High concentration of Auxins inhibits Root growth**.**
4. **Parthenocarpy:-** Spraying of Auxins on flowers induces Parthenocarpic fruits.
5. **Xylem differentiation; -** Auxins induce differentiation of xylem elements**.**
6. **Prevention of Abscisson layer: -** Auxins prevent formation of Abscission payer causing premature shedding of leaves, flowers and fruits.
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Applications: - 1) Seeds are soaked in auxin solution to reduce dormancy and induce quick seed germination**.2)** In Horticulture Auxins are used to used to induce root formation in stem cuttings**.3)** Auxins

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8. Cytokinins application retard break down of chlorophyll in leaves and delay

3. <u>Explain the role of Auxin and Gibberlins in Agriculture and Horticulture.</u>
Any 4 Role -2 marks+ any 4 Applications-2 marks each for auxin and Gibberlins.
Auxins are growth promoting phyto harmones.Role is:-

1) Cell division and cell elongation: - Auxins stimulate cell division in Vascular cambium and responsible fro secondary growth in dicots. High concentration of Auxin in shoot tips promotes cell division, in root tip it inhibits cell division**.**
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Unit 8: Plant response to light and temperature 4 Hrs

1.What is Vernalisation? Mention its significance. 1+1

Low temperature treatment of flowers to induce earlyflowering is called **"Vernalisation". Significance: -** 1) It shortens vegetative period of plant.2) Crops can be produced earlier.3) It increases cold resistance of plants and to fungal diseases.4) crops can be cultivated in places where they do not grow and Plant breeding can be accelerated.

2. What is phytochrome? Mention any two importance of it. 1+ ½ each

The proteinaceous pigment that inhibits flowering in short day plants on exposure to Red light and stimulates flowering in Long day plants by interruption in dark period is called "Phytochrome".

Importance: - Photoinduction and deinduction in different wave length, Flowering initiation, Inhibition of flowering.

5 MARKS QUESTIONS

1.Give an account of Photoperiodism. Definition-1, explain-7

Response of plants to relative length of day and night to flower is called 'Photoperiodism'.It was discovered by Garner and Allared in soya bean and Nicotiana.Based on the Photoperiodic responses, plants are classified into 3 groups. They are **1) Short day plants**:-The plants which require short period of light (8 to 10 hrs) and continous dark period for flowering are called 'Short day plants'. Ex: Aster, Dhalia, Chrysanthimum. A) In Short day plants prolongation of dark period initiates early flowering and dark period is critical. B) If dark period is interrupted with brief exposure of Red light, plants will not flower. C) Inhibotory effect of Red light can be overcome by exposure to far red light.**2) Long day plants:-** The plants which require long period of light for flowering are called 'Long day plants'.Ex: Spinach, Radish, Wheat. A) In long day plants light period is critical B)Brief exposure in dark or prolongation of light period stimulates flowering.**3)Day neutral plants**:- The plants in which Photoperiodism has no influence on flowering are called Day neutral palnts.Ex: Tomato,Cotton, Cucumber, Maize.

Photoperiodic induction: Initiation of flowering in a plant after exposure to light for required period is called 'Photoperiodic induction'.1) Photoperiod of 24 hrs cycle constitutes one inductive cycle.2) An increase in number of inductive cycles results early flowering.Ex: Xanthium.3) Continuos Inductive cycles promote floering.4) Floral harmone 'Florigen' is produced inleaves and then it is translocated through stimulus through living tissues to apical tips of plants resulting in flowering.

2.Describe Phytochrome

The proteinaceous pigment that inhibits flowering in short day plants on exposure to Red light and stimulates flowering in Long day plants by interruption in dark period is called "Phytochrome".
1) Phytochrome exists in 2 froms a) Red light absorbing form'Pr'.b) Far red light absorbing form 'Pfr'.
2) These 2 forms are photochemicaly interconvertible. 3) When 'Pr' form of pigment absorb Red light, It is converted into 'Pr' form. 4) When 'Pfr' form of pigment absorbs Far Red light, it is converted into 'PR' form.

During day PFR form of pigment accumulated in the plant inhibits flowering in short day palnts. During critical dark period it gradually changes to PR and induce flowering. A brief exposure with Red light will convert this form again into PFR and inhibits flowering.

3.Write note on Vernalisation. Definition- 1+ explanation-3+ Application-1

Low temperature treatment of flowers to induce early flowering is called **"Vernalisation".**

Based on the response to cold temperature stimulus plants can be classified into 2 types. They are **a) Inductive type—**Plants which are vernalised**. B) Non inductive type—**Plants which are not vernalised.
Site of Vernalisation: -1) Meristems are sites of stimulus reception and transmission. **2)** Grafting of vernalised tip of plant to non Vernalised plant initiates flowering due to transmission of substance called "Vernalin". **3)** In Annuals vernalisation is effective at seed stage, in Binneals and Perennials stimulates at meristem of shoot
.**Mechanism of Vernalisation**: - In a plant effect of low temperature treatment is lost, if it is immediately subjected to high temperature**.**It is believed that low temperature synthesise flower initiating substance which is degraded under high temperature. When high temperature treatment is not given after low temperature treatment, the flowering initiating substance is converted into stable product "Vernalin" and initiates flowering**.**
Two theories have been proposed to explain Vernalisation. They are 1) Phasic development theory by Lysenko. In this Thermophase depends on temperature and Photophase depends specific length of light and dark periods.2) Vernalin concept is proposed Melcher. In this chilling treatment induces the formation of newfloral harmone called 'Vernalin' which causes flowering.**Significance: -** 1) It shortens vegetative period of plant.2) Crops can be produced earlier.3) It increases cold resistance of plants and to fungal diseases.4) crops can be cultivated in places where they do not grow and Plant breeding can be accelerated.

Unit 9: Dormancy :1Hr

1.Mention any four methods of breaking dormancy. 1+1

1)Scarification 2) Impaction 3) Stratification 4) Chilling treatment 5) Light treatment 6) Pressure treatment.

2)What is seed dormancy? Mention its types. 1+1

Suspension of active growth temporarily in any phase of the life cycle of the plant is called **'Dormancy'.Types: 1) based on organs in which it occurs** a) Bud dormancy b) seed dormancy.
3) **Based on conditions a)** Imposed (Due to environmental factors) b) Innate (Due to internal factors like genetic).

5 MARKS QUESTIONS

1.Write a note on: a) causes of Dormancy 4 marks

Hard tough seed coat, seed coat impermeable to water and oxygen, immature embryo, presence of phenolic compounds and chemical compounds,sensiivity to light etc.

10 MARKS QUESTIONS

1.Explain Seed dormancy. Definition, types-1, 3 causes -3 marks, methods to break-3

Suspension of active growth temporarily in any phase of the life cycle of the plant is called as "Seed dormancy". It may vary from few months to few years. Breaking of dormancy depends on its cause and particular plant species. Some of them are as follows;

1) Scarification: - Softening of the seed coat is called 'Scarification'.It is naturally brought about about naturally by soil microbes or mechanically by thrashing or chemically by strong mineral acids.
2) Impaction:- In some plants opening in the seed coat is blocked by cork like filling which prevents entry of oxygen and water.
3**) Stratification**:-exposure of seed to moist at low temperature (5 to 10 degree C) for sufficient period of time to break dormancy in chilling requirement seeds is called "Stratification".
4) Stimulating compounds:- Phytoharmones like Kinetin and Gibberlins break dormancy and induce germination
.**5) light treatment**:- exposure of seeds to light promotes germination in positive photoblastic seeds, it can be broken by exposing them to Red light or white light.
6) Alternating temperature;- exposure of seed to an alternation of low and temperature between 10 to 20 degree Celsius improve germination.

2.Explain the methods of breaking seed dormancy. Any 5 methods 1 mark each.

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Unit 10: Plant movements: 2 Hrs

1.Differentiate between Phototactic and chemotactic movements. 1+1

Phototactic movement- Light induced movement of locomotion. Chemotactic:- Mvent of locomotion by influence of chemicals.

5 MARKS QUESTIONS

1.Explain Seismonastic movement. Definition- 1+Fig, explanation-4

Sleeping movement of plant organ due stimuls is called Nastic movement. Nastic movement response to external stimulus of Touch is called "Seismonastic movement". If terminal leaf let is touched, stimulus travels down in the form of harmone through Xylem to pulvinule, leaf lets close in pairs, then it passes to other pinna and finally reaches Pulvinus base resulting in drooping of whole leaf. After few minutes it recovers from shock and come back to normal position.

2.Give a brief account of Phototropism. Phototropism definition- ½ , fig, explanation-- 3 ½

Bending movement of the plant organ due to unilateral application of stimulus is called "Tropism". Phototrpism: - - Bending movement of the plant organ due to unilateral application of stimulus of light is called **"Phototropism".** Unequal distribution of Auxin at the stem tip due to unilateral stimulus of light cause bending movement towards light.

If the plant organ bends away from stimulus of light, it is called **"Negative Phototropism.** If the plant organ bends towards stimulus of Light, it is called" **Pasitive Geotropism**".This can be experimentally proved as follows:-

Phototropic chamber is a light proof wooden box with a small window on one side wall to allow light rays inside.Keep the seedling pot inside the phototropic chamber. Allow the set up for some time. After few days stem tip grows towards the window ie,. Stimulus of light and proves that stem tip is positively phototropic.

3.What is Tropism? Explain Geotropism and Phototropism.
Definition-1, Geotropism fig, explanation-3 ½, phototropism fig, explanation-- 3 ½

Bending movement of the plant organ due to unilateral application of stimulus is called "Tropism". Georopism: - Bending movement of the plant organ due to unilateral application of Gravitational stimulus is called **"Geotropism".** If the plant organ bend towards stimulus of gravity is called**" Pasistive Geotropism**". If the plant organ bend away from stimulus of gravity is called **"Negative Geotopism".**

Generally roots are positively geotropic and stem is negatively geotropic.If the plant organ is exposed to diffuse application of gravitational stimulus, it never shows any type of movement**.**This can be explained

with the help of an instrument called “Clinostat”. It consists of clock with an axis in which metallic pot with sapling is fixed.

When the clock is not working, stem tip bends towards light and grow away from stimulus of gravity. This proves bending movement of stem away from light ie,. Negative geotropism.

When the clock is in working condition, the pot along withseedling rotates one round per hour. During the rotation stem tip receives equal stimulus of gravity and stem tip instead of bending upwards grows horizontally.

Phototrpism: - - Bending movement of the plant organ due to unilateral application of stimulus of light is called **“Phototropism”.** Unequal distribution of Auxin at the stem tip due to unilateral stimulus of light cause bending movement towards light.

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V Semester- Paper –VII Plant Physiology and Metabolism

Unit 1: Plant-water relations(6 Hrs)

Importance of water, water potential and its components; A brief account of absorption of water [active and passive] and Ascent of sap[transpiration pull theory] .

Transpiration: Structure of stomata, Stomatal mechanism (Steward and K- ion theory) Factors affecting transpiration; Anti-transpirants .

Importance of water, water potential and its components; A brief account of absorption of water [active and passive] and Ascent of sap [transpiration pull theory] .

Importance of water

Water is essential for plant growth and development in enormous amounts. Water constitutes more than 70% of the fresh weight of a plant .Water supply affects the growth rate of plants considerably.

(i) **water** is a major component of the plant body.

(ii) Water is an essential solvent in which mineral nutrients absorbed through water are dissolved and translocated from the roots to the apex of the plant body.

(iii) Large number of metabolic reactions takes place in the water medium.

(iv) It maintains the structure of nucleic acids, proteins by supplying hydrogen bonding.

(v) Processes like photosynthesis use water as a reactant of raw material. Thus formation of complex carbohydrates.

(vi) Water is an essential component required to maintain the turgidity of the cell. It helps the cells to retain their tensile strength and provides proper shape to the cells. Turgidity is essential for the opening of the stomata, and also activity of several organelles.

(vii) Water also acts as a temperature buffer since it has an exceptionally high heat capacity for specific heat.

(viii) Water molecules have the unique property of adhesion and cohesion and thus these processes keep the water molecules together. This property helps in upward movement of water in the plant body.

(ix) The elongation phase of cell growth is mostly dependent on water absorption.

(x) Water is also a metabolic end product of respiration.

(xi) Plants absorb enormous quantities of water and simultaneously lose greater amounts of water through transpiration.

Imbibition

Adsorption of water by Hydrophyllic colloids present on the surface of the imbibant(Substance which imbibe water) is called '**Inbibition'.**Ex: Adsorption of water by seed coat, when seeds are soaked in water, Warping of wood during rainy season, Swelling of Rubber when soaked in Ether.

Imbibitional pressure:- Pressure excerted by the imbibant during imbibitions is called 'Imbibitional pressure'.Now the term is replaced by Matric potential. The magnitude of Matric potential is tremendous.Ex: If a roch with wood piece inserted in crack is soaked in water, wood adsorb water and rock splits.

Significance of Imbibition:-1)Imbibition is involved in adsorption of water from soil by root hair cell wall. 2) It is essential for dry seeds before germination.

Diffusion

Molecules of liquid or Gases or Solid have tendency to distribute evenly throughout the available space. These have Kinetic energy inherent in them. When they colloid with one another, they get deflected in direction where chances of collision are less.

The process of movement of particles of solid, liquid or gases from region of higher concentration to their region of lower concentration utilising kinetic energy is called' Diffusion'. Ex:- 1) **Diffusion of solid into liquid**:-Movement of molecules of **$CuSO_4$ or $KMno_4$ crystals into water** in a beaker.2) **Diffusion of liquid into liquid:-** movements of particles of **ink into water** in a beaker.3) **Diffusion of Gases:-**Diffusion of molecules of **perfume or Ammonia or H_2S when bottle** is opened**.**

Diffusion Pressure:- The **pressure exerted by the kinetic activity** of the **diffusing particles to migrate is called 'Diffusion Pressure'.** It is directly proportional to the concentration of the diffusing particles.**Ex**: The gas filled baloon has high Diffusion Pressure than the air which surrounds it. When ballon is damaged, confined gas molecules with high diffusion pressure will diffuse into its surrounding air.

Significance:- 1) Diffusion is essential in the exchange of gases during Respiration and Photosynthesis.

2) It is responsible for stomatal transpiration.

3) It helps in passive uptake of ions during absorption.

4) It helps an important role in transpiration of water, minerals and food materials over short distances.

Osmosis

Osmosis is a special type of Diffusion discovered by Nollet(1742) . Diffusion of water from the region of its higher water potential to the region of its lower water potential through the semi permeable membrane is known as 'Osmosis'.

Membranes of Plant cells:-

Membranes are thin sheet like structures with the property of permeability. On this basis 4 kinds of membranes are recognised. They are as follows:-

1. **Permeable membrane**:- The membrane which allows both solvent and solute molecules of a solution to pass through it is called '**Permeable membrane'.Ex:** Cellulosic cellwall, Filter paper
2. **Semi- Permeable membrane:-** The membrane which allows only solvent but not solute molecules of a solution to pass through it is called ' **Semi Permeable membrane'.Ex:** Egg membrane, Sheep bladder, Parchment paper,.
3. **Selectively Permeable membrane:- T**he membrane which allows certain molecules of solute along with solvent molecules to pass through it is called '**Selectively Permeable membrane'.Ex:** Plasma membrane, Tonoplast.
4. **ImPermeable membrane:-** The membrane which a do not allow solvent and solute molecules of a solution to pass through it is called '**ImPermeable membrane'. Ex:** Cuticle,Suberised cell wall, Plastic sheet, Rubber sheet.

Solutions

Solution is a homogenous, stable mixture of solute and solvent. There are 3 types of solutions with respect to the cell sap and concentration of external solution. They are:-

1. **Hypertonic solution**:- The external solution where concentration is more than the concentration of cell sap is called '**Hypertonic solution'**.
2. **Hyportonic solution**:- The external solution where concentration is less than the concentration of cell sap is called '**Hypotonic solution'**.
3. **Isotonic solution**:- The external solution where concentration is equal to the concentration of cell sap is called '**Isotonic solution'**.

Endosmosis: - Diffusion of water into the cell through plasma membrane is called '**Endosmosis:'.** It takes place when the plant cell is placed in Hypotonic solution. Due to endosmosis, the cell become **Turgid**. Ex: Increase in size of dry grapes when placed in water.

Exosmosis:- Diffusion of water out of the cell through plasma membrane is called '**Endosmosis:'.** It takes place when the plant cell is placed in Hypertonic solution. Due to endosmosis, the cell become **Flaccid.** Ex: shrinkage of fresh grapes when placed in Concentrated sugar solution.

Plasmolysis

Shrinkage of Protoplast due to **Exosmosis**, when cell is present in **hypertonic solution** is called **'Plasmolysis'**. The cell or tissue in this condition is called **Plasmolysed,** cell becomes **flaccid**.

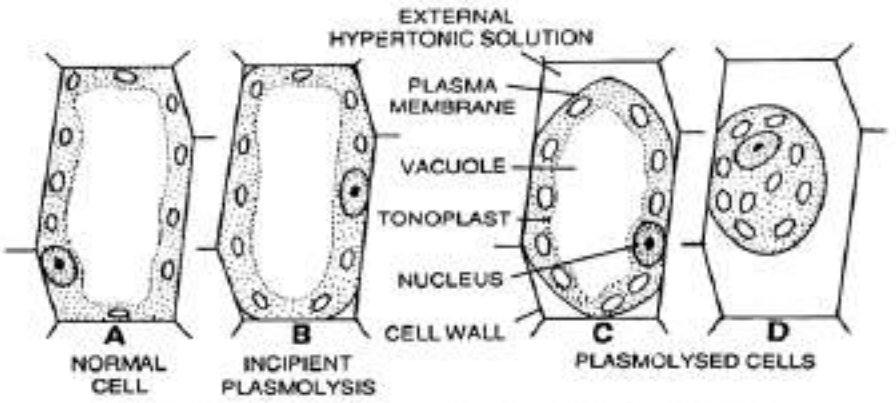


Fig. 2.9. Plasmolysis. Stages in plasmolysis of a plant cell.

In normal cell protoplasm is tightly pressed against cell wall. When plant cell is placed in hypertonic solution, due to exosmosis protoplasm begins to contract from the cell wall. This is called as "Incipient **plasmolysis**". When external solution is very much concentrated than cell sap, exosmosis continues, protoplasm seperates from the cell wall to from a spherical mass at the centre of the cell. This is called as **Plasmolysis. (Evident plasomysis**). **Significance**: - Plasmolysis prevents the growth of moulds& bacteria in preserved food stuffs like pickles, jams.

Deplasmolysis:- Regaining of the normal condition of plasmolysed cell or Tissue due to endosmosis is called **'Endosmosis'**.

When plasmolysed cell or Tissue is placed in water, **due to endosmosis, the protoplasm assumes normal shape and position.** The cell become **Turgid.**

Significance of Osmosis

1. Osmosis helps in Absorption of water from soil solution by root hair
2. It helps in movement of water between cells in the plant body

3. It helps to maintain shape, size posture, stature due to turgidity.
4. It controls Seismonastic movement in mimosa pudica **.**
5. Turgor pressure is responsible for Stomatal movement **.**
6. Turgor pressure is responsible Dehiscence of Sporangia & bursting of fruit.
7. Increase in Osmotic pressure increases resistance of plants to drought , frost **.**
8. Turgid cells of root tip easily penetrate in soil particles.
9. Plasmolysis prevents the growth of moulds& bacteria in preserved food stuffs like pickles, jams.

Osmotic pressure Turgor pressure , Wall pressure

1. **Osmotic pressure(OP):-** The pressure developed in the **solution due to dissolved solute in it,** when it is **separated from the solvent by a semi-permeable membrane is called 'Osmotic pressure'**. It is measured in terms of atmosphere**.**

   Osmotic pressure' is directly proportional to the concentration of dissolved solutes in the solution. Higher the concentration of solution, higher the Osmotic pressure' and lower the concentration of solution lower will be the Osmotic pressure'. Op will not increase by addition of insoluble solutes**.**
2. **Turgor pressure (TP): The** Pressure built up by cytoplasmic membrane when cell is placed in water or hypotonic solution is called '**Turgor pressure'.**

   When living cell or tissue is placed in water or Hypotonic solution, water enters into the cell sap due to Endosmosis. Increase in size, develops a pressure, which presses the protoplasm aganist the cell wall. This is called **Turgor pressure**
3. **Wall Pressure (WP):-** Equal amount of pressure in opposite direction exerted by cell wall on the plasma membrane. **Wall pressure.**

   In a Turgid cell as Turgor pressure increases, plasma membrane exerts pressure on the cell wall. The cell wall being rigid and elastic exerts an equal and opposite pressure called **'Wall Pressure'.**

   Turgidity: - At a given time, when Turgor pressure is equal to wall pressure, entry of water into the cell stop. This status of cell is called **'Turgidity'.**

   Flaccid:- When living plant cell or tissue is placed in Hypertonic solution , water comes out of the cell sap due to exosmosis, protoplasm shrinks and the cell becomes' **Flaccid'.**

Water Potential and its components

Water Potential Definition:-

Water potential is the potential energy of water in a system compared to pure water. It is measured in kilopascals (kPa) and is represented by the Greek letter Psi (Ψ). Water potential is never positive but has a maximum value of zero, which is that of pure water at atmospheric pressure.

When it comes to impure water, or water that has solutes in it, the more solute there is, the more negative Ψ becomes, since the solute molecules will attract the water molecules and restrict their freedom to move.

Movement of Water Molecules

Water moves from areas of where water potential is higher (or less negative), to areas where it is lower (or more negative), and we refer to this movement as *osmosis.* water will move from inside of the cell, where Ψ is higher, to outside of the cell, where Ψ is lower. This can lead to the death of cells in living organisms. On the other hand, a cell that is placed in a pure water solution could take up water until it bursts and dies. Therefore, cells need an environment that does not differ significantly in its solute concentrations.
In a plant water potential is sum total of 3 components .namely matric, solute and pressure potential.

a) **Matric potential (**Ψ_m**)** : matric potential is defined as the amount by which water potential of the cell sap is reduced due to adsorption of water molecules by hydrophilic colloids of protoplasm . It is not significant as it does not allow free movement of water molecules.
(Matric potential is the forces between water molecules and surfaces or substances, such as soil or cell membranes. The matric potential is always negative and is more significant in dry systems, such as soils, because we find that the water particles are strongly attached to the soil particles.)

b) **Solute potential (** Ψ_s**)**: Solute potential is defined as the amount by which water potential of cell sap is reduced due to solute particles present in it. It represents negative numbers.
(Solute potential depends on the amount of solute in a solution, and it decreases as the Concentration of solute increases.)

c) **Pressure potential (Ψp):** Pressure potential is defined as the amount by which water potential of the cell sap is reduced due to wall pressure (Pressure exerted by cell wall on cell contents) and Turgor pressure (equal pressure exerted by cell membrane on cell wall). It represents positive sign.
(The pressure potential refers to the physical pressure exerted by objects or cell membranes on water molecules, and it increases with increasing pressure. Note that pressure potential is usually maintained at a positive in plant cells in order for them to hold their shape, allowing the plant to stay rigid.)

d) Gravitational potential (Ψ_g): gravitational potential is the way earth's gravity influences the freedom of water molecules to move.

$\Psi = \Psi_s + \Psi_p + \Psi s + \Psi_m$
$\Psi = \Psi_s + \Psi_p$
Where, Ψ_s stands for solute potential, Ψp for pressure potential, and Ψ_m for the matric potential.

A Brief account of Absorption of Water by Roots

Water Absorption: Organ, Mechanism: - Absorption of water and nutrient is carried by the younger portions of a root, near its tip. The very tip is covered with a sheathing root cap which protects the delicate underlying tissues as the root pushes its way through the soil**.**

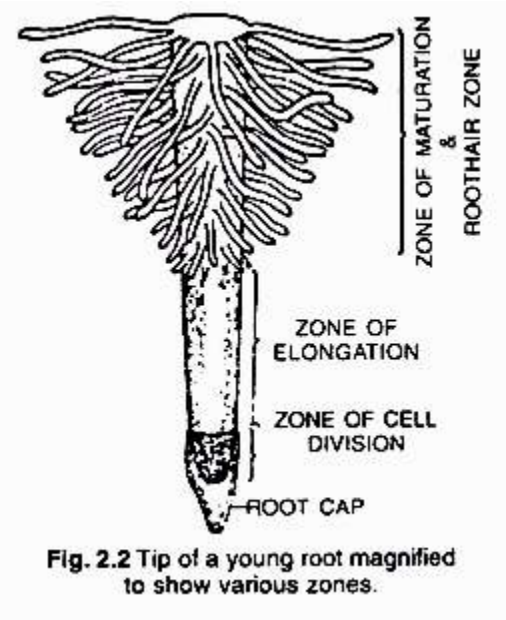


Fig. 2.2 Tip of a young root magnified to show various zones.

Besides root cap, three more zones can be recognized in the young root tip.**These zones are:**

- **Zone of cell division or meristematic zone:** The thin-walled cells of this region are alike and constantly divide, results in increases in length of root.
- **The zone of elongation:** The cells formed in the meristematic region become longer in the region of elongation.
- **The zone of maturation & Root Hair Zone:** In this region some cells take on structural features which enable them to conduct water. Others become specialized for the conduction of food, and still others for food storage.

Root hairs develop in the younger part of the maturation zone .Plants absorb capillary water from the soil through Root hair. Cell wall of root hair is composed of hydrophillic cellulose and pectin. . internal to it is plasma membrane. It encloses large central vacuole filled with cell sap and thin layer of cytoplasm and Nucleus.

When root hair has a high osmotic pressure and is exposed to the surrounding soil water in the soil, the cells and xylem vessel have lower pressures. Water will pass from root hair to xylem by diffusion from the soil to the roots following the same osmotic relations. Thus, the root hair will take up water from the surrounding medium as water move by diffusion from regions of higher water potential to regions of lower water potential.

The force with which water will be drawn from the soil will depend entirely upon the difference between the osmotic pressure external and the osmotic pressure of the xylem vessels. The greater the difference, the greater will be the force with which water is drawn into the vessels through the cortical cells.

Generally the osmotic pressure of the cell sap of the xylem can reach a value as low as the osmotic pressure of the surrounding soil solutions. vessels form a continuous pipe line from the roots to the leaves. Once water from the soil reaches the main transpiration current in the xylem vessels, water is taken upwards to the leaves for utilisation and excess water escapes through stomata.As a result there generally is a higher osmotic pressure in the sap of the xylem vessels than the water outside the root hair in the soil.

The osmotic pressure of the root hair cells generally varies from 3 to 5 atmospheres. Whenever water potential of such soil exceeds that of young root cells and root hairs, water will move from soil into the root. This mechanism of absorption of water is referred to as **passive absorption** because the entry of water into the roots is brought about by conditions which originate in the top of the plant and the root cells apparently play a passive role.The water can be absorbed by root cells by forces which develop there and are often called **active absorption**. This active absorption takes place in plants when transpiration rate is relatively low and the soil contains water in abundance.

This active absorption of water can only be in very small amounts since water would tend to leak out so rapidly by diffusion that enormous amount of respiratory energy would be required to maintain the gradient.

Mechanism of Water Absorption:

Entry of water from soil into Xylem of Root:-

Soil enters the root by Osmosis. Movement of water across the cortex into xylem takes place by 2 path ways. They are **Apoplast and Symplast path way.**

1. **Apoplast path way:-**In Apoplast type cell wall of cortical cells imbibe water and **through intercellular spaces it passes due to capillary action and diffusion.**
2. **Symplast path way:-**In Symplast type water passes **through Plasmodesmata and net work of cytoplasm of cortical cells , then through passage cells and pericyle reach xylem.**

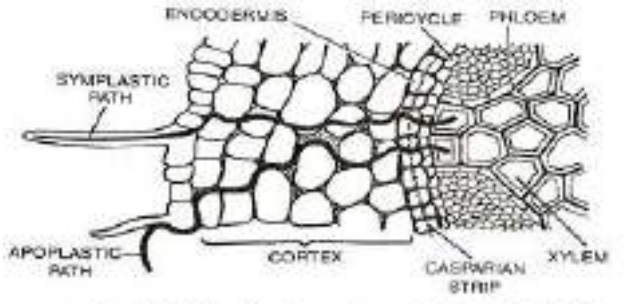
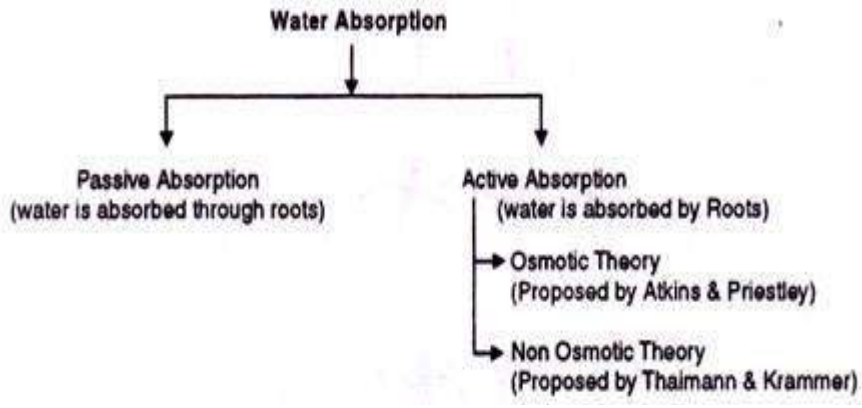


Fig. 11.21. Apoplastic and symplastic pathways of water and ions transport across the root.

The actual absorption of water when a root hair is in contact with a number of cortical cells of the root and xylem vessel, water will enter the root hair, pass from there into the cortical cells and finally into the xylem if there be a gradient of water potential from the root hairs to the xylem vessels.

It is the gradient of water potential from the root hair to the xylem vessels that is essential for the absorption of water by the roots.

The mechanism of water absorption can be explained by two approaches.



1. <u>Passive absorption:</u>

Root does not play active role. Force responsible for absorption develops due to transpiration. No expenditure of energy for absorption, process.

1. As the leaf cells lose water in transpiration, they develop water deficit (turgor deficit, D.P.D. or Suction force)

2. Their water potential becomes lower and they draw water from the xylem of the veins.

3. This causes the xylem of the veins to develop the S.F. as well as low water potential.

4. Therefore, veins draw water from the petiole, the petiole from the stem, and the stem from the root, and hence water from the soil automatically enters the roots through the root hairs.

5. Thus, the suction force responsible for the absorption of water by the root actually originates

6. The root system merely acts as a physical absorbing system.

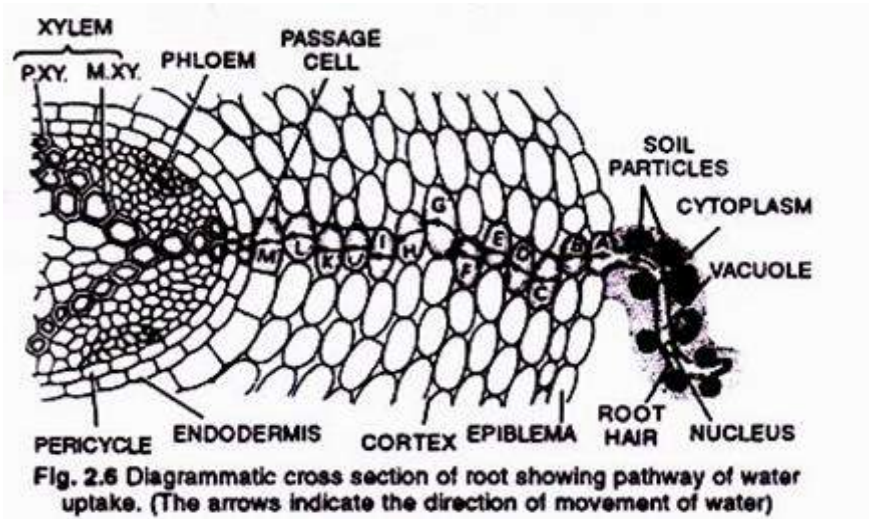


Fig. 2.6 Diagrammatic cross section of root showing pathway of water uptake. (The arrows indicate the direction of movement of water)

2. Active Absorption:

Water is absorbed as a result of activity of root and does not concern with any role of shoot Two theories have been put forward to explain the actual mechanism of active absorption.

(a**) Osmotic theory and (b) Non osmotic theory**

(a) Osmotic theory:

Osmotic theory is Proposed by Atkins and Priestley. Water is absorbed due to osmotic difference between soil water and that of tonoplasm. D.P.D. of root hair is increased due to high O.P and low TP of root water is absorbed by endosmosis TP of root hair increase and D.P.D. decreases water moves from root hair to inner cells and finally reaches into the xylem.

(b) Non Osmotic theory:

Non osmotic theory is Proposed by Thimann and Kramer. Water absorption is an active process occurs due to non osmotic reason against the DPD. Process require energy (ATP) comes from respiration.

1. Operate in very slowly transpiring plants.

2. Occurs against the D.P.D. gradient and requires the expenditure of energy released from respiration.

3. There may be some carrier substances in the wall of root cells, which bind with water and carry, it to the inner tissue, (certain bacteria in higher plants).

4. Auxin increases rate of the transpiration as well as water absorption.

Root pressure, guttation and bleeding are the manifestation of active water absorption. The available evidence indicates that passive absorption accounts for most of the water absorbed by plants. Active absorption is important only in slowly transpiring plants growing in soil near field capacity.

Ascent of Sap and (Translocation of water)

Upward movement of water from Root system to the Shoot system is called 'Ascent of sap'. Xylem is the path of Ascent of sap.

Mechanism of Ascent of sap

A) Vital Theory:-

According to Vital theory **Ascent of sap is due to Vital activities in the living cells of Xylem of stem. It includes 2 theories Relay pump theory and Pulsatory theory.**

1. **Relay pump theory** :- Relay pump theory was proposed by Godlewski (1884). According to him water rises upward in xylem in stepwise manner due to **rhythmic change of osmotic pressure in vessels, parenchyma and medullary rays**.
   When osmotic pressure of living parenchyma is high, they draw water from lower vessel and osmotic pressure becomes low. Due to low osmotic pressure water from parenchyma is pumped into above vessel. This process is repeated, Thus water rises up.
   Objection: This theory was disproved by Straburger(1893) and confirmed by Overton(1911), Dougal(1929). They showed that ascent of sap continued even aftr killing living cells by high temperature treatment or Poison uptake.
2. **Pulsatory theory:-**This theory was proposed b J.C.Bose(1923). According to him Ascent of sap is due **to Pulsatory activity** of living cells of innermost cortical cells, just outside endodermis. To explain **Pulsatory activity** he invented **'Cresograph'.**
   'Cresograph' consists of an electric probe connected to galvanometer. When needle of the electric probe was inserted into stem slowly, needle of the Galvanometer showed slow oscillations. When it reached inner cortical layer, it showed violent oscillations**.**
   According to him, when cells absorb water they expand, after pushing water to xylem, they contract. This pulsatory activity helps in Ascent of sap.
   - **Objections:-**Shull, Mac Dougal showed that there is no relationship between Pulsatory activity and Rate of Translocation of water.
   - Strasburger showed that the Ascent of Sap continued even aftr killing of living parenchyma cells by Picric acid.

   B). Root pressure theory

   Stephen hales coined the term 'Root pressure'. The **Hydrostatic pressure built up by water in the outer boundary of the stele due to continuous absorption** is called **'Root pressure'. It is responsible for Ascent of sap.**

   Demerits: -
   - **Magnitude of** Root pressure is 3 atmosphere. It does not account for Ascent of sap. In tall trees which require 12 atmosphere.
   - Root pressure is not observed in all plants.
   - Ascent of sap is observed in absence of Root pressure.

- During summer when rate of transpiration is rapid, Root pressure is low. During spring when rate of transpiration is slow root pressure is high. Thus there is no relationship between Root pressure and Ascent of sap**.**

C).Physical force theory

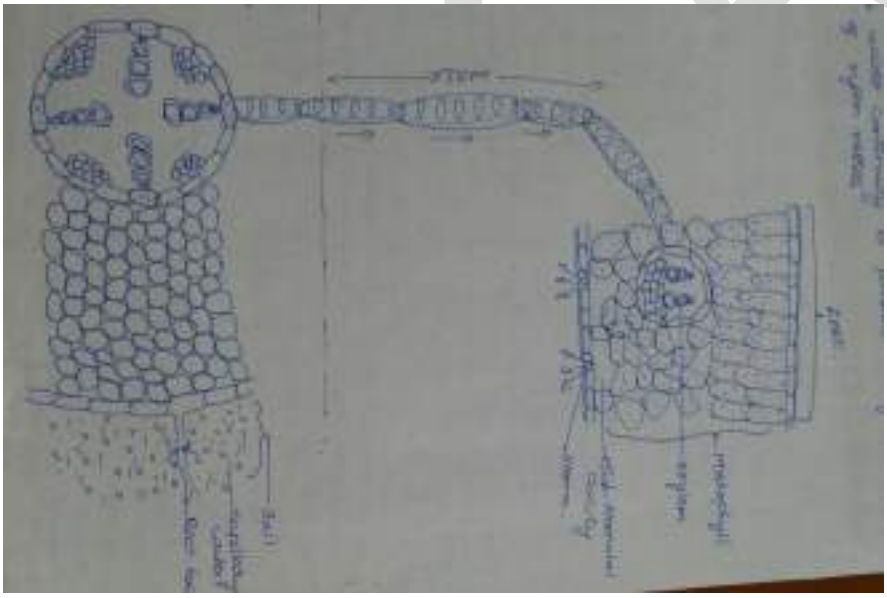
According to this theory physical forces in xylem elements of plants are responsible for Ascent of sap. **1) Capillary force theory** -According to Boehm capillary force in xylem vessel is responsible**.** Objection:- Capillary force can not function due to cross wall at each cell, magnitude is low, ends of vessels are not dipped in water, lower terrestrial plants have only tracheids. **2) Imbibitional theory**: - According to Sachs & Urger Imbibitional force is responsible for Ascent of sap**.** Objection:- Ascent of sap is through lumen of vessel and not through wall**.** **3) Atmospheric theory:-** According to this theory water moves up in xylem to fill up drop in atmospheric due to loss of water during transpiration .Objection:- No vaccum at upper end of plant for atm. Pressure to elevate water beyond 30ft., lower end of the column do not directly open in soil water**.**

4) Transpiration pull theory OR **Cohesion –Tension Theory** OR **Dixon and Jolley Theory: -**

This theory was proposed by **Dixon & Jolley** , supported by Renner, Curtis, Clark ,Levitt. According to this theory two forces are responsible for ascent of sap. They are:-

1) **Cohesive & Adhesive** properties of water to form water column.

2) **Transpiration pull exerted on this column**.



Water molecules are held together tightly due to strong **cohesive force** (mutual force of attraction due to hydrogen bonds between them) they also have **Adhesive property** (strong attraction between water column and inner walls of xylem). Thus continuous water column is formed from leaf to root which can not be broken. The water net has two terminals Root tip near absorbing region and sub stomatal cavity in mesophyll.

Transpiration creates DPD, results in flow of water from adjacent mesophyll cells; this DPD reaches cells abutting vasculature & xylem elements. Due to continuous transpiration, high DPD causes tension on the water column& it is transported down into root up to area of absorption .Thus water is pulled up due to suction force (Transpiration pull) due to transpiration. **Objection:** - Entry of air bubbles in the xylem disturbs the continuity of water column water column.

Transpiration: Structure of stomata, Stomatal mechanism (Steward and K- ion theory) Factors affecting transpiration; Anti-transpirants

Transpiration takes place through surface of leaves. It is known as Foliar transpiration (more than 90%). Transpiration occurs through young or mature stem is called as Cauline transpiration. **Depending upon the plant surface, transpiration is classified into three types:**

1. Stomatal Transpiration:-Water vapour diffuses through minute pore (stomata) present in soft aerial part of plant is known as Stomatal Transpiration. about 85 – 90% of water loosed by the stomatal transpiration.

2. Lenticular Transpiration:-Water evaporates through openings present on the older stems called Lenticels and the transpiration that takes place through Lenticel is known as Lenticular Transpiration. Huber observed in some plants that water lost by lenticular transpiration was about 0.1%.

3. Cuticular Transpiration:-Water evaporates through cuticle is called cuticular transpiration. The amount lost is about 5 to 10 percent of the total transpiration. It depends upon the thickness of cuticle.

Structure of stomata

The stomata are very minute apertures, found on the epidermis of the leaves. Each stoma is surrounded by two kidney-shaped special epidermal cells, known as guard cells.

The epidermal cells surrounding the guard cells of the stoma are known as accessory or subsidiary cells. The number of stomata may range from thousands to lacs per square centimeter on the surface of the leaf.

Each stoma is surrounded by two guard cells. The kidney-shaped guard cells contain chloroplasts.

stomatal mechanism in plant cells.

The mechanism of the closing and opening of the stomata depends upon the presence of sugar and starch in the guard cells.

During day time or in the presence of light, the guard cells of the stomata contain sugar synthesized by their chloroplasts. The sugar is soluble and increases the concentration of the sap of guard cells. Due to higher concentration of the cytoplasm of guard cells, the water comes to them from the neighbouring cells by Endosmosis and they become turgid. With the result the stomata remain open.

In the night or in the absence of light the sugar present in guard cells converts into the starch. The starch is insoluble, and this way the cell sap of the guard cells remains of much lower concentration than those of neighbouring cells, and the neighbouring cells take out the water from the guard cells by Exosmosis making them flaccid and the stomata closed.

The conversion of sugar into starch during night and vice-versa in day time depends upon the acidity (pH) and alkalinity of the cell sap of guard cells.

During night there is no photosynthesis and the carbon dioxide accumulates in the guard cells, converting the cell sap into weak acidic starch.

During day time the carbon dioxide is used in the process of photosynthesis, the cell sap becomes alkaline and the starch converts into sugar.

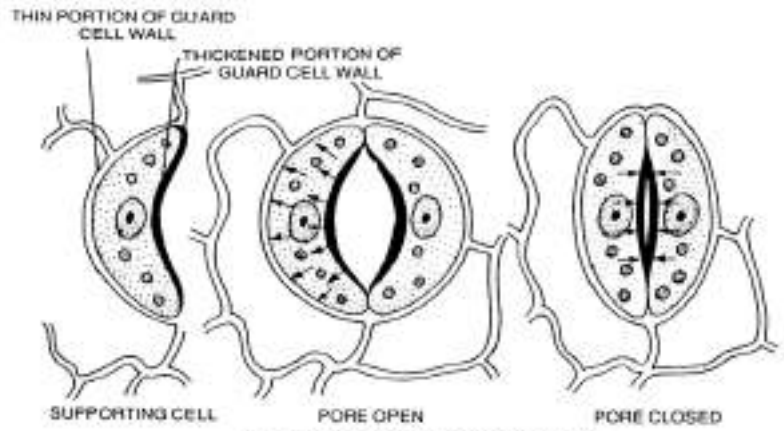


Fig. 2.12. Opening and closing of stomata

The important theories of stomatal movement are as follows: Many theories such as Theory of photosynthesis, Theory of glycolate metabolism **,** Starch Sugar inter-conversion theory **,** potassium transport ion **theory are put forward time to time to explain stomatal mechanism.**

Starch Sugar Inter-conversion Theory:

(i) According to **Lloyd** (1908) turgidity of guard cell depends on inter-conversion of starch and sugar. It was supported by Loft-field (1921). He found out that guard cells contain sugar during day time when they are open and starch during night when they are closed.

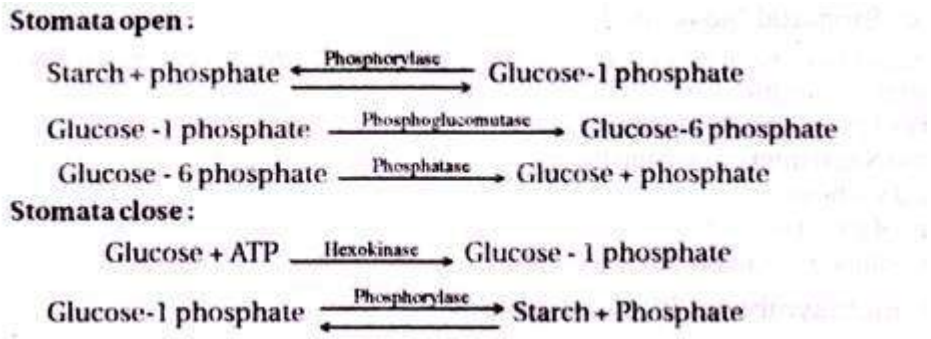
$$\text{Starch} \underset{\text{night}}{\overset{\text{day}}{\rightleftharpoons}} \text{Sugar}$$

(ii) **Sayre** (1926) observed that during day time due to constant removal of carbon-dioxide by photosynthesis stomata open in neutral or alkaline pH, . Stomata remain closed during night when there is no photosynthesis and due to accumulation of carbon-dioxide, carbonic acid is formed that causes the pH to be acidic. It is supported by Scarth (1932) and Small et. al. (1942).

iii) Yin and Tung (1948) observed that during Day time starch is converted into glucose-1, phosphate in the presence of an enzyme phosphorylaseand stomata opens. dark phases (changing CO_2 concentration) control the changes in pH.

(iv) Steward's scheme:

Steward (1964) proposed modified scheme **of inter-conversion of starch and sugar for stomatal movement.** According to him conversion of starch to Glucose -1 phosphate is not sufficient. It should be converted to glucose to increase sufficient osmotic pressure. For this, ATP is also required through respiration in presence of oxygen. Guard cell carries enzymes like Phosphorylase, Phosphoglucomutase, Phosphatase and Phosphorylase. These enzymes help in opening and closing of the stomata.



Based on the above mentioned theory, process of opening and closing of stomata may be summarized as given below.

In Light: Photosynthesis takes place

(1) →Decreased CO_2Concentration in leaf cells

(2) →Increase in pH of guard cells

(3) → Hydrolysis of starch to sugar by enzymes

(4) → Increase of Osmotic Pressure of guard cells

(5) → Endosmosis of water in guard cells

(6) →Increase in T.R of guard cells

(7) →Aperture opens (Fig. 4.6)

Demerits of the starch-sugar inter-conversion theory:

Demerits of starch-sugar inter-conversion theory are as follows:-

1. In the presence of light when starch disappears from guard cells, malic acid appear and not the sugars.
2. Starch has not been reported in the guard cells of many monocots such as Iris, Amatyllis, Allium.
3. According to this theory O.P. of guard cells increases due to the formation of glucose-1- phosphate in guard cells but it is found that the presence of phosphate ions causes the development of same O.P as does the presence of glucose-phosphate.
4. Enzyme phosphorylase helps in conversion of starch to glucose-1-phosphate but not in the formation of starch from glucose-1-phosphate. This reaction is controlled by some other enzyme about which we do not know yet.

Active K^+ Transport or Potassium Pump Theory and Role of Abscisic Acid: Or Active Potassium Pump Theory

The concept of K^+ ion transport was given by **Fujino** and supported, elaborated by **Levitt & Rashke** in 1975. It is an active mechanism which needs ATP. Mechanism is explained as follows.

Opening of Stomata during Daytime (in presence of light):

Opening of stomata depends upon following conditions:

(a) In Presence of light.

(b) Decrease in starch contents of guard cells.

(c) Increased concentration of malic acid in guard cells.

(d) Influx of K^+ ions into guard cells.

(e) Efflux of H^+ ions from guard cells.

(f) Intake of CI ions by guard cells.

(g) Low CO_2 concentration in an around guard cells.

(h) High pH (more than 7) in guard cells (hence, alkaline medium of the cell sap in guard cells).

(i) High Turgor Pressure in guard cells due to endosmosis, (turgidity of cells).

(j) And stomata open.

Explanation of Levitt Concept:This is explained as follows:

In the guard cells, starch are converted into malic acid in presence of light (during day time).Protons (H^+) thus formed are used by the guard cells for the uptake of K+ ions (in exchange for the protons H^+). This is an active ionic exchange and requires ATP energy and cytokinin (a plant hormone). The concentration of K^+ ions increases and the concentration of H+ ions decreases in guard cells. The pH of the cell sap in guard cells also increases (pH becomes more than 7 and the medium becomes alkaline).

There is also an increased uptake of CI" (anions) by the guard cells to maintain the electrical and ionic balance inside and outside the guard cells. The malate anions formed in the guard cells are neutralized by the K+ ions. This results in the formation of potassium malate.

Malate anions + K^+ →Potassium malate

Potassium malate enters the cell sap of the guard cells thereby reducing the water potential while increasing the osmotic concentration (and the O.P.) of the cell sap. Hence, endosmosis occurs, guard cells become turgid and kidney-shaped and the stomata opens.

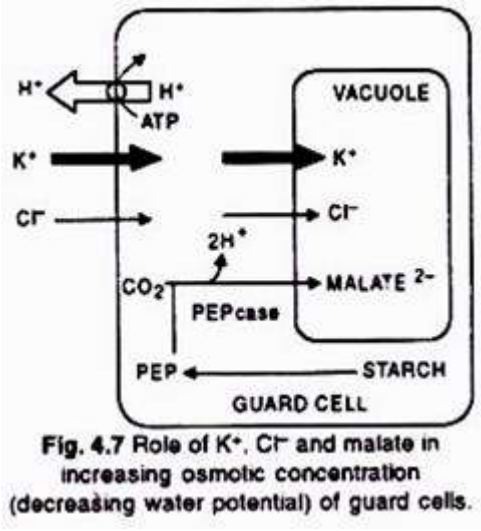


Fig. 4.7 Role of K^+, Cl^- and malate in increasing osmotic concentration (decreasing water potential) of guard cells.

It is also observed that the CO_2 concentration is low in and around guard ceils during day time. This is due to high photosynthetic utilization of CO_2. It helps in opening of stomata.

B. Closing of Stomata in Absence of Light (Darkness/Night Time):

Closing of stomata depends on following conditions:

(a) Absence of light.

(b) Decreased concentration of malic acid in guard cells.

(c) Efflux of K^+ ions from guard cells.

(d) Influx of H^+ ions in guard cells.

(e) Acidic medium of the cell sap in guard cells.

(f) Loss of Cl^- ions from guard cells.

(g) Increases CO_2 concentration in and around guard cell due to release of CO_2 in respiration combined with the absence of photosynthetic activity in dark.

(h) Presence of plant growth inhibiting hormone abscissic acid (ABA),

(i) Loss of turgidity and loss of kidney-shape by guard cells.

All these conditions represent the reversal of the daytime events. Under these conditions, the guard cells lose water by exosmosis and become flaccid. This causes closing of the stomata.

Factors Affecting Transpiration in Plants

1. Humidity of Air:

Humidity or amount of water vapour in the atmosphere, surrounding the plant has influence on Transpiration. On damp foggy atmosphere the rate of transpiration decreases as the outer air remains saturated with water vapour. The less moisture there is in air, the greater will be the rate of transpiration.

2. Light or Illumination:

The opening and closing of the stomata depend on light. due to absorption of radiant energy and its transformation into heat, temperature of the leaf is raised bringing about an increase in transpiration rates.

3. Temperature:

It increases the rate of transpiration as it hastens transformation of water into water vapour.

4. Wind:

By wind or air current water vapour given off during transpiration is removed; thus saturation of the surrounding air is avoided which otherwise would retard the rate of transpiration. Winds of high however, retard transpiration, because the stomata close up due to high winds. Moreover, winds of high velocity bring about a reduction in temperature which undoubtedly affects transpiration.

5. Atmospheric Pressure:

When atmospheric pressure is high, the rate of transpiration is low. Plants growing in high altitudes have distinctly lower atmospheric pressures, and those plants have high rates of transpiration, if other environmental factors are not limiting.

6. Soil Factors:

As all necessary water is absorbed from the soil, factors like water content, composition, temperature, concentration of soil solution, etc., indirectly influence the rate of transpiration.

ROLE OF TRANSPIRATION (Transpiration is "Necessary EVIL or an " Unavoidable Evil"

There are 2 conflicting views regarding the role of Transpiration. According to one view **'Transpiration is advantageous'** and according to other view '**Transpiration is Disadvantageous'**. Hence Transpiration is considered as **"Necessary EVIL or an " Unavoidable Evil".**

Advantageous of Transpiration:-

1. Transpiration creates suction force to absorb water from soil.
2. Transpiration helps in passive absorption of water and Ascent of sap, by creating Transpiration pull in the leaves.
3. Transpiration helps in mineral uptake by developing Suction force.
4. Transpiration helps to remove excess of water from the plant body.
5. Transpiration stream helps in translocation of solutes from one part of plant to another part.
6. Transpiration brings down internal temperature by allowing fresh water to flow throughout the plant body.
7. Opening and closing of stomata during Transpiration indirectly influence Respiration and Photosynthesis.

Disadvantageous of Transpiration:-

1. **Excess of** Transpiration causes scarcity of soil water.
2. **High rate of** Transpiration results in internal water deficit which retard growth.
3. **High rate of** Transpiration with low rate of absorption cause wilting of plants.
4. **Excess of** Transpiration leads to structural adaptations in Xerophytes.
5. **Excess of** Transpiration induce formation of Absisic acid results in wilting of leaves.

Transpiration is rather harmful than beneficial to plants. Even in such condition Transpiration is unavoidable, due to stomata which remain open for gaseous exchange during photosynthesis and Respiration and it can not check stomatal Transpiration. Hence Curtis in 1926 called Vital, unavoidable phenomenon of plants the Transpiration as **"Necessary EVIL " and Barns regarde it as " Unavoidable Evil".**

Antitranspirants

Anti transpirants are **"Substances applied to the plants to reduce Transpiration without causing significant effect on other plant processes**".

Types of Anti transpirants

Antitranspirants are chemicals, it can be grouped into 4 types as follows:-

1. **Low viscocity waxes**:- When Low viscocity waxes are sprayed on leaves , they prevent evaporation of water through stomata.

2. **Colourless plastic, Polythene bags**:- When Colourless plastic, Polythene bags are covered on leaf, form thin transparent film on the surface and prevent evaporation of water through stomata, but allow diffusion of Oxygen and carbon di oxide.
3. **Abssisic acid (ABA), Phenyl mercuric acetate, Oxyethylene dicenyl succinic acid**: **Abssisic acid** (ABA) is a natural growth inhibitor known to cause stomatal closure. **Phenyl mercuric acetate** is a Fungicide. When it is sprayed in concentration of 10m, it is non toxic to plants and cause partial closure of stomata for 2 weeks.
4. **Carbon di oxide**: Carbon di oxide is an effective Antitranspirant. Increase in Carbon di oxide concentration from its normal 0.03 % to0.05%, it causes partial closure of stomata and avoid stomatal transpiration. But it is possible only in Green houses.
   High Carbon di oxide concentration cause complete closure of stomata which adversely affect photosynthesis.

Significance of Antitranspirants:-

Antitranspirants are used to cultivate high priced crops in agricultural production, in Nurseries for seedling transplantation with limited available water.

2 Marks Questions

1. What is Water potential? Mention its components,
2. Mention any 4 significance of water.
3. Differentiate between active and Passive Absorption.
4. What is Ascent of Sap? Mention its path.
5. What is Transpiration? Mention its types.
6. Define Cohesive and Adhesive force.
7. Mention Merit and demerit of Transpiration Pull.
8. What are Antitranspirants? Give examples.
9. Mention Significance of Antitransirants.
10. What are Stomata? Mention its function.
11. Mention factors affecting Transpiration.

5Marks Questions

1. Write a note on Water Potential.
2. Explain Osmotic absorption of water
3. Describe Passive absorption.
4. Explain Transpiration Pull Theory.
5. List importance of water.
6. Explain Stomatal mechanism.
7. With neat labelled diagram explain of Stomata.
8. Write a note on Antitranspirants.
9. Explain Stewards starch inter conversion theory.

10 Marks Questions

1. Describe mechanism of water absorption.
2. Explain Active absorption of water.
3. Describe Transpiration pull theory with merits and Demerits.
4. Explain Proton transport theory.

Unit2: Mineral nutrition(3 Hrs)

Essential elements, macro and micronutrients; Role and deficiency symptoms of Nitrogen, phosphorus, Potassium, Magnesium, Zinc, boron, and Molybdenum Hydroponics

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Mineral Nutrition in Plants:

Introduction

All green plants are autotrophs. Hence, they require the supply of inorganic materials from outside for synthesis of their own organic material.

Apart from the elements carbon, hydrogen and oxygen that may be absorbed as water, carbon dioxide or oxygen, together makeup a large part of the weight of a plant, all the inorganic materials are absorbed by the plants directly or indirectly from the soil with the help of their roots.

The source of these inorganic materials in the soil is minerals; they are called as **mineral elements or mineral nutrients**. The process involving the absorption, distribution and utilization of mineral substances by the plants for their growth and development is called **mineral nutrition**.

Mineral Elements in Plants:

On the basis of their effects on plant, mineral elements are generally of two types:

i**. Essential and**

ii. Non-essential.

Only about 17-20 elements are found to be essential. The rest elements are called non-essential without which a plant can survive and reproduce. The non-essential elements may be beneficial or toxic. Beneficial elements improve growth or reduce disease susceptibility without which a plant can still complete its life cycle. For example, Silicon (Si) in grasses, Sodium (Na) in C_4 plants and halophytes. Toxic elements impair growth either in low or high concentrations.

Any mineral ion concentration in tissues that reduce the dry weight of tissues by about 10% is considered toxic. Toxic level for any element also varies for different plants. For example, aluminum (Al) is always toxic in the acidic soil but acts as beneficial element for tea plant.

Na, Zn, B, Mo, Ma, Cu and Fe are toxic if present at high concentration is soil. It is very often seen that the uptake of one element inhibits the uptake of another element. For example, excess of magnesium uptake induce deficiency of iron, magnesium and calcium.

1. **Macronutrients** Element:

Carbon, Hydrogen and Oxygen:

Although these macronutrients elements are not minerals in the true sense, they are still included in the list as they are most essential for plant life. These three elements are also called framework elements. Plants absorb them from air and soil in the form of carbon dioxide and water.

2. Macronutrients Element:

Nitrogen:

Soil is the chief source of nitrogen. **It is absorbed from the soil in two major ionic forms:**

Nitrate (NO_3^-) and ammonium (NH_4^+). Soils generally remain deficient in nitrogen, and soil fertility always depends on added nitrogen.

Functions of Nitrogen:

(i) The most recognized role of nitrogen in the plant is its presence in the structure of protein molecule.

ii) It is the constituent of such important biomolecules like purines and pyrimidine's which are found in DNA and RNA.
(iii) Nitrogen is found in the structure of porphyrin molecules which are the percursors of chlorophyll pigments and cytochromes that are essential in photosynthesis and respiration.
(iv) The coenzymes like NAD^+, $NADP^+$, FAD, etc., are essential to the function of many enzymes and nitrogen is a structural component of these coenzymes.
(v) Other compounds in the plant such as some vitamins contain nitrogen.

Deficiency Symptoms of Nitrogen:

(i) A general chlorosis, i.e., the yellowing of leaves, especially in the older leaves, due to a loss in chlorophyll content appears first. In severe cases these leaves become completely yellow and then light tan as they die and frequently fall off the plant.
(ii) This yellowing symptom appears last in the younger leaves, because they receive soluble forms of nitrogen transported from older leaves.
(iii) In some cases production and accumulation of anthocyanin pigments is found. As a result a purplish colouration appears in stems, petioles, and lower leaf surfaces.
(iv) The starch content is increased with the decrease in protein content.
v) Plant growth remains stunted and lateral buds remain dormant.
(vi) Flowering is suppressed or delayed; in the latter case the fruits and seeds are small and weak.

3. Macronutrients Element:

Phosphorus:

Phosphorus is very often the limiting nutrient in soils. It is present in the soil in inorganic and organic forms. It is absorbed as inorganic phosphate anions ($H_2PO_4^-$).
In the organic portion of the soil organic forms of phosphorus may be found in nucleic acid, phospholipids and inositol phosphates, which are not the utilizable forms of the element. These organic compounds are decomposed, and phosphorus is transformed into an inorganic form which is readily absorbed by the root system.

Factors controlling the availability of phosphorus are:

(i) PH of the soil solution.
(ii) Dissolved aluminum and iron which precipitate out phosphate as un-absorbable aluminum and iron phosphates.
(iii) Available calcium which may form salts with all forms of phosphate, which are easily available to the plant due to high solubility in water.
(iv) Anion exchange, that takes place between the minerals present in the clay micelles and the phosphate ion under mild acidic conditions.

(v) Presence of microorganisms in the soil, which temporarily fix phosphorus in organic structures that, is eventually returned to the soil in a bound form for the utilization of plants.

Functions of Phosphorus:

(i) It is a constituent of nucleic acids. Both DNA and RNA have a sugar-phosphate backbone in their structures. Triphosphate forms of nucleotides are precursors of nucleic acids.

(ii) Phosphorus is a constituent of phospholipids or phosphoglycerides or glycerol phosphatides which along with proteins are characteristic major components of cell membranes.

(iii) Phosphorus is a constituent of the coenzymes NAD^+ and $NADP^+$, which take part in most of the cellular oxidation-reduction reactions involving hydrogen transfer. Most of the important metabolic processes like photosynthesis, respiration, nitrogen metabolism, carbohydrate metabolism, fatty-acid metabolism, etc., are dependent on the action of these coenzymes.

(iv) Phosphorus is a constituent of ATP and other high energy compounds.

(v) All the intermediate of glycolysis between glucose and pyruvate are phosphorylated compounds.

Deficiency Symptoms of Phosphorus:

(i) Phosphorus-deficient plants may develop dead necrotic areas on the leaves, petioles, or fruits.

(ii) The plants show a general overall stunted appearance with often dark green colouration.

(iii) Sometimes phosphorus deficiency may cause leaf-fall and purple or red anthocyanin pigmentation.

(iv) The older leaves are usually affected first and become dark brown because of the mobility of phosphorus to the younger leaves under deficiency conditions.

(v) Sometimes distortion in the shape of the leaves is observed and may be confused with zinc deficiency.

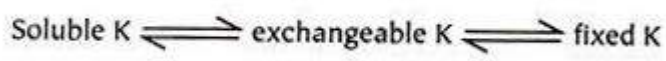
(vi) Large amounts of pith and small amounts of vascular tissues are found in the stems of phosphorus-deficient tomato plants.

(vii) In some cases a deficiency of this element causes an accumulation of carbohydrates.

Macronutrients Element:

4. Potassium:

Potassium is present in the soil in soluble form, fixed or bound form and in an exchangeable form. Most of the potassium content of the soil is non-exchangeable (fixed) and, unavailable to the plant. Equilibrium exists in the soil between the three forms of potassium.



Functions of Potassium:

(a) Physiological Functions:

(i) Potassium has been shown to be linked with carbohydrate metabolism.

(ii) It is essential for translocation of sugar.

(iii) Stomatal opening in higher plants requires potassium. If there is an influx of potassium ions (K^+) into the guard cells during stomatal opening at the expense of ATP. Potassium accumulation in the guard-cell vacuole results in osmotic swelling of guard cell and stomatal opening.

(iv) Potassium has a general role in the regulation of water in plant cells. Under water- stress conditions potassium being absorbed selectively prevents the plant from losing water.

(b) Biochemical Functions:

(i) The reactions, involved in the phosphorylation of carboxyl groups and inter-conversions of enol-keto intermediates are activated by potassium.

(ii) Potassium is required by the enzyme acetic thiokinase from spinach leaves for maximal activity.

(iii) Potassium might act as a regulator of the enzyme pyruvate kinase through repression of synthesis of the enzyme.

(iv) Folic acid metabolism has been shown to require potassium.

(v) γ-glutamylcysteine synthesis specifically requires potassium.

(vi) Potassium is required by the enzyme succinyl-CoA synthetase isolated from tobacco for maximal activity.

(vii) Nitrate reductase formation in rice seedlings specifically requires potassium.

(viii) There is an absolute requirement for potassium by starch synthetase isolated from sweet com.

(ix) Potassium, through its role in ATPase activity, may be involved in ion transport across biological membranes.

Deficiency Symptoms of Potassium:

(i) Due to easy mobility of potassium, deficiency symptoms first appear on older leaves. A mottled chlorosis followed by the development of dark necrotic lesions at the tip and margins of the leaf is generally found. The leaf-tips curve downwards and the margins roll inward towards the upper surface.

(ii) In cereals, cells at the leaf-tip and margin die first, and the necrosis spreads basipetally toward the leaf bases.

(iii) Potassium deficient cereal grains develop weak stalks, and their roots become susceptible to root rotting organisms. As a result, the plants easily get lodged by wind or rain.

(iv) Generally, potassium deficient plant exhibits stunted growth with shortened internodes.

(v) Anatomically, potassium deficiency causes disintegration of pith cells and formation of secondary pholem in tomato plants.

Macronutrients Element

5. Magnesium:

Magnesium is an exchangeable cation. It is present in the soil in water soluble, exchangeable, and fixed form. Magnesium is found to be present in soil abundantly as magnesium silicate, an unavailable form which becomes available to plants after weathering. Magnesium is absorbed as divalent Mg^{2+}.

It may be available to plants from some fixed forms of minerals like magnesite ($MgCO_3$), livine [$(MgFe)_2 SiO_4$], and dolomite ($MgCO_3.CaCO_3$). Of them dolomite is the most popular and economical source of magnesium fertilizer.

Functions of Magnesium:

Magnesium, like calcium, also serves as a structural component and is involved as a cofactor in many enzymatic reactions.

(a) Structural Functions:

(i) Magnesium is a component of the chlorophyll structure.

(ii) Magnesium is required to maintain ribosome integrity.

(iii) Magnesium is necessary to maintain the structural integrity of chromatin fibre. It is involved in coiling of 110Å thick DNA histone protein fibre to form a 300Å thick chromatin fibre.

(b) Physiological and Biochemical Functions:

(i) Magnesium plays two very important roles in plant in photosynthesis and carbohydrate metabolism.

(ii) The release of energy in the hydrolysis of high energy compounds like ATP is greatly influenced by Mg^{2+}. It complexes with ATP, ADP and AMP with differing affinities, resulting in hydrolysis of these compounds.

(iii) Mg^{2+} has also a direct role on potassium-sodium stimulated ATPase activity.

(iv) Mg^{2+} is necessary for full activity of the two principal CO_2 fixing enzymes, PEP carboxylase and RuBisCO.

(v) Mg^{2+} is also an activator for DNA and RNA polymerases involved in DNA and RNA synthesis from nucleotide triphosphates. Thus Mg^{2+} helps in protein synthesis by activating enzymes of nucleic acid synthesis and forming imitation complexes with mRNA, ribosome and fMet initiator tRNA.

Deficiency Symptoms of Magnesium:

(i) Extensive interveinal chlorosis of the older leaves is the first symptom, and as the deficiency becomes more acute, eventually reaches the younger leaves. This is because magnesium is a mobile element.

(ii) Chlorosis is followed by anthocyanin pigmentation and then necrotic spotting.

(iii) Anatomically magnesium deficiency causes extensive chlorenchyma development and scanty pith formation.

Micronutrients in plant growth.

Some elements are needed for the normal growth of the plant but only in minute amounts. They are essential for the life and the growth of the plants in small amounts, called trace or micronutrient elements.

Trace elements can be conveniently divided into four groups:

(a**) The essential**—so far the following six have been conclusively proved to be essential for normal plant growth—B, Zn, Cu, Mn, Mo and Co

(b) **The probably essential**—-elements like selenium, barium, etc.

(c) **The toxic**—all essential macro- and micronutrients in high dosages.

[d**) Physiologically inactive elements**— Arsenic, etc.

1. **ZINC(Zn)**

Occurence: - Zn is present to a range of 3-350 mg/L in the whole plant. It is available for plants from soil in the form of Ferro magnesium minerals, Magnetite, Biolite and Horn blend.

PHYSIOLOGICAL ROLE:-

1) Zn acts as an activator enzymes such as Carbonic anhydrase, Alcoholic dehydrogenase Hexokinase etc.
2) Zn plays an important role in synthesis of Tryptophan (Precursor of Auxin-IAA).

DEFICIENCY SYMPTOMS:-

- Severe **Zn** deficiency effects on fruit trees. Deficiency of Zn causes Mottle leaf disease in Apple, Citrus, and Walnut.
- Stunted growth due to shortened internodes.
- Chlorosis of tip and margin of older leaves.

2. **BORON (B)**

Occurance: - It is present to an extent of 2.75 ppm (mg/l) is available for plants as ions from soil in the form of Silicates, Borate, Boric acid.

PHYSIOLOGICAL ROLE:- It regulates Carbohydrate metabolism.

1) Facilitates translocation of Sugars in plants.
2) Regulates cell division, Regeneration, cellular differentiation and development.
3) It regulates water relations, active salt absorption, Nodulation in Legumes.
4) It forms complex at cell membrane which facilitate its passage across membrane.

DEFICIENCY SYMPTOMS OF BORON

1) Zn deficiency causes death of shoot tip.
2) Suppress flower formation.
3) Leaves become coppery, Brittle, Curve inwards.
4) Stunted root growth.

3.MOLYBDENUM(Mo)

Occurrence: - It is present in the soil solution as Molybdate ions, Adsorbed to soil particles as an exchangeable and non exchangeable form.

PHYSIOLOGICAL ROLE:

- It is essential for nodulation in Legumes, Reduction of Nitrates to Nitrites, Synthesis of Tanins.
- It is a co factor for synthesis of Ascorbic acid.
- Regulates Amino acid concentration in plants.

DEFICIENCY SYMPTOMS:-

- Mo deficiency causes Whiptail disease in Cauliflower.
  - •Chlorotic intervienal mottling of older leaves.
  - •Flower formation is retarded.
  - •In Cereals like Oats grain formation is reduced.

‘**HYDROPONICS’** OR ‘**SOIL LESS GROWTH’**, OR ‘**SOLUTION CULTURE**

Soil is required for terrestrial plants as a source of water and mineral nutrients, if the plant is provided with balanced nutrient and water, it can be grown even without the soil. In 1860 Julius von sachs , Geman Botanist demonstrated that Plants could be grown to maturity in a defined nutrient solution in absence of soil , and called this as Hydroponics.

The growth of plant in balanced nutrient solution is called 'Hydroponics' or 'Soilless growth', it is also called 'Solution culture 'as it involves the growth of plants by using nutrient solution.

All plants require certain inorganic mineral nutrients and water for their nutrition but not the soil. Seedling shows healthy growth and gives good crop yield as it gives when growth in soil.

PROCEDURE for Hydroponics :-

- Take water containing balance inorganic micro and macro nutrients in a borosilicate bottle.
- Close the mouth of bottle with a lid containing two holed rubber cork.
- Introduce health herbaceous seedling into the bottle through one hole of the cork.
- Introduce a bent glass tube into the bottle through the other hole in cork, to provide aeration of solution. Allow the set for some days.

SIGNIFICANCE OF HYDROPONICS:-

1. Hydroponics helps to cultivate commercial ornamental plants and Vegetables in areas under extremely cold and dry environment.
2. It helps to grow plants where soil is unsuitable for cultivation.
3. By this method essential elements can be identified and their deficiency symptoms are discovered.

2 Marks questions

1. What is Hydroponics? Mention its significance.
2. What are Micro and Macro Nutrients? Give example.
3. Mention Role of Boron.
4. List Deficiency Symptoms of Zinc
5. Give Role and defieciency symptoms of molybdenum.

10 Marks questions

1. Mention the role and Deficiency symptoms of Nitrogen, Potassium and Phosphorous.
2. Give an account of Micronutrients you have studied.

Unit 3: Photosynthesis (10 Hrs)

Photosynthetic apparatus, Photosynthetic Pigments (Chl a, b, xanthophylls, carotene); Photo system I and II, reaction centre, antenna molecules; Electron transport and mechanism of ATP synthesis; C3, C4 and CAM pathways of carbon fixation.

The Process of Photosynthesis in Plants

Introduction:

Photosynthesis (Photon = Light, Synthesis = Putting together) is an anabolic process by which green plant synthesize carbohydrates (initially glucose) using carbon dioxide, water, pigments and sunlight.

Photosynthesis is transformation of solar energy/radiant energy/light energy into chemical energy. According to Van Neil and Robert Hill, oxygen liberated during photosynthesis comes from water and not from carbon dioxide.

Thus, the biochemical reaction for photosynthesis can be written as:

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sun Light}} C_6H_{12}O_6 + 6O_2 \uparrow + 6H_2O$$

Significance of Photosynthesis:

1. The process of photosynthesis is unique to green and other autotrophic plants. It **synthesizes organic food from inorganic raw materials**.

2. Photosynthesis **converts radiant or solar energy into chemical energy**. The same gets stored in the organic food as bonds between different atoms. Photosynthetic products provide energy to all organisms to carry out their life activities.

3. Coal, petroleum and natural gas are fossil fuels which have been produced by the application of heat and compression on the past plant and animal parts (all formed by photosynthesis) in the deeper layers of the earth.

4. All **useful plant products** are derived from the process **of photosynthesis**, e.g., timber, rubber, resins, drugs, oils, fibers, etc.

5. It is the **only known method by which oxygen is added to the atmosphere** to compensate for oxygen being used in the respiration of organisms and burning of organic fuels.

6. Photosynthesis **decreases the concentration of carbon dioxide** which is being added to the atmosphere by the respiration of organisms and burning of organic fuels.

7. **Productivity of agricultural crops depends upon the rate of photosynthesis**.

Photosynthetic apparatus, Site of Photosynthesis:

All green plant tissues can photosynthesize, but the majority of photosynthesis usually takes place in the leaves. The cells in a middle layer of leaf tissue called the **mesophyll** contain chloroplast.

- **Chloroplast in green plants constitutes the photosynthetic apparatus and act as site of photosynthesis**.

- Chloroplasts of higher plants are **discoid or ellipsoidal** in shape measuring 4 —6 μ in length and 1—2 μ in thickness.

- It is a **double membranous** cytoplasmic organelle of eukaryotic green plant cells. The thickness of the two membranes including periplastidial space is approximately 300Å.

- Chloroplast is filled with a hydrophilic matrix known as **stroma**. In stroma are embedded a number of flattened membranous sacs known as **Thylakoids.** Photosynthetic pigments occur in thylakoid membranes.

- Aggregation of thylakoids form stacks of coin like structures known as **granna**. **A grannum** consists near about 20 — 30 thylakoids. Each thylakoid encloses a space known **Asloculus**. The end of disc shape thylakoid is called as **margin** and the area where the thylakoids membranes are appressed together is called **partition.** Some of the granna are connected with thylakoids of other granna by **stroma lamella or fret membranes.**

- **In photosynthetic prokaryotes** (blue-green algae and Bacteria) chloroplast is absent. In photosynthetic bacteria **Chromatophore** is present and In blue-green algae **photosynthetic lamellae** are present.

Stroma contains cp-DNA (0.5%), RNA (2—3%), Plastoribosome (70S), enzymes for carbon dioxide assimilation, proteins (50—60%), starch grains and osmophilic droplets, vitamin E and K, Mg, Fe, Mn, P, etc. in traces. **Thylakoid membrane and stroma lamella** both are composed of lipid and proteins.

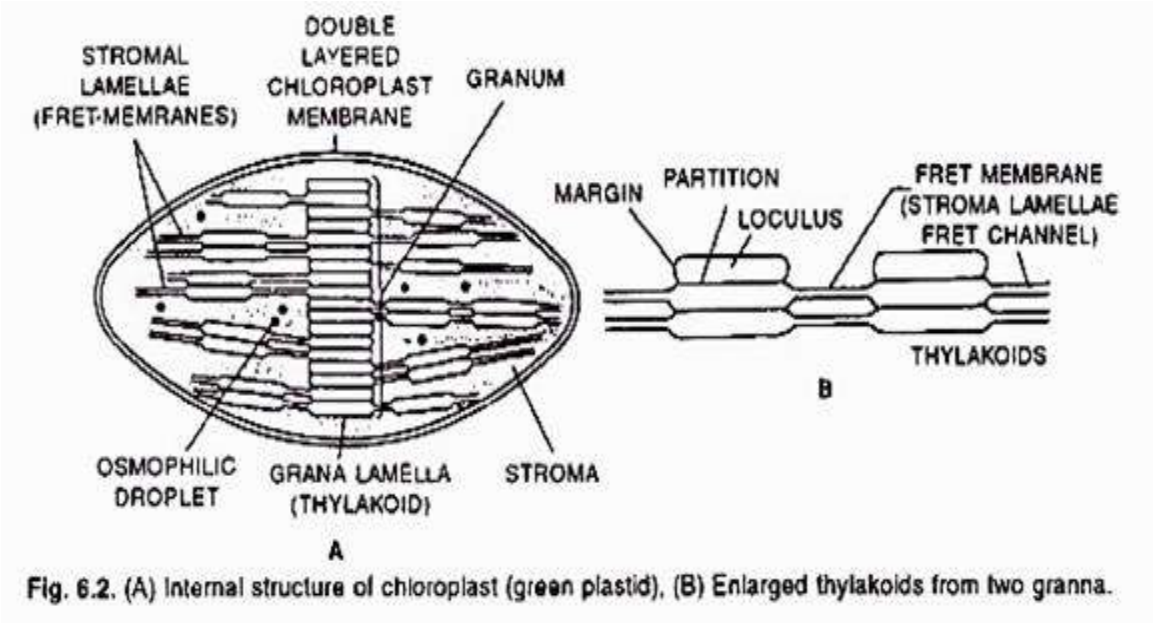
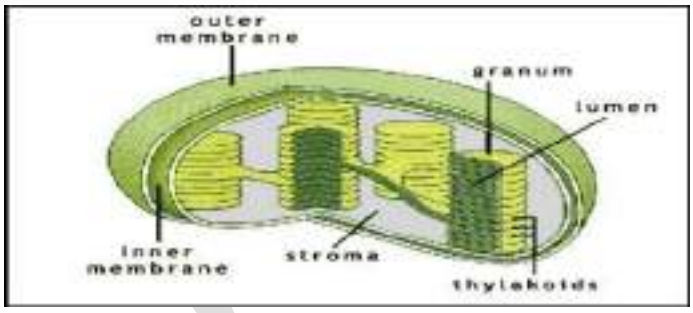


Fig. 6.2. (A) Internal structure of chloroplast (green plastid), (B) Enlarged thylakoids from two granna.



Photosynthetic Pigments (Chl a, b, xanthophylls, carotene)

Photosynthetic pigments are substances that absorb sunlight and initiate the process of photosynthesis.

Photosynthetic pigments are grouped into 3 categories:

***(i)* Chlorophyll:**

These are green coloured most abundant photosynthetic pigments that play a major role during photosynthesis. Major types of chlorophylls which exist in plants and photosynthetic bacteria are **Chlorophyll a, b, c, d and e, Bacteriochlorophyll a, b and g, and Chlorobium chlorophyll**.

The **structure of chlorophyll** was first studied by Wilstatter, Stoll and Fischer in 1912. Chemically a chlorophyll molecule consists of a **porphyrin head** (15 x 15Å) and **phytol tail** (20Å). Porphyrin consists of tetrapyrrole rings and central core of Mg. Phytol tail is side chain of hydrocarbon. It helps the chlorophyll molecules to attach with thylakoid membrane.

Out of various types of chlorophyll, chlorophyll a and chlorophyll b are the most important for photosynthetic process. **Chlorophyll a** is found in all photosynthetic plants except photosynthetic bacteria. Hence it is called as **Universal Photosynthetic Pigment** .

***(ii)* Carotenoids:**

Carotenoids are **yellow, red or orange colour pigments** embedded in thylakoid membrane in association with chlorophylls but their amount is less. These are insoluble in water and precursor of Vitamin A. These are of two of types, namely Carotene and Xanthophyll .

Carotenes($C_{40}H_{56}$) are pure hydrocarbons, red or orange in colour. Some of the common carotenes are -α, β, γ and δ carotenes, Phytotene, Neurosporene, Lycopene (Red pigment found in ripe tomato). β—carotene on hydrolysis gives Vitamin A.

Xanthophylls are yellow coloured oxygen containing carotenoids and are most abundant in nature. The most common xanthophyll in green plant is Lutein ($C_{40}H_{56}O_2$) and it is responsible for yellow colour in autumn foliage. Both carotene and xanthophylls are soluble in organic solvents like chloroform, ethyl ether, carbondisulphide etc.

***(iii)* Phycobilins (Biliproteins):**

These are water soluble pigments and are abundantly present in algae, and also found in higher plants. There are two important types of phycobilins-Phycoerythrin (Red) and Phycocyanin (Blue). Like chlorophyll, these pigments are open tetrapyrrole but do not contain Mg and Phytol chain.

Principles of Light absorption:-

- The source of light for photosynthesis is sunlight. Discrete particles present in light are called photons. They carry energy and the energy contained in a photon is termed as quantum.
- The energy content of a quantum is related to its wave length.Shorter the wave length, the greater is the energy present in its quantum.
- Depending upon the wave length electromagnetic spectrum comprises cosmic rays, gamma rays, X-rays,-UV rays, visible spectrum, infra red rays, electric rays and radio waves.
- Photosynthetic pigments absorb light only in the visible spectrum ranges from 390 nm to 760 nm (3900 – 7600A).

- A ray of light falling upon a leaf behaves in 3 different ways. The leaves absorb near about 83% of light, transmit 5% and reflect 12%. From the total absorption, 4% light is absorbed by the chlorophyll.

- Visible spectrum can be resolved into light of different colours i.e., violet (390-430 nm), blue or indigo (430-470 nm), blue green (470-500 nm), green (500 – 580 nm), yellow (580 – 600 nm), orange (600 – 650 nm), orange red (650 – 660 nm) and red (660 – 760 nm). Red light above 700 nm is called far red. Radiation shorter than violet are UV rays (100 – 390 nm). Radiation longer than those of red are called infra red (760 – 10,000 nm).

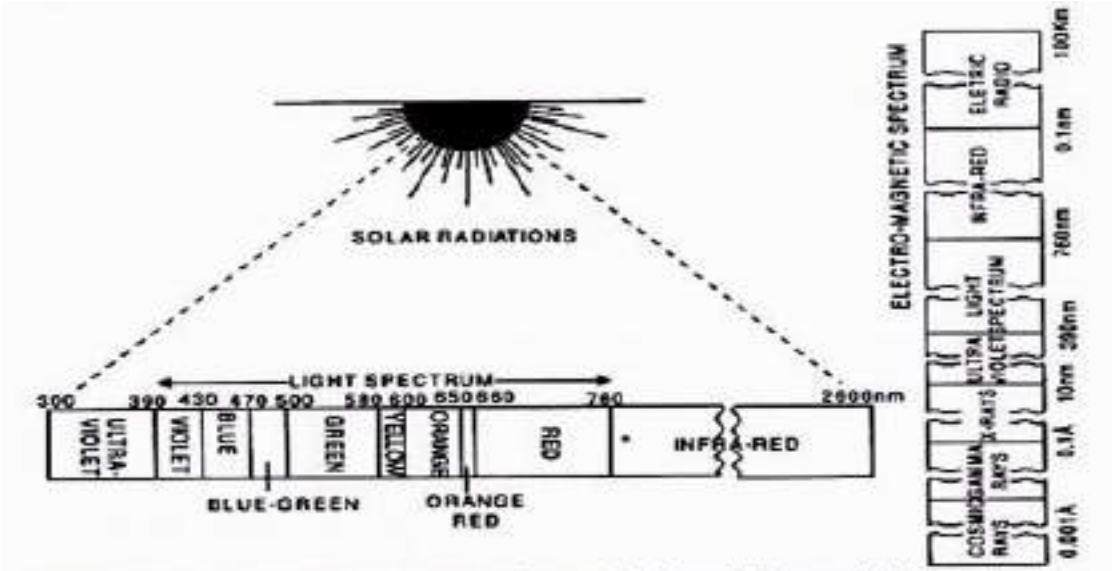


Fig. 6.3(b). Electromagnetic spectrum. Range of solar radiations and light spectrum.

Absorption Spectrum:

All photosynthetic organisms contain one or more organic pigments capable of absorbing visible radiation which will initiate the photochemical reactions of photosynthesis. It varies from pigment to pigment. When the amount of light absorbed by a pigment is plotted as a function of wave length, we obtain absorption spectrum as follows:-

Photo system OR Pigment system(PS):-

A group of co-ordinating photosynthetic molecules necessary to affect a photochemical act (absorption and transfer of the light quantum to trapping centre) is called Photo system. R. Emerson suggested the existence of photo system. park and Beggins named the photosystem as 'Quantosomes'.

According to Emerson there are 2 kinds of Photo systems on Grana lamellae and Stroma lamellae. They are Pigment system I (Photosystem I) and Pigment system II (Photosystem II).

A) Photo system I :-It is the smaller Photo system having size of 110A^{o} , present on outer surfaces of both Grana lamellae and Stroma lamellae of the chloroplast. It is composed of **Pigment molecules** and **Electron carriers**.

- **Pigment molecules** are chlorophyll and Carotenoids. About 200 Chl-a molecules are present which includes Chl-a$_{670}$, Chl-a$_{680}$, Chl-a $_{690}$. Single molecule of Chl-a $_{700}$ constitutes **Reaction centre.** Ligth energy from other pigments is transferred to Reaction centre for its conversion. Energy rich electrons are expelled from it for further photochemical act. In addition to it Chl-b and 50 molecules of Carotene are present.
- **Electron carriers** are 1 molecule of **Ferrodixin reducing substance,** 1 or 2 molecules of **Ferrodoxin,** 2 molecules of **Cytochrome-b$_6$,** 1 molecule of **Cytochrome f,** one molecule of **Plastocyanin.**

Role of Photo system I :-

1. Photo system takes part in trapping light energy and it's conversion into chemical energy.
2. Photo system involves in Cyclic and Non-cyclic Photophosphorylation during Dark reaction.
3. Photo system take part in production of assimilatory powers NADP $^{+}$+ H^{+} and ATP molecules.

B) Photo system II :-Photo system II is the larger Photo system having size 185A^{o}. It is located on the inner surface of Grana lamellae. . It is composed of **Pigment molecules** and **Electron carriers**.

Pigment molecules include about 250 molecules of Chl-a, Chl-b, 50 molecules of carotenoids mostly xanthophylls. Chl-a include Chl-a $_{660}$, Chl-a $_{670.}$ Single molecule of Chl-a $_{680}$ or P$_{680.}$ It constitutes **Reaction centre.**

Electron carriers are one molecule of **Pheophytin (colourless chlorophyll that laks Mg^{++}),** One molecule of **Plastoquonine,** 2 molecules of **Cytochrome b$_6$,** unknown protein **'Zn' and Mn $^{++}$.**

Role of Photo system II :-

1. Photo system II takes part in traping light energy and its convertion into chemical energy.
2. Photo system II involves in only Non-cyclic phosphorylation.
3. Photo system II involves in photo ionization of water and liberation of Oxygen.
4. Photo system II takes part in production of assimilatory power ATP molecule.

Both the pigment systems are inter-connected by a third integral protein complex called cytochrome b – f complex. The other intermediate components of electron transport chain viz., **PQ (plasto quinone**) **and PC (plastocyanin**) act as mobile electron carriers between two pigment systems.

	Photo system II :- PS-I	**Photo system II :-PS-I**
1	PSI is found in thylakoid membrane and stroma lamella.	PS II is found in thylakoid membrane.
2	It contains pigments chlorophyll a 660, chlorophyll a 670, chlorophyll a 680, chlorophyll a 690, and chlorophyll a 700.	It contains pigments as chlorophyll b 650, chlorophyll a 660, chlorophyll a 670, chlorophyll a 678, chlorophyll a 680 – 690 and phycobillins.

3	Chlorophyll a 700 or $P_{700}$is the reaction centre of PS I.	$P_{680-690}$ is the reaction centre of PS II.
4	Chlorophyll a content is more in PS I	Chlorophyll a content is less in PS II
5	Carotenoids are present both in PS II	Carotenoids are present both in PS II
6	PS I is active in both red and far red light.	PS II is inactive in far red light.
7	PS I is associated with both cyclic and non-cyclic photophosphorylation	PS II is associated with only non-cyclic photophosphorylation.
8	wave length longer than 680 nm affect only pigment system I.	Wave length of light shorter than 680 nm affect both the pigment systems.

Antenna molecules: Each pigment system consists of a central core complex and light harvesting complex (LHC). LHC comprises **antenna pigments** associated with proteins (antenna complex). Their main function is to harvest light energy and transfer it to their respective reaction centre. The core complex consists of reaction centre associated with proteins and also electon donors and acceptors.

Mechanism of Photosynthesis:-

Photosynthesis is an oxidation reduction process in which water is oxidized and carbon dioxide is reduced to carbohydrate.

Blackmann (1905) pointed out that the process of photosynthesis consists of two phases:

(1) **Light reaction** or **Light-dependent phase or photochemical phase**: - During light reaction, oxygen is evolved and assimilatory power ATP and $NADPH_2$ are formed.

(2) **Dark reaction** or **Light independent phase or Biochemical phase**:-During dark reaction assimilatory power is utilized to synthesize glucose.

(i) Oxygenic photosynthesis (with evolution of O_2) takes place in green eukaryotes and cyanobacteria (blue-green algae).

$$CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{Sugar} + \text{Oxygen}$$

(ii) Anoxygenic photosynthesis (without the evolution of O_2) takes place in photosynthetic bacteria.

$$CO_2 + H_2S \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{Sugar} + \text{Sulphur or other oxidised compounds or some other inorganic compounds.}$$

I. Light Reaction (Photochemical Phase):

Light reaction or photochemical reaction takes place in thylakoid membrane or granum and it is completely dependent upon the light. The raw materials for this reaction are pigments, water and sunlight.

It can be discussed in the following three steps:

1. Excitation of chlorophyll
2. Photolysis of water

3. Photophosphorylation

1. Excitation of Chlorophyll:

It is the first step of light reaction. When P_{680} or P_{700} (special type of chlorophyll a) of two pigment systems receives quantum of light then it becomes excited and releases electrons.(When photon of light strikes pigment molecules, all the pigments absorb light energy and transfer it to reaction centre Chl-a $_{700}$ PS-Iand Chl-a_{680} in PS-II. These chlorophyll molecules become exited and expel energy rich electrons to electron acceptors.

$$\text{Chlorophyll} \xrightarrow{\text{Light}} \text{CHl}^{+} \text{(oxidised)} + e^{-} \text{(electron)}$$

2. Photolysis of Water and Oxygen Evolution (Hill Reaction):

First time Van Neil discovered that the source of oxygen evolution H_2O.

The idea was supported by R. Hill.

The splitting of water into Hydrogen and ions and hydroxyl ions during photosynthesis is called **Photolysis of water**. Mn, Ca, and CI ions play prominent role in the photolysis of water. Thus formed hydroxyl ions unite to from water, Oxygen and Electrons.This reaction is also known as **Hill reaction**. To release one molecule of oxygen, two molecules of water are required.

$$4H_2O \xrightarrow{\text{Light}} 4H^{+} + 4(OH^{-})$$
$$4(OH) \longrightarrow 4(OH) + 4e^{-}$$
$$4(OH) \longrightarrow 2H_2O + O_2 \uparrow$$
$$2H_2O \longrightarrow 4H^{+} + 4e^{-} + O_2 \uparrow$$

The evolution of oxygen from water was also confirmed by Ruben, Randall, Hassid and Kamen (1941) using heavy isotope (O_{18}) in green alga Chlorella.

3. Photophosphorylation:

Synthesis of ATP from ADP and inorganic phosphate (pi) in presence of light in chloroplast is known as **Photophosphorylation.** It was discovered by Arnon (1954).

Photophosphorylation is of two types.

(a) Cyclic photophosphorylation

(b) Non-cyclic photophosphorylation.

(a) Cyclic Photophosphorylation:

The process of photophosphorylation in which an electron expelled by the excited photo Centre (PSI) is returned to it after passing through a series of electron carriers is called **"Cyclic Photophosphorylation"**.

1. It occurs in low light intensity, wavelength longer than 680 nm and when CO_2 fixation is inhibited.
2. Absence of CO_2 fixation results in non requirement of electrons as $NADPH_2$ is not being oxidized to $NADP^{+}$.
3. Cyclic Photophosphorylation is performed by photosystem I only. Its photo Centre P_{700} extrudes an electron with a gain of 23 kcal/mole of energy after absorbing a photon of light.

4. After losing the electron the photo Centre becomes oxidized. The expelled electron passes through a series of carriers FeS, ferredoxin, plastoquinone, cytochrome b- f complex and plastocyanin before returning to photo Centre.
5. While passing between ferredoxin and plastoquinone and/or over the cytochrome complex, the electron loses sufficient energy to form ATP from ADP and inorganic phosphate.

6. Halobacteria(Halophile bacteria) also perform Photophosphorylation but ATP thus produced is not used in synthesis of food. These bacteria possess purple pigment bacteriorhodopsin attached to plasma membrane. As light falls on the pigment, it creates a proton pump which is used in ATP synthesis.

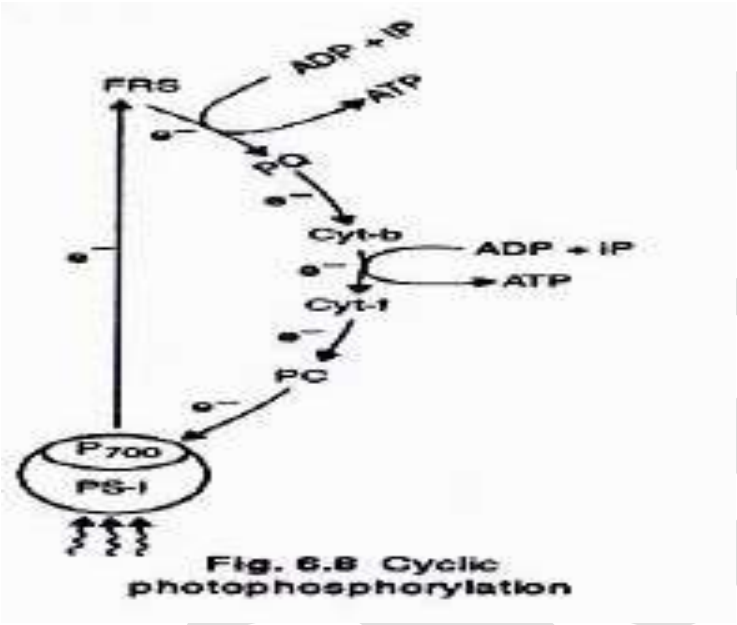


Fig. 6.8 Cyclic photophosphorylation

(b) Noncyclic Photophosphorylation (Z-Scheme):

The normal process of photophosphorylation in which the electron expelled by the excited photo Centre (reaction centre) does not return to it is called "**Noncyclic Photophosphorylation",** It is also called **"Z scheme'** as electrons travel in Zig-Zag manner through electrons carriers.

1. Non-cyclic photophosphorylation is carried out in collaboration of both photo system I and II.
2. Electron released during photolysis of water is picked up by reaction centre of PS-II, called P_{680}. When the reaction centre absorbs light energy, these electrons are extruded out. (The extruded electron has an energy equivalent to 23 kcal/mole).
3. It passes through a series of electron carriers— Phaeophytin, PQ, cytochrome b- f complex and plastocyanin.
4. While passing over cytochrome complex, the electron loses sufficient energy for the synthesis of ATP.

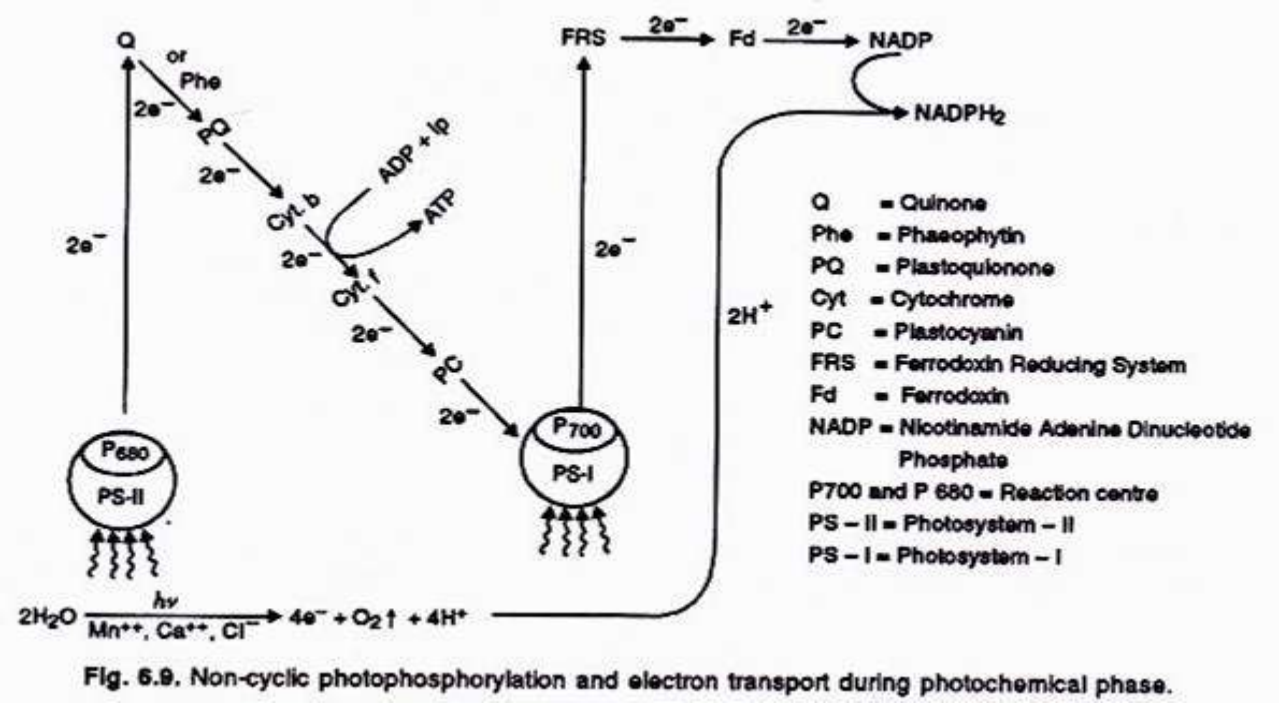


Fig. 6.9. Non-cyclic photophosphorylation and electron transport during photochemical phase.

5. The electron is handed over to reaction centre P_{700} of PS-I by plastocyanin. P_{700} extrudes the electron after absorbing light energy.
6. The extruded electron passes through FRS ferredoxin, and NADP -reductase which combines it with $NADP^+$ for becoming reduced through H+ releasing during photolysis to form $NADPH_2$. ATP synthesis is not direct.
7. The energy released by electron is used for pumping H^+ ions across the thylakoid membrane. It creates a proton gradient. This gradient triggers the coupling factor to synthesize ATP from ADP and inorganic phosphate (Pi).

<u>CONCLUSION</u>: At the end of Light reaction assimilatory powers like strong reducing agents $NADPH_2$ and High chemical energy compound ATP are formed with the liberation of Oxygen.

II. <u>Dark Reaction OR Thermochemical reaction OR Carbon assimilation reaction.</u>

Dark reaction is the Second Part of mechanism of photosynthesis. It is not light dependent process. It takes part in Stroma part of the chloroplast. It is an independent of light .Hence it is called **Dark reaction**, (But it depends upon the products of light reaction of photosynthesis, i.e., $NADPH_2$ and ATP). In 1905 Blackman demonstrated Thermo chemical reduction of Co_2 into carbohydrate. Hence it is also called **"Blackmann reaction".**

The CO_2 assimilation takes place both in light and darkness when the substrates $NADPH_2$ and ATP are available. CO_2 fixation is closely linked to the light reactions. During evolution three different ecological variants have evolved with different CO_2 incorporation mechanism: **C_3, C_4 and CAM plants**.

Calvin or C_3 Cycle or PCR (Photosynthetic Carbon Reduction Cycle):

- **C_3 Cycle** is the basic mechanism of CO_2 is fixation to form carbohydrates. It was proposed by Melvin **Calvin**.
- Calvin along with A.A. Benson, J. Bassham used radioactive isotope of carbon (C^{14}) in Chlorella pyrenoidosa and Scenedesmus to determine the sequences of dark reaction. For this work Calvin was awarded Nobel Prize in 1961. Hence it is called "**Calvin cycle**".
- During Calvin cycle 3 **Carbon compound Phospho glyceric acid is first stable product**, hence this path way is also called **"C_3 cycle".** To synthesize one glucose molecule Calvin cycle requires $6CO_2$, 18 ATP and 12 $NADPH_2$.

Calvin cycle completes in 4 major phases:

1. **Carboxylation phase**
2. **Reductive phase**
3. **Glycolytic reversal phase (sugar formation phase)**
4. **Regeneration phase**

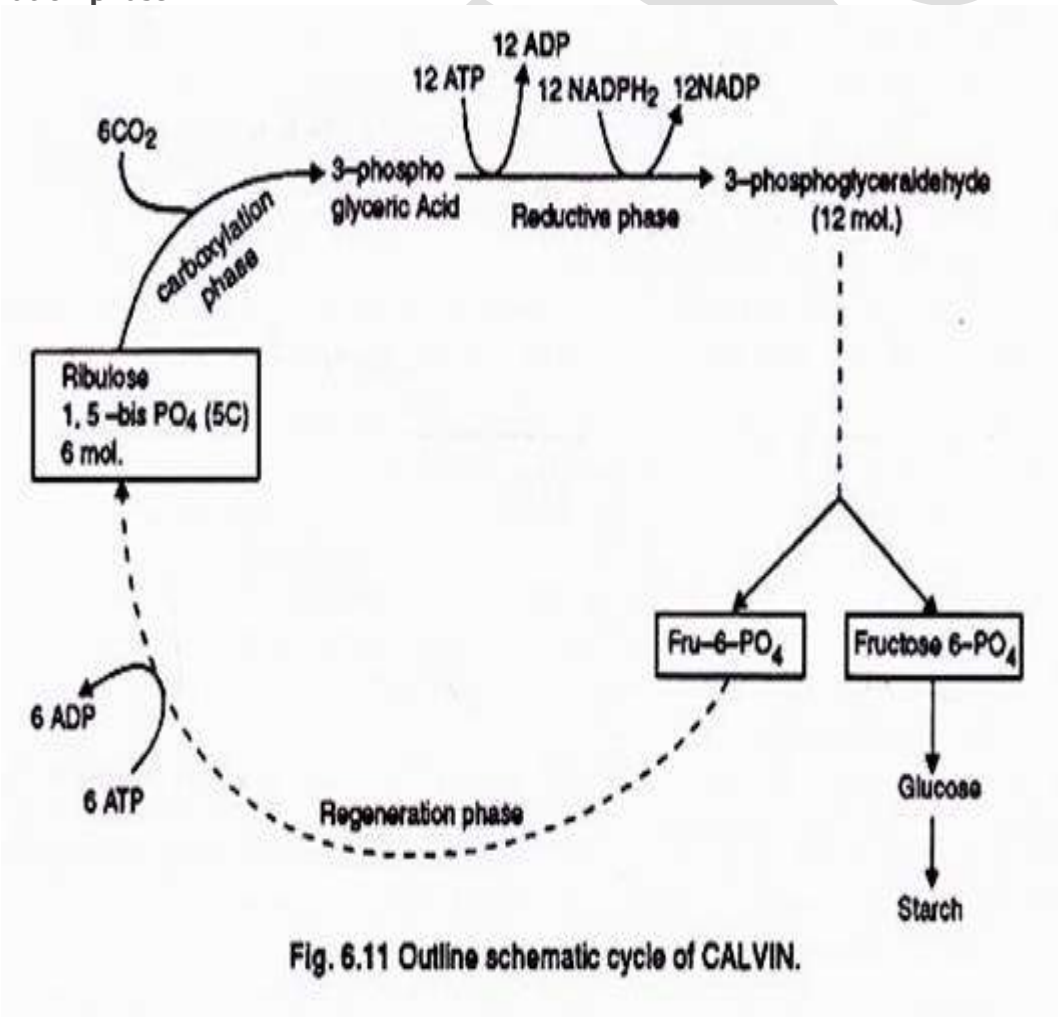


Fig. 6.11 Outline schematic cycle of CALVIN.

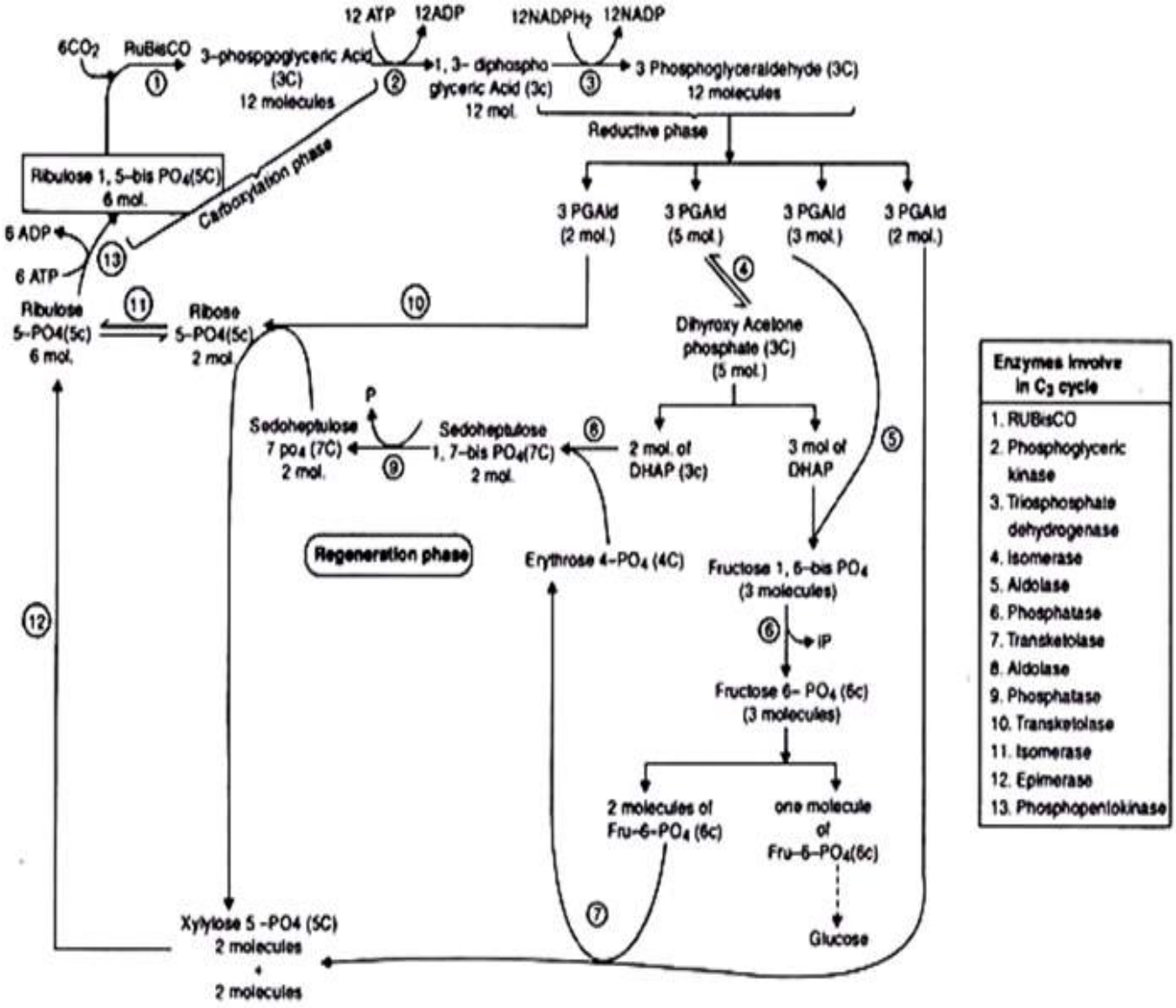
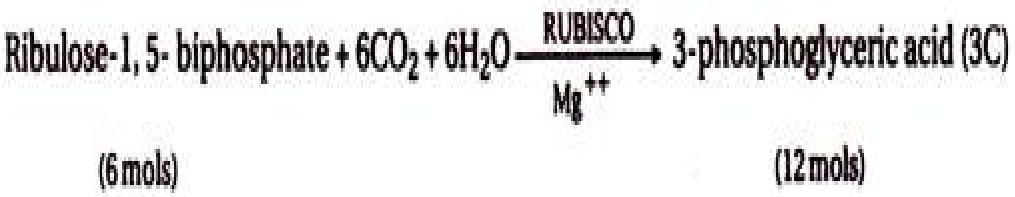


Fig. 6.12 C_3 cycle/CALVIN CYCLE.

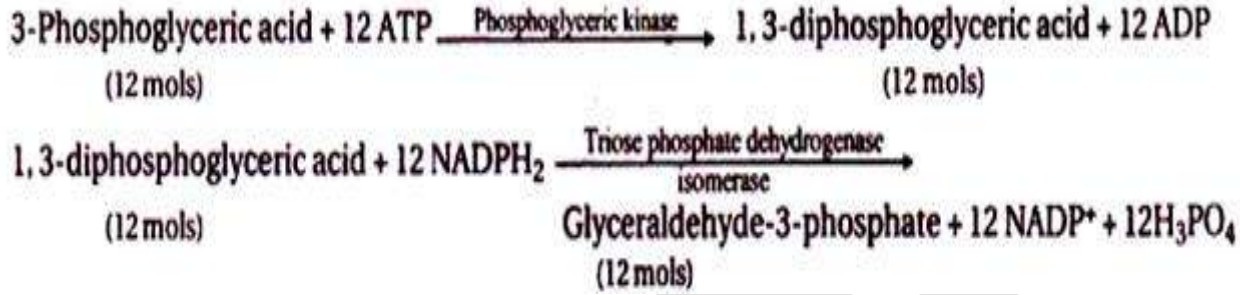
1. Carboxylation phase:

CO_2 enters the leaf through stomata. In mesophyll cells, CO_2combines with a phosphorylated 5-carbon sugar, called **Ribulose bisphosphate** (or RuBP) in presence of an enzyme RUBISCO(RUBP carboxylase). 6 molecules of RUBP absorb 6 molecules of CO2 to form 6 molecules of unstable Carbon compound.(2-carboxy 3-keto 1,5-biphosphorbitol) Which breaks down into two molecules of first stable product 3-phosphoglyceric acid (PGA) of dark reaction (C_3 Cycle).



2. Reductive Phase:

The PGA molecules are phosphorylated by ATP molecule and reduced to form 3-phospho-glyceraldehyde (PGAL) by $NADPH_2$ (product of light reaction known as assimilatory power).



3. Formation of sugar (Glycolytic Reversal Phase):

- Out of two molecules of 3-phosphoglyceraldehyde (PGAL) one molecule is converted to its isomer 3-dihydroxyacetone phosphate (DHAP).
- DHAP reacts with one molecule of Phosphoglyceraldehyde to form Fructose 1,6-biphosphate in presence of Aldolase..
- Fructose 1,6-biphosphate is converted into Fructose-6- phosphate and one molecule of phosphoric acid in presence of phosphotase.
- Fructose-6- phosphate is converted into Fructose-1- phosphate which forms Glucose 1- phosphate.
- Fructose-1- phosphate and Glucose 1- phosphate condense to from Sucrose.

$$\underset{(1\ mol)}{\text{3-phosphoglyceraldehyde}} \xrightarrow[\text{isomerase}]{\text{Phosphotriose}} \underset{(1\ mol)}{\text{3-dihydroxyacetone phosphate}}$$

One mol of 3-dihydroxyacetone phosphate reacts with 1 mol of 3-phosphoglycraldehyde to form one molecule of fructose-1, 6-biphosphate.

$$\underset{(1\ mol)}{\text{3-Phosphoglyceraldehyde}} + \underset{(1\ mol)}{\text{Dihydroxyacetone phosphate}} \xrightarrow{\text{Aldolase}} \underset{(1\ mol)}{\text{Fructose-1, 6-biphosphate (6C)}}$$

One mol of fructose-6-phosphate and one mol of phosphoric acid is released from one mol of fructose-1, 6-biphosphate with the help of the enzyme phosphatase with utilization of one mol of H_2O.

$$\underset{(1\ mol)}{\text{Fructose-1, 6-biphosphate}} \xrightarrow[H_2O]{\text{Phosphatase}} \underset{(1\ mol)}{\text{Fructose-6-phosphate}} + H_3PO_4$$

Fructose-6-phosphate is converted to fructose-1-phosphate which forms glucose-1-phosphate.

$$\underset{(1\ mol)}{\text{Fructose-6-phosphate}} \longrightarrow \underset{(1\ mol)}{\text{Fructose-1-phosphate}} \longrightarrow \underset{(1\ mol)}{\text{Glucose-1-phosphate}}$$

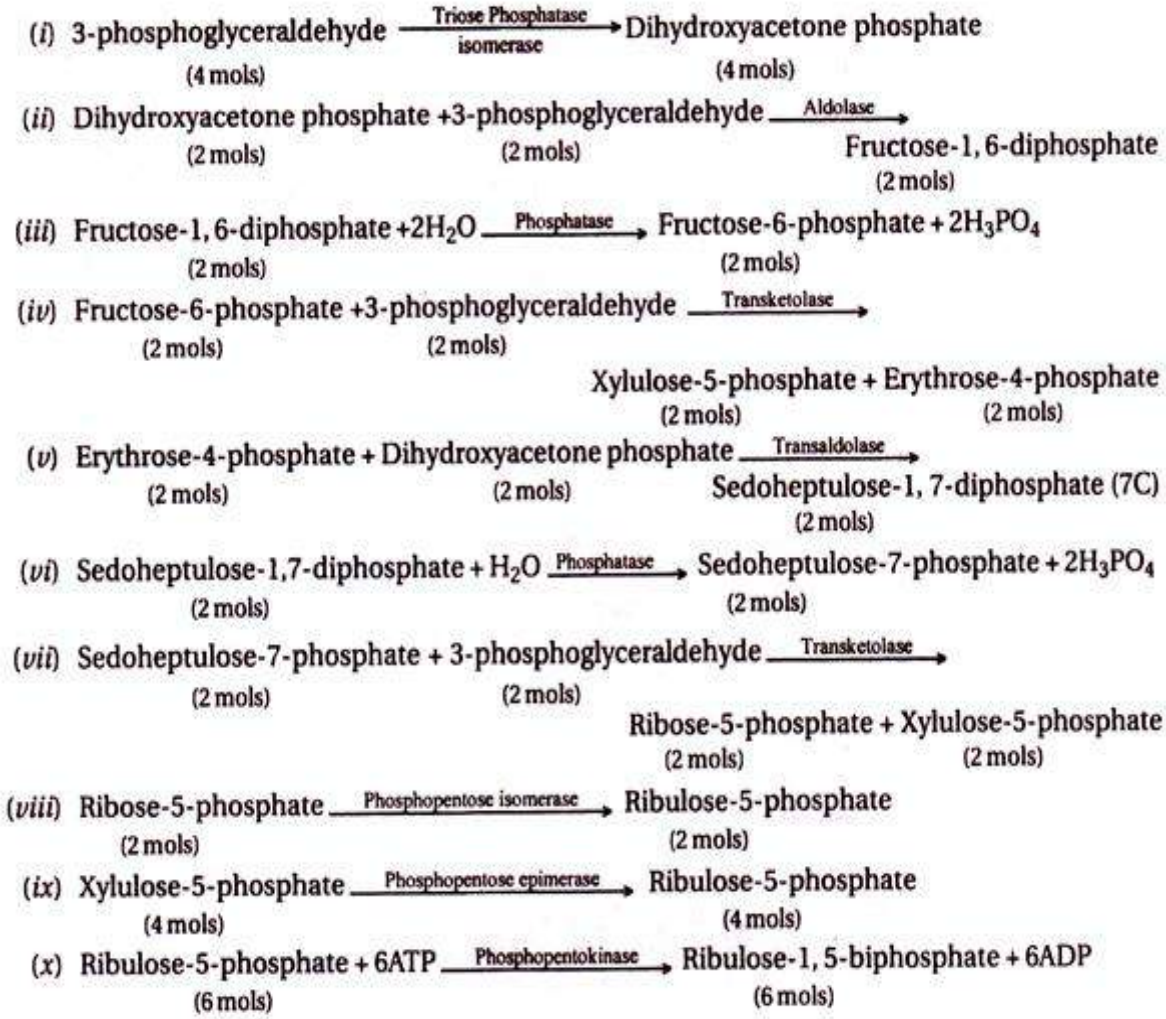
Fructose-6-phosphate and glucose-1-phosphate condense to form sucrose.

$$\underset{(1\ mol)}{\text{Fructose-6-phosphate}} + \underset{(1\ mol)}{\text{Glucose-1-phosphate}} \xrightarrow{\text{Phosphatase}} \underset{(1\ mol)}{\text{Sucrose}}$$

From sucrose are produced other carbohydrate, *e.g.*, starch etc.

5. **Regeneration of RUBP:**

The remaining PGAL molecules are subjected to several biochemical steps to regenerate 6 molecules of RUBP to complete the cycle.



Summary of Photosynthesis:

(A) Light Reaction takes place in thylakoid membrane or granum

$$24H_2O \longrightarrow 24OH^- + 24H^+$$
$$18ADP + 18P_i \longrightarrow 18ATP$$
$$12NADP^+ + 24H^+ \longrightarrow 12NADPH_2$$
$$24OH^- - 24e \longrightarrow 12H_2O + 6O_2$$
$$24OH \longrightarrow 12H_2O + 6O_2$$

(B) Dark Reaction (C_3 cycle) takes place in stroma of chloroplast.

$$6CO_2 + 18\,ATP + 12\,NADPH_2 \xrightarrow{Enzymes} C_6H_{12}O_6 + 6H_2O + 18ADP + 18iP + 12NADP$$

$$\text{Addition of A \& B}: 6CO_2 + 24H_2O \xrightarrow[Chlorophyll]{Light} C_6H_{12}O_6 + 18H_2O + 6O_2$$

or

$$6CO_2 + 18\,ATP + 12\,NADPH_2 \xrightarrow{Enzymes} C_6H_{12}O_6 + 6H_2O + 18ADP + 18iP + 12NADP$$

$$\text{Addition of A \& B}: 6CO_2 + 12H_2O \xrightarrow[Chlorophyll]{Light} C_6H_{12}O_6 + 6H_2O + 6O_2$$

C_4 Cycle (Hatch and Slack path way OR Kortschak Cycle OR (Dicarboxylic acid cycle):-

In Graminae members during Dark reaction fixation of carbon di oxide takes place by **$C_{4\ path}$ way**. It is so called because the first intermediate stable compound produced is 4'C' compound oxalo acetic acid. It is composed of 2 carboxyl groups, hence it is also be referred as the **Di-carboxylic acid cycle** . it was first explained by Hatch and Slack hence called **Hatch and Slack Path way.**

This pathway was first reported in members of family Poaceae like sugarcane, maize, sorghum, in subtropical plant like Atriplex spongiosa (Salt bush), Dititaria samguinolis, Cyperus rotundus, Amaranthus etc. and also among certain members of Cyperaceae and certain dicots.

Structural Peculiarities of C_4 Plants (Kranz Anatomy):

- C_4 plants have a characteristic leaf anatomy called **Kranz anatomy**.
- Dimorphic (two morphologically distinct type) chloroplasts occur in C_4 plants.
- The vascular bundles of leaves in C_4 plant are surrounded by a layer of bundle sheath cells that contain large number of chloroplast twithout grana.
- But mesophyll surrounding this contains small chloroplast with Grana.
- C_4 Path way involves 2 carboxylation reactions. one taking place in chloroplast of Mesophyll and another in chloroplas of Bundle sheath.

In Mesopyll cell:

(i) Chloroplast is small in size, well developed grannum and less developed stroma.
(ii) Both PS-II and PS-I are present. Non cyclic photophosphorylation takes place.
(v) ATP and $NADPH_2$ produces.
(vi) Stroma carries PEPCO but absence of RuBisCO.
(vii) CO_2 acceptor is PEPA (3C) but absence of RUBP
(viii) First stable product OAA (4C) produces.

In Bundle sheath Cell:

(i) Size of chloroplast is large
(ii) Stroma is more developed but granna is poorly developed.
(iii) Only PS-I present but absence of PS-II
(iv) Non Cyclic photophosphorylation does not takes place.

(v) Stroma carries RuBisCO but absence of PEPCO.

(vi) CO_2 acceptor RUBP (5c) is present but absence of PEPA (3C)

(vii) C3-cycle takes place and glucose synthesies.

(viii) To carry out C3-cycle both ATP and NADPH2 comes from mesophyll cell chloroplast.

1. **Fixation of CO_2** Carbon dioxide from atmosphere is accepted by Phosphoenol pyruvic acid (PEPA) present in stroma of mesophyll cell chloroplast and it converts to oxaloacetic acid (OAA) in the presence of enzyme PEPCO (Phosphoenolpyruvate carboxylase).
2. **Formation of Malic acid**: This OAA enters into the chloroplast of bundle sheath cell and there it undergoes oxidative decarboxylation yielding pyruvic acid (3C) and CO_2.
3. The carbon dioxide released in bundle sheath cell reacts with RuBP (Ribulose 1, 5 bisphosphate) in presence of RUBISCO and carry out Calvin cycle to synthesize glucose. Pyruvic acid enters mesophyll cells and regenerates PEPA. In C_4 cycle two carboxylation reactions take place.

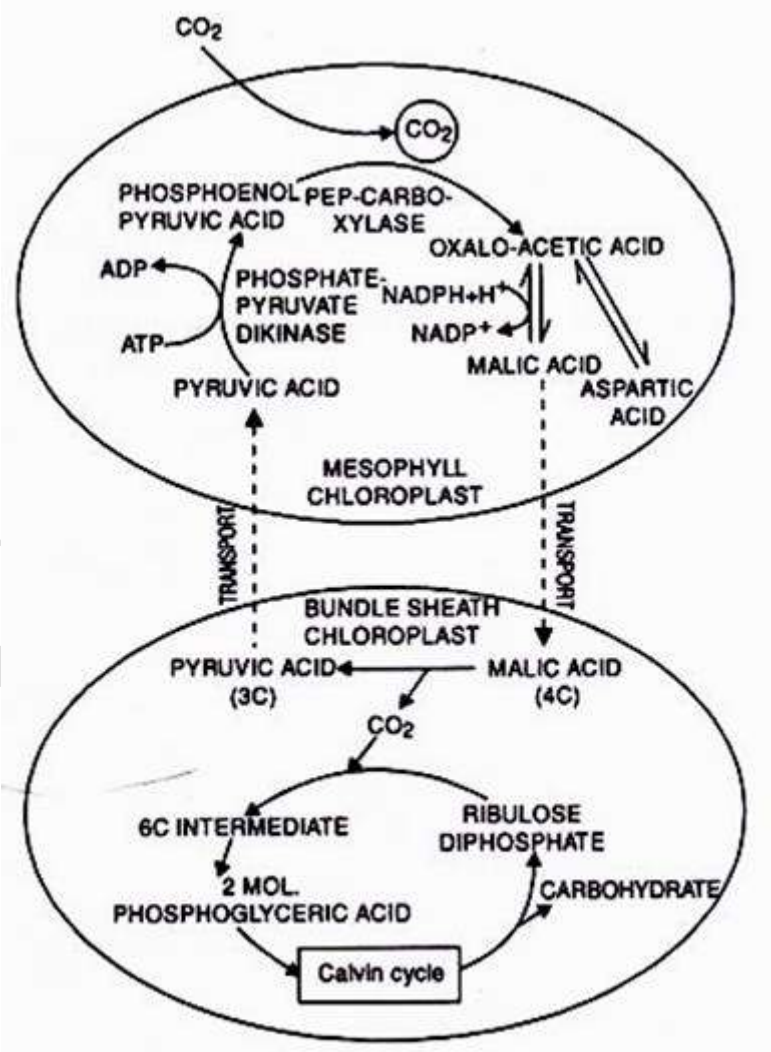


Fig. 6.14. HSK pathway or C_4 cycle

Reactions taking place in mesophyll cells are stated below: -(1st carboxylation)

C_4 plants are better photosynthesizes. There is no photorespiration in these plants. To synthesize one glucose molecule it requires 30 ATP and 12 $NADPH_2$.

Significance of C_4 Cycle:

1. C_4 plants have greater rate of carbon dioxide assimilation than C_3plants because PEPCO has great affinity for CO_2 and it shows no photorespiration resulting in higher production of dry matter.
2. C_4 plants are better adapted to environmental stress than C_3 plants.
3. Carbon dioxide fixation by C_4 plants requires more ATP than C_3plants for conversion of pyruvic acid to PEPA.
4. Carbon dioxide acceptor in C_4 plant is PEPA and key enzyme is PEPCO.
5. They can very well grow in saline soils because of presence of C_4organic acid.

Crassulacean Acid Metabolism (CAM Pathway):-

It is a mechanism of photosynthesis which occurs in succulents and some other plants of dry habitats where the stomata remain closed during the daytime and open only at night. The process of photosynthesis is similar to that of C_4 plants but instead of spatial separation of initial PEPcase fixation and final Rubisco fixation of CO_2, the two steps occur in the same cells (in the stroma of mesophyll chloroplasts) but at different times, night and day, e.g., Sedum, Kalanchoe, Opuntia, Pineapple (Fig. 6.13). (CAM was for the first time studied and reported by Ting (1971).

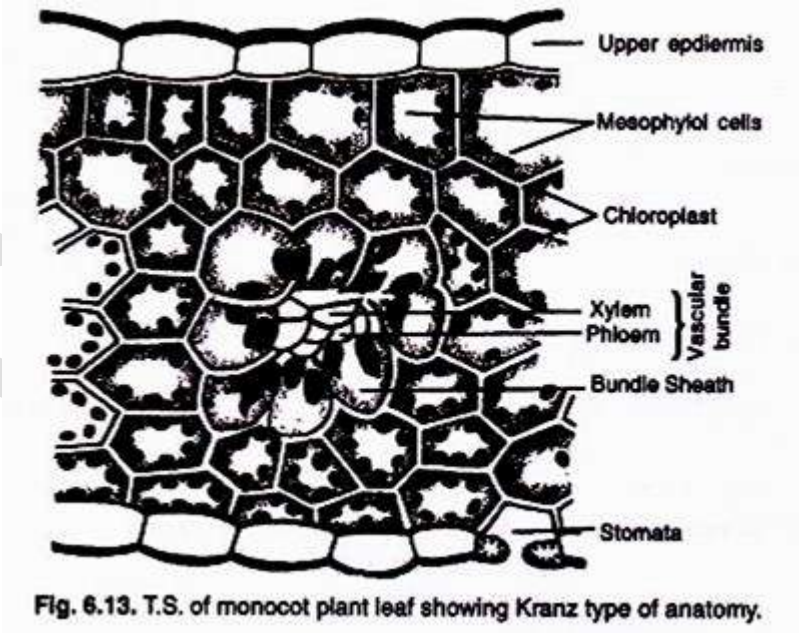


Fig. 6.13. T.S. of monocot plant leaf showing Kranz type of anatomy.

Characteristics of CAM Plants:-

1. Stomatal movement is scoto-active.
2. Presence of monomorphic chloroplast.
3. Stroma of chloroplast carries both PEPCO and RUBISCO.
4. Absence of Kranz anatomy.
5. It is more similar to C_4 plants than C_3 plants.

6. In these plants pH decreases during night and increases during day time.

Mechanism of CAM Pathway:

PHASE I. During night:-

Stomata of Crassulacean plants remain open at night. Carbon dioxide is absorbed from outside. With the help of Phosphoenol pyruvate carboxylase (PEPCO) enzyme the CO_2 is immediately fixed and here the acceptor molecule is Phosphoenol pyruvate (PEP).

$$PEP + HCO_3^- (CO_2 + H_2O) \xrightarrow{PEPCO} \text{Oxaloacteic acid (OAA)} + H_3PO_4$$

$$\text{Oxaloacetic acid} + NADPH \xrightarrow{\text{Dehydrogenase}} \text{Malic Acid} + NADP^+$$

Malic acid is the end product of dark fixation of CO_2. It is stored inside cell vacuole.

PHASE II:- During day time

The stomata in Crassulacean plants remain closed to check transpiration, but photosynthesis does take place in the presence of sun light. Malic acid moves out of the cell vacuoles. It is de-carboxylated with the help of malic enzyme. Pyruvate is produced. It is metabolized.

$$\text{Malic Acid (Malate)} + NADP^+ \xrightarrow[\text{Enzyme}]{\text{Malic}} \text{Pyruvate} + CO_2 + NADPH_2$$

The CO_2 thus released is again fixed through Calvin Cycle with the help of RUBP and RUBISCO. This is a unique feature of these succulent plants where they photosynthesis without wasting much of water. They perform acidification or dark fixation of CO_2 during night and de-acidification during day time to release carbon dioxide for actual photosynthesis.

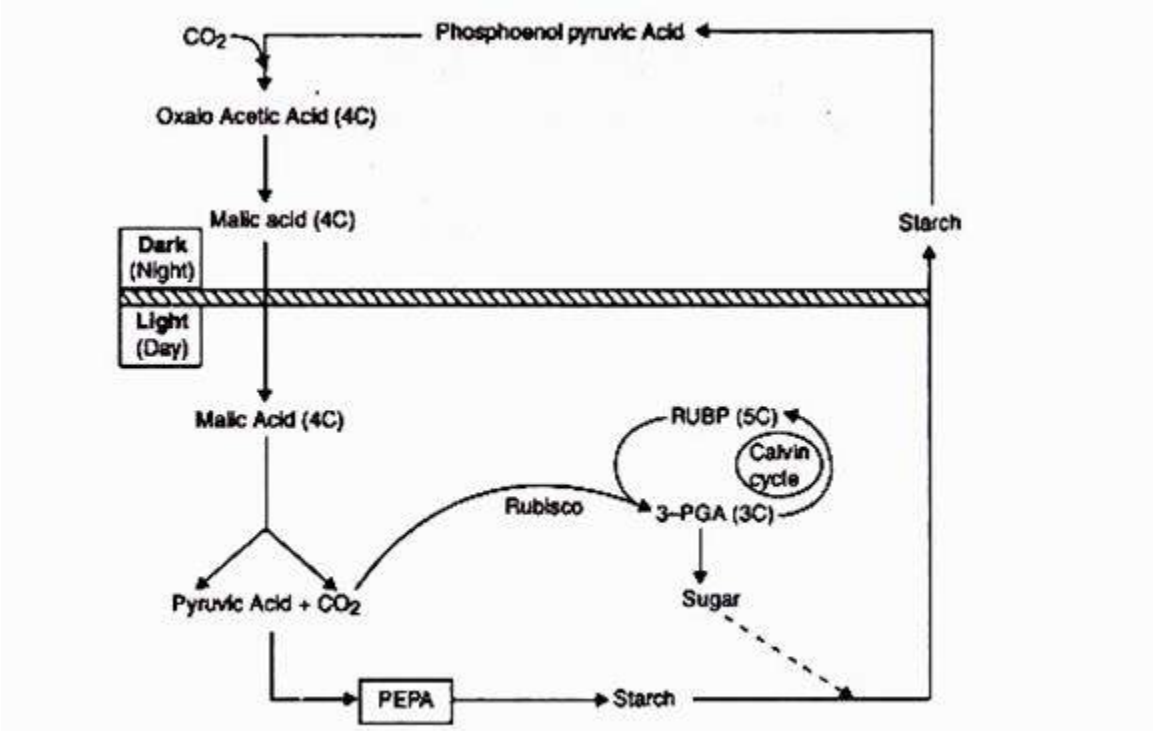


Fig. 6.15. Mechanism of Crassulacean acid metabolism (CAM) showing CO_2 uptake from outside during night and its utilisation in photosynthesis during daytime.

Ecological Significance of CAM Plants:

These plants are ecologically significant because they can reduce rate of transpiration during day time, and are well adapted to dry and hot habitats.

1. The stomata remain closed during the day and open at night when water loss is little due to prevailing low temperature.

2. CAM plants have parenchyma cells, which are large and vacuolated. These vacuoles are used for storing malic and other acids in large amounts.

3. CAM plants increase their water-use efficiency, and secondly through its enzyme PEP carboxylase, they are adapted to extreme hot climates.

4. CAM plants can also obtain a CO_2 compensation point of zero at night and in this way accomplish a steeper gradient for CO_2 uptake compared to C_3 plants.
5. They lack a real photosynthesis during daytime and the growth rate is far lower than in all other plants (with the exception of pineapple).

2. Marks questions

1. What is Photosynthesis? Mention the pigments involved.
2. What is Cyclic Photo phosphorylation?
3. Differentiate between Cyclic and Non-Cyclic Photophosphorylation
4. What is meant by Kraz anatomy? Mention organells involved.
5. Expand CAM. Mention its significance.

5 Marks questions

1. Explain Cyclic Photophosphorylation.
2. Explain Non-Cyclic Photophosphorylation.
3. Write note on Photosynthetic pigment.
4. DescribeCAM plants.
5. Differentiate between C_3 and C_4 Cycle.
6. With neat labelled Diagram explain chloroplast/Photosynthetic apparatus.
7. ExplainC_4 Cycle /Hatch and Slack path way / Kortschak Cycle / Dicarboxylic acid cycle.
8. Explain PS-I and PS-II.

10 Marks questions

1. Describe Light reaction.
2. Explain Calvin cycle (C_3).

Unit 4: Respiration (6 Hrs)

Structure of mitochondrion, Glycolysis, anaerobic respiration, TCA cycle; Oxidative Phosphorylation, Pentose Phosphate Pathway.

Definition:-

Organisms use stored energy such as glucose and starch for their activities by oxidising them into simple low energy molecules carbon dioxide and water. The **process of oxidation (**breakdown) **of complex high energy food molecules into simple low energy molecules like** CO2 and H_2O, releasing the energy in living cells is known **as "Respiration"**. The compounds that are oxidised during process of respiration are called "**Respiratory substrates"**. They may be carbohydrates, fats and proteins.

- The energy released during oxidation of energy rich compounds is made available for activities of cells through an intermediate compound called **adenosine triphosphate** (ATP).
- The whole of energy contained in respiratory substrates is released slowly in several steps of reactions controlled by different enzymes.
- Respiration takes place in all types of living cells, called **cellular respiration**.
- During respiration oxygen is utilised, and CO_2 water and energy are released as products.
- 686 kcal or 2870 kJ of energy is liberated per molecule of glucose. The released energy is utilised in various energy-requiring activities of the organisms, and the carbon dioxide released during respiration is used for biosynthesis of other molecules in the cell.

The reaction that occurs in common respiration of glucose may be summed up as follows:

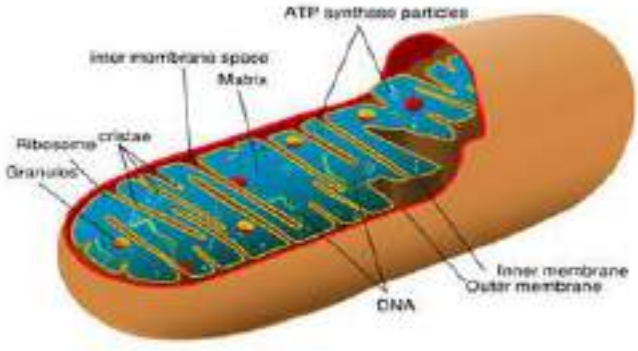
$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{enzymes}} 6CO_2 + 6H_2O + \text{Energy}$$

(2870 kJ or 686 kcal)

Structure of Mitochondria

Mitochondria chondriosomes are regarded as " Respiratory apparatus". These are present in cytoplasm of a cell. In 1850 Kollikar observed it. In 1897 Benda named it. Shape and size varies from cell to cell. It is 2 to8 µm in length and 0.2 to 1 µm in diameter.

Typical Mitochondrion is Rod shaped bounded **by 2 layered Lipoprotein** membranes enclosing proteinaceous granular **Mitochondrial matrix** which is composed of DNA, RNA, Ribosomes, proteins and enzymesthat takes place in Kreb's cycle.Space between 2 layers is called **Perichondrial space**.outer membrane smooth , inner membrane is convoluted forming inflodings called **Cristae.** On the surface of Cristae knob like stalked particles called '**Rackers particles" or 'Oxysoms' or 'Elementary particles**.each particle has Base , stalk and spherical head.base has an intergral membrane protein complex **Fo** and Head has membrane protein complex **F1** for ATP synthesis during oxidative phosphorylation. **Function:** Mitichondria are power house of Eukaryotuc cells as they take part in ATP generation during Aerobic respiration



Types of Respiration:

There are two main types of respiration. They are (i) Aerobic, and (ii) Anaerobic.

(i) Aerobic Respiration:

Aerobic respiration is **complete oxidation** of stored food (organic substances) **in the presence of oxygen,** and releases carbon dioxide, water and a large amount of energy Ex: higher organisms.

The overall equation is:

$$C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{oxidation}]{\text{enzymes}} 6CO_2 + 6H_2O + \text{energy}$$

(2870 kJ) or (686 k cal)

(ii) Anaerobic respiration:

Anaerobic respiration is an **incomplete oxidation of stored food** resulting in the formation of carbon dioxide and ethyl alcohol or various organic acids, such as malic, citric, oxalic, tartaric **in absence of oxygen**. Very little energy is released by this process to maintain activity of protoplasm.

EX: bacteria and fungi. Many tissues of higher plants, seeds in storage, fleshy fruits, and succulent plants, such as cacti temporarily take anaerobic respiration. **The equation is as follows:**

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + \text{Energy}$$

(247 kJ) or (28 k cal)

This process of oxidation in microbes is known as fermentation. This is quite similar to that of anaerobic respiration in case of higher plants.

Mechanism of Respiration:

There are two major phases of respiration**: (i) Glycolysis, and (ii) Krebs cycle.**

- During respiration, **carbohydrates are converted into pyruvic acid** through a series of enzymatic reactions. This series of reactions is known as **glycolysis** which takes place in **cytosol.**
- **Pyruvic acid enters mitochondria**, where several enzymes catalyse the reactions, and pyruvic acid finally **converts into CO_2 and water**. This series of enzymatic reactions is known as **Krebs cycle.**

Glycolysis(Greek words, glycos = sugar and lysis = splitting).

The scheme of glycolysis was discovered by three German Scientists, Gustav **Embden**, Otto **Meyerhof** and J. **Parnas**, and therefore, referred as **EMP pathway**. Glycolysis is common to both aerobic and anaerobic respiration.

Glycolysis occurs in cytoplasm of cells. During this process, glucose undergoes partial oxidation to form two molecules of pyruvic acid.

The main steps of glycolytic pathway are as follows:-

a. Phosphorylation of Sugar (i.e., First Phosphorylation):-Glucose and fructose are phosphorylated to give rise to **glucose-6-phosphate and fructose-6-phosphate,** respectively, by the activity of enzyme **hexokinase**, in presence of ATP. The phosphorylated form of glucose then isomerises to produce fructose-6-phosphate. Isomerisation takes place with the help of enzyme phosphohexose isomerase.

Further steps of metabolism of glucose and fructose are quite similar.

Equations are as follows:

$$\text{Glucose (6C) + ATP} \xrightarrow[Mg^{2+}]{\text{hexokinase}} \text{Glucose-6-phosphate + ADP}$$

Now isomerisation occurs :

$$\text{Glucose-6-phosphate} \underset{\text{isomerase } Mg^{2+}}{\overset{\text{phosphohexose}}{\rightleftharpoons}} \text{Fructose-6-phosphate}$$

b. Phosphorylation of Fructose-6-Phosphate (i.e., Second Phosphorylation):

Fructose-6-phosphate is phosphorylated and **fructose-1, 6-bisphosphate** produced by the action of enzyme **phosphofructokinase** in presence of ATP.

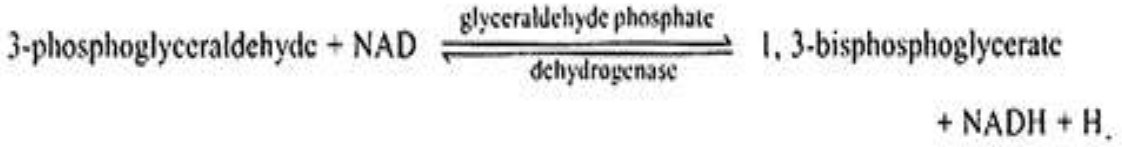
$$\text{Fructose-6-phosphate + ATP} \xrightarrow[Mg^{2+}]{\text{phosphofructokinase}} \text{Fructose-1, 6-bisphosphate + ADP}$$

c. Splitting:-Fructose- 1, 6-bisphosphate splits into two molecules of **triose phosphate, i.e., 3-phosphoglyceraldehyde (PGAL**) and **dihydroxyacetone phosphate (Di HAP),** which are interconvertible.

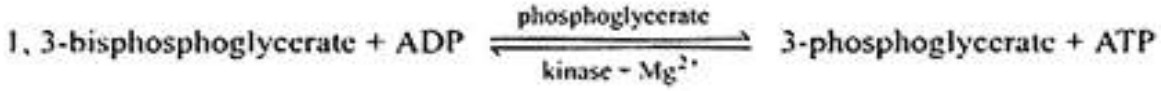
$$\text{Fructose-1, 6-bisphosphate} \overset{\text{aldolase}}{\rightleftharpoons} \text{3-phosphoglyceraldehyde (PGAL) + dihydroxyacetone phosphate (Di HAP).}$$

d. Oxidative Dehydrogenation:-

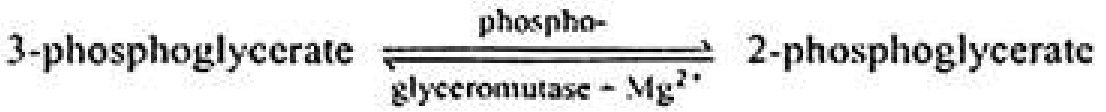
After formation of 3-phosphoglycerldehyde (PGAL) is oxidized to a carboxylic acid, i.e., **1, 3-bisphosphoglycerate**, and NAD is reduced to NADH.



e. <u>Formation of ATP:-</u>1, 3-bisphosphoglycerate is converted into **3-phosphoglycerate** by enzyme **phosphoglycerate kinase**, and ATP is generated during this process. Direct synthesis of ATP from intermediate metabolites is called substrate level phosphorylsation.



f. <u>Isomerisation:-</u>3-phosphoglycerate is converted into its isomer **2- Phosphoglycerate** by catalytic activity of enzyme **phosphoglyceromutase.**



g. <u>Dehydration:-</u>2-phosphoglycerate converts into **phosphoenol pyruvate** (PEP) in the presence of enzyme **pyruvate kinase** and liberates ATP.

<u>Generation and Utilisation of ATP during Glycolysis:</u>

During glycolytic pathway, the molecules of ATP are produced by

(i) Direct transfer of phosphate to ATP and

(ii) Oxidation of NADH produced during glycolytic pathway to NAD^+.

<u>In the end of glycolysis net gain of ATP:-</u>

(i) During glycolysis two triose phosphate molecules are formed from one glucose molecule, and **4 ATP molecules are produced**.

(ii) Out of 4 ATP molecules, 2 ATP molecules are utilised in first few steps in converting glucose to fructose-1, 6 bisphosphate.

(iii) **3 ATP molecules are produced** from oxidation of each of two molecules of NADH produced during catabolism of glucose.

(iv) In all, a **net gain of 8 molecules** occurs during process of glycolysis.

(v) In anaerobic respiration, NADH + H^ is not converted to ATP, and therefore, only 2 ATP molecules are produced.

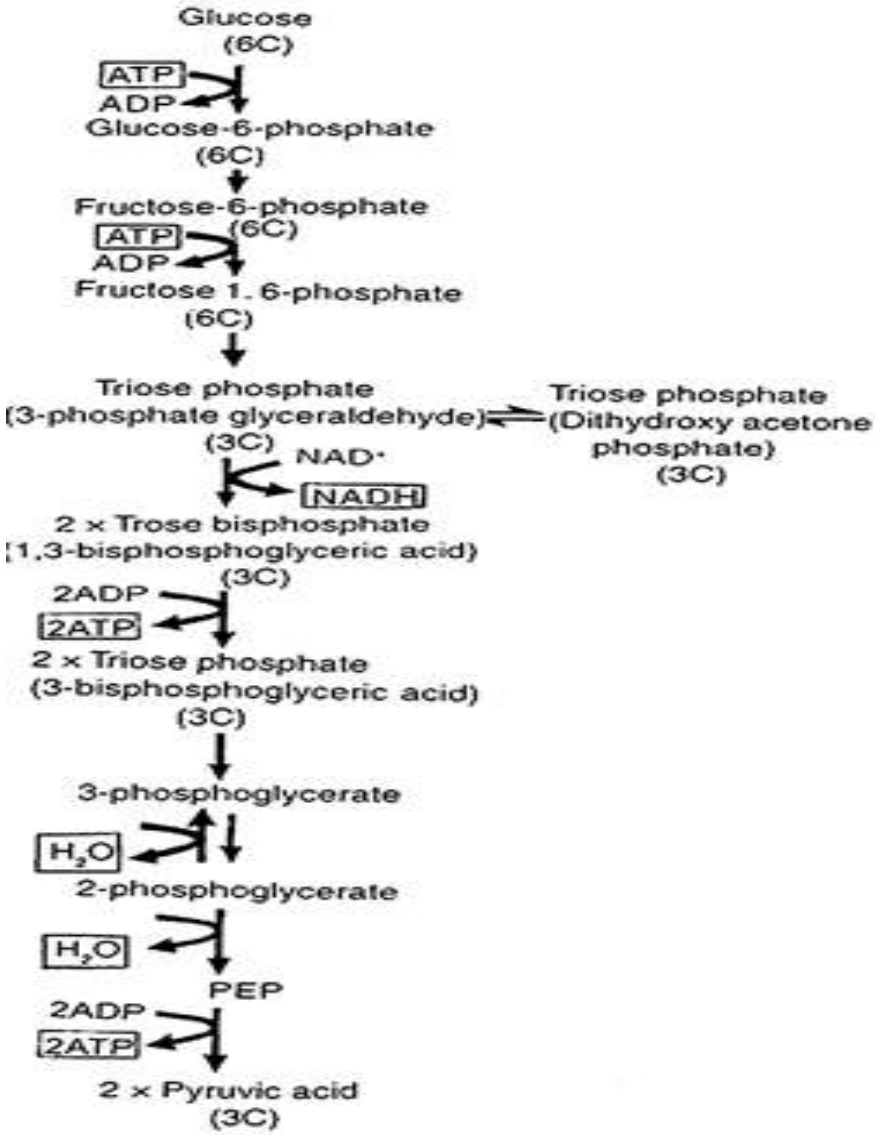


Fig. 4.2. Main steps of glycolysis or EMP pathway.

Oxidative Decarboxylation Pyruvic Acid :(Aerobic Oxidation of Pyruvic Acid)

Pyruvic acid generated in cytoplasm through glycolysis is transferred to mitochondria. **One of the three carbon atoms of pyruvic acid is oxidised to carbon dioxide** in a reaction called "**oxidative decarboxylation".**

Pyruvate is decarboxylated, and later oxidised by enzyme pyruvate dehydrogenase. This enzyme is made up of a decarboxylase, lipoic acid, TPP, transacetylase and Mg^{+2}.Acetyl Co-A acts as substrate entrant for Krebs cycle. **The equation is as follows:**

$$\text{Pyruvate} + \text{NAD+} + \text{Co-A} \xrightarrow[\text{dehydrogenase}]{\text{pyruvate}} \text{Acetyl Co-A} + \text{NADH} + H^{+} + CO_2^{-}$$

Acetyl Co-A can enter into mitochondria while pyruvic acid cannot.

Krebs Cycle:

Sir Hans Adolf Krebs, discovered role of **pyruvate in conversion of glucose hydrogens into fumarate**. In 1937 he discovered**, tricarboxylic acid cycle** (i.e., TCA cycle), also known as **Citric acid cycle** or **Krebs cycle**. **Citric acid cycle occurs in matrix of mitochondria**. This cycle involves two decarboxylations and four dehydrogenations.

Various steps of these reactions are as follows:

2. In 1937 H.A. **Krebs proposed** cyclic aerobic oxidation of Pyruvic acid into carbon di oxide and water. Hence it is called **Kreb's cycle** .It takes place in the mitochondrial matrix.
3. In Krebs cycle"The first intermediate compound is citric acid. Hence it is also called as "**Citric acid cycle".**
4. Citric acid and Iso citric acid have 3 carboxyl groups. Hence this path way is also called as "**Tricarboxylic acid cycle"**. (TCA Cycle).
5.

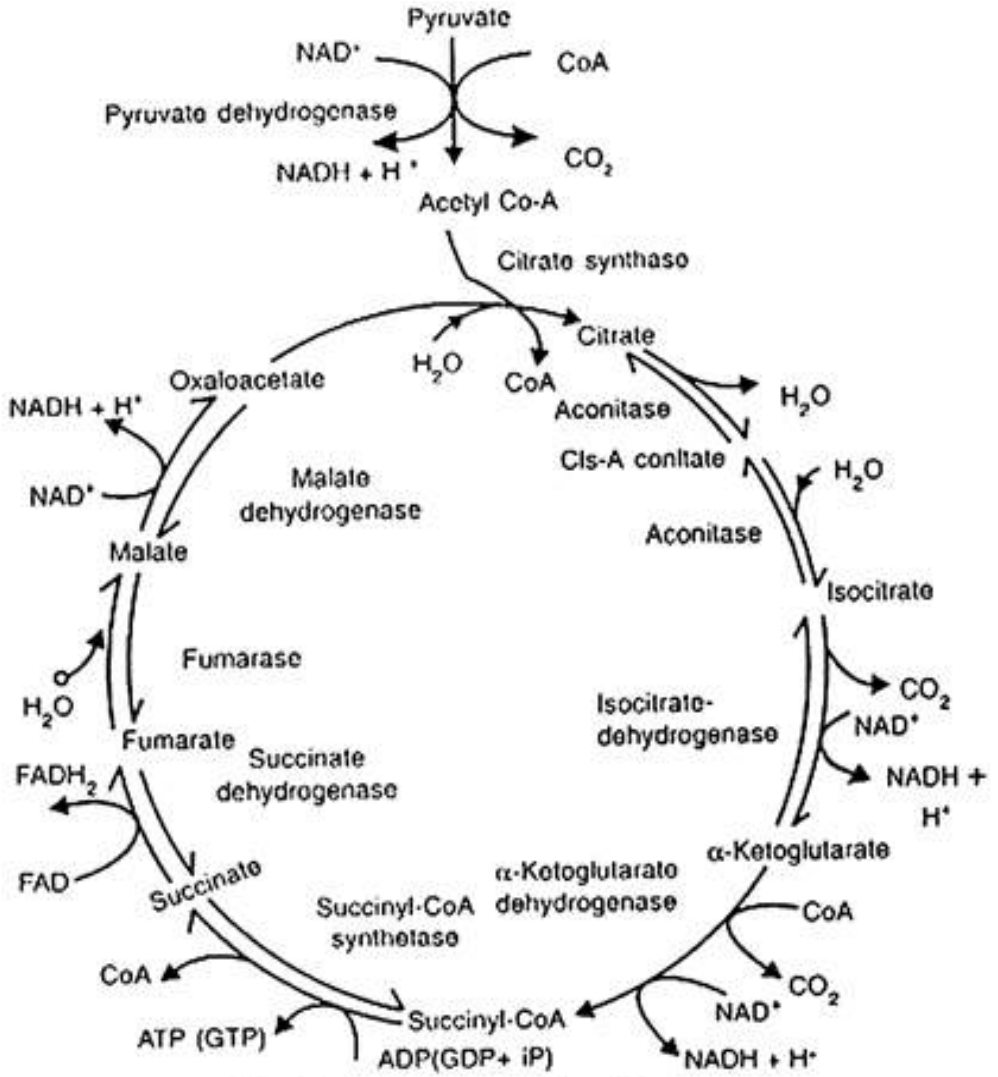


Fig. 4.3. Krebs cycle or citric acid cycle.

Acetyl Co-A formed by oxidative decarboxylation of Pyruvic acid enters Krebs cycle, combines with Oxalo acetic acid to from Citric acid . It is subjected to series of enzymatic reactions which end up with formation of Oxalic acid. Reactions involved are as follows:-

1. **Codensation:-** 2 'C' Acetyl Cp-A reacts with 4 'C' oxalo acetic acid to form 6 'C' citric acid in presence of condensing enzyme 'Citric synthetase'.

2. **Dehydration:-** Citric acid loses a molecule of water to form Cis- aconitic acid in presence of Aconitase and Fe++.

3. **Hydration**:-Cis- aconotic acid reacts with one molecule of water to form Iso citric acid in presence of Aconitase.

4. **Dehydration**:-Iso citric acid is oxidized to Oxalo succinic acid in presence of Iso citric dehydrogenase. NAD is reduced to NADH+ + H +.

5. **Decarboxylation:- Oxalo succinic acid is decarboxylated into** α Keto glutaric acid in presence of Oxalo succinic decarboxylase and Mn^{++}. One molecule of Co_2 is released.

6. **Oxidative decarboxylation:-**α Keto glutaric acid is oxidatively decarboxylated to form '4C' succinyl CO-A inpresence of α Keto glutaric dehydrogenase. One molecule of Co-A is used up , one molecule of Co_2 is released .NAD^+ is reduced to NADH + H^+.

7. **Hydration:-**Succinyl CO-A is hydrolysed to Succinic acid in presence of Succinic thio kinase. One molecule of water is used up, Co-A is released. One molecule GDP (Guanosine di phosphate) is converted into GTP (Guanosine Tri phosphate). This process is called as " Substrate phosphorylation".

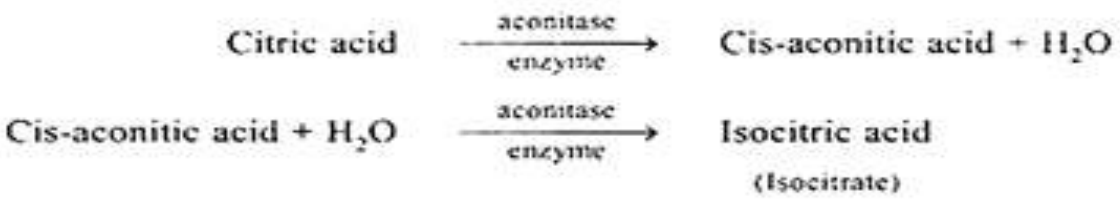
8. **Dehydrogenation:-** Succinic acid is oxidised to Fumaric acid i presence of Succinic Dehydrogenase. FAD is reduced to $FADH_2$.

9. **Hydration**:-Fumaric acid reacts with one molecule of water in presence of Fumerase.

10. **Dehydrogenation:-** Malic acid is oxidised to Oxaloacetic acid in presence of malic dehydrogenase. One molecule NAD is reduced to $NADH_2$.

Conclusion: - At the end of Kre's cycle for oxidation of 2 molecules of Pyruvic acid following end products are formed. A) 2+6 = 8 molecules of NADH2. B) 2 molecules of FADH2 3) 2+ 4=6 molecules of Carbon di oxide. 4) 2 moleclules of ATP.

The starting point of Krebs cycle is entrance of acetyl Co-A into a reaction to form citric acid. Krebs Now, citrate (citric acid) is isomerised to isocitrate (isocitric acid).

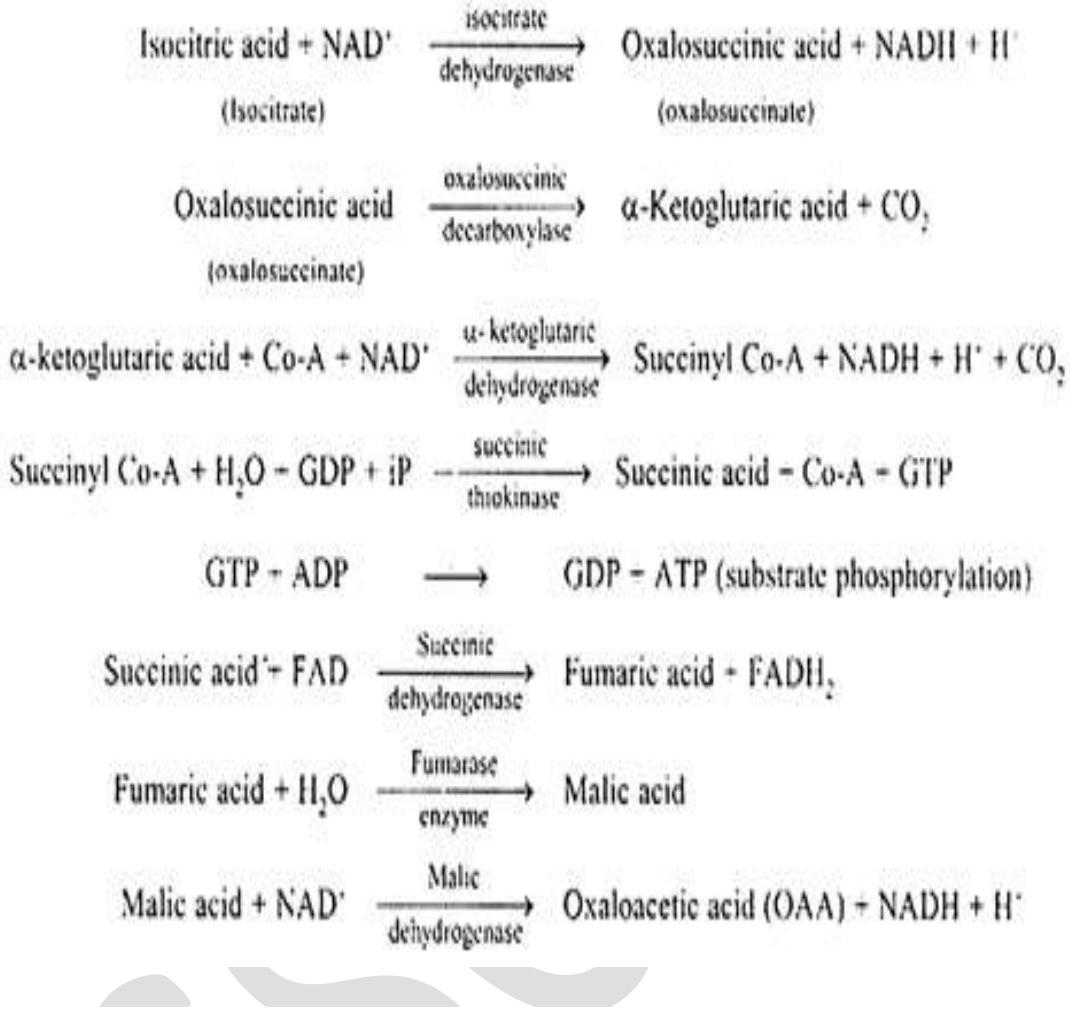


During citric acid cycle (Krebs cycle) 3 molecules of $NAD^{\pm}$ and one molecule of FAD (Flavin Adenine Dinucleotide) are reduced to produce NADH and $FADH_2$, respectively.

NADH and FAD produced are linked with electron transport system (ETS) and produce ATP by oxidative phosphorylation.

This may be summarised in following equation:

$$\text{Pyruvic acid} + 4NAD^{+} + FAD + 2H_2O + ADP + iP \xrightarrow{\text{mitochondrial matrix}} 3CO_2 + 4NADH + 4H^{+} + FADH_2 + ATP$$



In the end of Krebs cycle, **glucose molecule is completely oxidised**. From one glucose molecule, **two pyruvic acid molecules are formed**. After oxidation of one pyruvic acid molecule, three CO_2 molecules are released. Thus, in all 6 molecules of CO_2 are released.

Significance of Krebs cycle:

a. During Krebs cycle, carbon skeletons are obtained for use in growth and maintenance of the cell.

b. Many intermediate compounds are formed which are used in synthesis of other biomolecules, such as amino acids, nucleotides, chlorophyll, cytochromes and fats.

c. Krebs cycle is major pathway for generation of ATP molecules, which make energy currency of the cell.

f. Energy is released from glucose, and is used in various biochemical reactions.

Electron Transport System (ETS) OR Oxidative phosphorylation

Oxidative phosphorylation or Electron transport system is the final step of mechanism of Aerobic respiration. It takes place in '**F' particles or 'Oxisomes' of cristae in Mitochondria.**

In the whole process**, oxygen effectively allows the production of ATP by phosphorylation** of ADP, is called **oxidative phosphorylation**.(synthesis of ATP is called phosphorylation, and as it takes place in presence of oxygen, it is called **oxidative phosphorylation).**The enzyme required for synthesis of ATP, is called ATP synthase. This is located in F_1, or head piece of $F_0 – F_1$ or elementary particles. ATP synthase enzyme becomes active in ATP formation, where there is a proton gradient saving higher concentration of H_2.

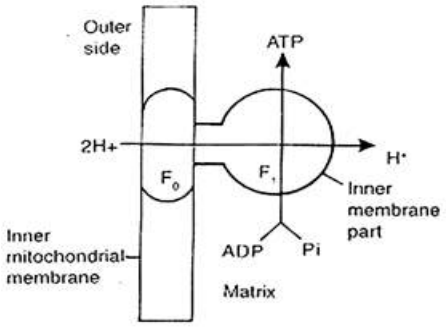


Fig. 4.5. Synthesis of ATP by inner membrane particles of mitochondrion.

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The Oxidation of reduced Co enzymes like NADH+ + H and FADH + H+ by atmospheric oxygen is known as ' **Terminal oxidation'**.During this hydrogen ions pass into perichondrial space. Energy rich electrons of hydrogen atoms passes through various electron carriers present in inner membrane of mitochondrion by Redox process. These electron carriers constitute **'Electron transport system'. (ETS**). During this process some amount of energy will be released at oxidation level of electron carriers. This energy is utilissed for the synthesis of ATP from ADP & Pi. This process is called as **"Oxidative phosphorylation**". Mechanism is as follows:-

1. NADH2 transfer 2 electrons and 2 Hydrogen ions to Flavin Monophosphate (FMN). NADH2 is oxidized to NAD and FMN is reduced to FMNH2.
2. Co-Q H2 accepts H2 atoms from FMNH2 or FADH2 and become reduced into Co-QH2.
3. Co-QH2 transfer 2 electrons of cytochrome –b and release 2 hydrogen ions.
4. Hydrogen ions move along proton gradient. Electron passes from cyt-b to cyt-c, cyt-a, cyt-a3 by redox process.
5. Finally Hydorgen from the medium and electrons from cyt-a3 are assepted by oxygen to form one molecule of water. This is called 'Terminal oxidation".

During electron transport, Phosphorylation of ADP tp ATP takes place utilizing free energy released at oxidation of electron carriers at 3 sites. These are between NADH and FAD, between cyt-b and cyt-c, between cyt-a and cyt-a3. This is called 'Oxidative phosphorylation".

Incomplete oxidation of organic substances like Glucose in the living cells without utilizing oxygen to release energy is known as "Anaerobic respiration".

C6 H12O6 ---------2CO2 + 2 C2H5OH + 56 K.cal. energy.

Mechanism of anaerobic respiration:-Anaerobic oxidation takes place in 3 main steps. They are as follows:-

- Formation of Pyruvic acid:-Glucose is oxidized by dehydrogenation into 2 molecules of pyruvic acid .

  2NAD 2NADH + H+
  Glucose ---------- 2 Pyruvic acid
  GLYCOLYSIS
  2ADP + 2Pi 2 ATP
- Formation of Acetaldehyde: - Pyruvic acid under anaerobic condition undergoes decarboxylation to from Acetaldehyde.
- Formation of Ethyl alcohol: - Acetaldehyde is reduced to ethyl alcohol using NADH 2 produced during Glycolysis.

  2 NADH+ H+ NAD
  2Acetaldehyde ----------2 Ethyl alcohol
  Dehydrogenase
  - Overall reactions can be represented as

    Glucose + 2 ADP + 2 Pi ---------- 2 CO2 + 2 Ethyl alcohol + 2 ATP.

Conclusion:- At the end of Anaerobic respiration oxidation of one molecule of CO2 , 2 molecules of Ethyl alcohol and 2 Molecules of ATP are formed

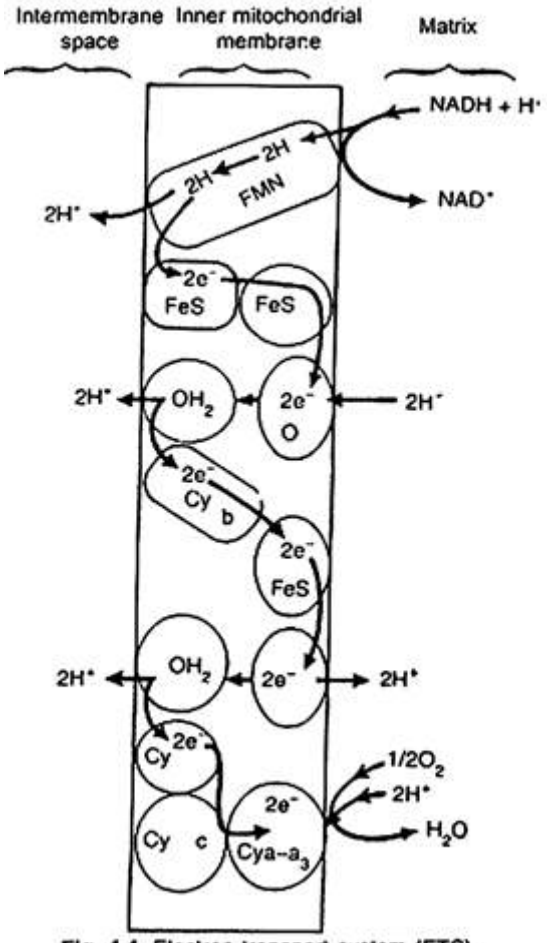

Fig. 4.4. Electron transport system (ETS)

Oxidation of one molecule of $NADH_2$ produces 3 ATP molecules whereas a similar oxidation of $FADH_2$ produces 2 ATP molecules.

Net gain of ATP:

Complete oxidation of glucose to CO_2 and water shows that there is a net gain of 38 ATP. Each NADH + H^+ produces 3 ATP molecules, while $FADH_2$ forms only 2 ATP molecules at the end of reaction. Thus Net ATP gain is as follows:-

$$NADH + H^+ + 1/2\ O_2 + 3\ ADP + 3\ iP \longrightarrow NAD + 3\ ATP + H_2O$$

$$FADH_2 + 1/2\ O_2 + 2\ ADP + 2\ iP \longrightarrow FAD + 2\ ATP + H_2O$$

Thus, total gain of ATP in aerobic respiration is as follows:

Glycolysis ⟶ 8 ATP

Pyruvic acid ⟶ Acetyl Co-A ⟶ 6 ATP

Krebs cycle ⟶ 24 ATP

Total ⟶ 38 ATP

$$C_6H_{12}O_6 + 6O_2 + 8H_2O + 38\ (ADP + H_3PO_4) \longrightarrow 6CO_2 + 14H_2O + 38\ (ATP + H_2O).$$

However, in most eukaryotic cells, 2 molecules of ATP are required for transport of NADH produced in glycolysis into mitochondrion for further oxidation, and therefore, net gain of ATP is 36 molecules.

OR

Electron Transport System (ETS)OR Oxidative Phosphorylation

Oxidative Phosphorylation:

- The process of production of ATP by phosphorylation of ADP in presence of oxygen and ATP synthase is called **oxidative phosphorylation.**
- ATP synthase, also known as complex V. It consists of two major components, i.e., F_1, and F_0.
- The F_1 headpiece is a peripheral membrane protein complex and contains the site for ATP from ADP and inorganic phosphate (iP).
- F_0 is an integral membrane mitochondrial-protein complex which forms the channel through which protons cross the inner membrane.
- The passage of protons through the channel is coupled to the catalytic site of the F_1 component for the production of ATP.
- Oxidation of one molecule of $NADH_2$ produces 3 ATP molecules whereas a similar oxidation of $FADH_2$ produces 2 ATP molecules

By the end of Krebs cycle, glucose molecule oxidises completely, but the energy does not release till NADH and $FADH_2$ oxidise through electron transport system (ETS).

The metabolic pathway through which electron passes from one carrier to another, is called electron transport system (ETS). It is also known **as electron transport chain or mitochondrial respiratory chain.**

- Electron transport system is operative in the inner mitochondrial membrane.
- The electron transport system consists of a series of coenzymes and cytochromes that take part in passage of electrons from a chemical to its ultimate acceptor with a loss of energy at each step.
- The electron carriers include flavins, iron sulphur complexes, quinones and cytochromes. Most of them are prosthetic groups of proteins.
- Electron transport system in mitochondria consists of four complexes which are found in bases of stalked particles in the inner mitochondrial membrane, and also ubiquinone (UQ) or coenzyme Q and cytochrome c which are not bound to stalked particles but act as mobile electron carriers between the complexes.

1. **Complex-I**:

It Consists of NADH-dehydrogenase or NADH-Q reductase which contains a flavoprotein FMN (flavin mononucleotide) and is associated with iron-sulphur (Fe-S) proteins. This complex is responsible for passing electrons (also protons) from mitochondrial NADH to ubiquinone (UQ), located within inner mitochondrial membrane.

$$NADH + H^+ + FMN \longrightarrow FMNH_2 + NAD^+$$
$$FMNH_2 + 2Fe^{3+}\,S \longrightarrow FMN + 2Fe^{2+}\,S + 2H^+$$
$$2Fe^{2+}\,S + Q + 2H^+ \longrightarrow 2Fe^{3+}\,S + QH_2$$

Complex-II:

It consists of succinate dehydrogenase which contains a flavoprotein FAD (flavin adenine dinucleotide) in its prosthetic group and is associated with non heme iron-sulphur (Fe S) proteins.

This complex receives electrons (also protons) from succinic acid and passes them to ubiquinone (UQ). Ubiquinone also receives reducing equivalents via $FADH_2$ that is generated during oxidation of succinate.

$$FADH_2 + 2Fe^{3+}\ S \longrightarrow 2Fe^{2} + S + 2H^{+} + FAD$$

$$2Fe^{2+}\ S + Q + 2H^{+} \longrightarrow 2Fe^{3+}\ S + QH_2$$

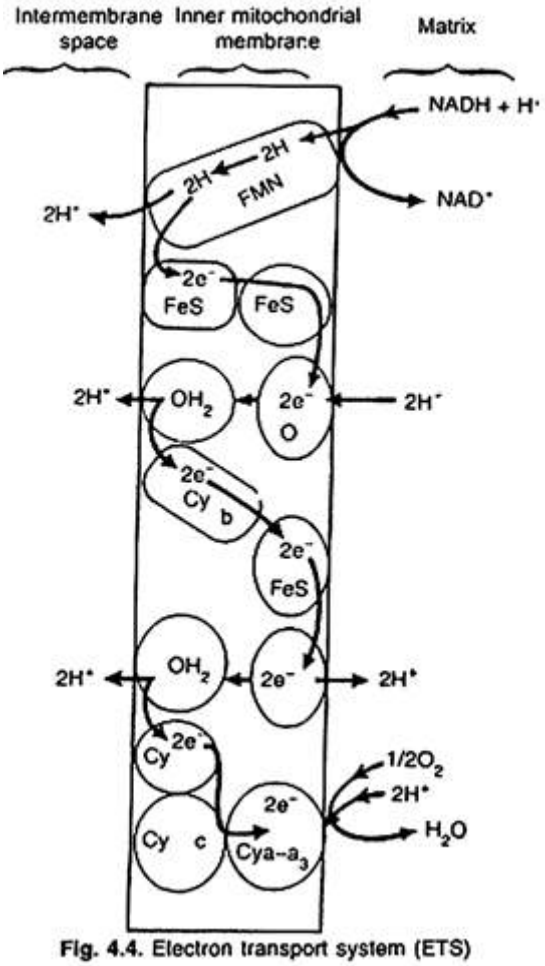

Fig. 4.4. Electron transport system (ETS)

2. **Complex-III:**

It consists of ubiquinol, cytochrome c and cytochrome bc_1 .The reduced ubiquinone is called ubiquinol. Here ubiquinol is oxidised with the transfer of electrons to cytochrome c via cytochrome bc_1. It acts as a mobile carrier for transfer of electrons between complex III and complex IV.

This complex is called QH_2-cytochrome c reductase complex. This bears three components, i.e., cytochrome b, non-heme iron sulphur (Fe – S), and cytochrome c_1. Coenzyme Q is also involved between Fe-S and cytochrome c_1.

The equations are as follows:

$$QH_2 + 2Fe^{3+}\ cy\ b \longrightarrow Q + 2H^+ + 2Fe^{2+}\ cy\ b$$

$$2Fe^{2+}\ cy\ b + 2Fe^{3+}\ S \longrightarrow 2Fe^{3+}\ cy\ b + 2Fe^{2+}\ S$$

$$2Fe^{2+}\ S + Q + 2H^+ \longrightarrow 2Fe^{3+}\ S + QH_2$$

$$QH_2 + 2Fe^{3+}\ cy\ c_1 \longrightarrow Q + 2H^+ + 2Fe^{2+}\ cy\ c_1$$

Now, cytochrome c, transfers electrons to cy c. Like coenzyme Q, cy c is also mobile carrier of electrons.

3. **Complex-IV:**

It is known as cytochrome c oxidase complex. This contains cytochromes a and a_3, along with two copper centres. This complex receives electrons from cytochrome c and passes them to 1/2 O. Two protons are needed and Hp molecule is formed (terminal oxidation). Here, O_2 is ultimate acceptor of electrons. It combines with protons to form metabolic water or respiratory water.

$$\underset{(Fe^{++})}{2\ \text{Ferrocytochrome}} + 2H^+ + 1/2\ O_2 \rightleftharpoons \underset{(Fe^{+++})}{2\ \text{ferricytochrome}\ c} + H_2O$$

5.Complex-V:

When electrons are transferred from one carrier to next carrier via complexes 1 to IV in electron transport system (ETS), they are coupled to ATP synthase enzyme complex for production of ATP from ADP and inorganic phosphate (iP).

Number of ATP molecules synthesised during ETS. Depends on nature of electron donor.

- **Oxidation of one molecule of NADH gives rise to 3 molecules of ATP**.
- One molecule of $FADH_2$ gives rise to 2 molecules of ATP. ATP synthase complex is called complex V.
- During transportation of electrons, hydrogen atoms split into protons and electrons. The electrons are carried by cytochromes.
- Hydrogen atom is accepted by oxygen to form water; the electrons again recombine with their protons.

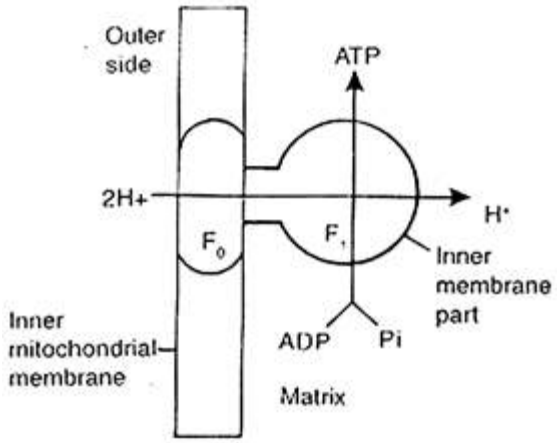

Fig. 4.5. Synthesis of ATP by inner membrane particles of mitochondrion.

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Net gain of ATP:

Complete oxidation of glucose to CO_2 and water shows that there is a net gain of 38 ATP.

Each NADH + H^+ produces 3 ATP molecules,

$FADH_2$ forms only 2 ATP molecules at the end of reaction.

$$NADH + H^+ + 1/2\ O_2 + 3\ ADP + 3\ iP \longrightarrow NAD + 3\ ATP + H_2O$$

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$$C_6H_{12}O_6 + 6O_2 + 8H_2O + 38\ (ADP + H_3PO_4) \longrightarrow 6CO_2 + 14H_2O + 38\ (ATP + H_2O).$$

In eukaryotic cells, 2 molecules of ATP are required for transport of NADH produced in glycolysis into mitochondrion for further oxidation; therefore, **net gain of ATP is 36 molecules.**

Pentose path way

Pentose path way is a major path way for aerobic respiration of Glucose, through Glycolysis and Krebs cycle.

Various reactions of Pentose path way are as follows:-

1. 6 molecules of **Glucose -6 phosphate** in presence of Coenzyme NADP are oxidised into 6 molecules of **6 Phosphoglucono lactone**. 6 moleculesof NADP are reduced in the reaction which are reversible**.**
2. 6 Phosphoglucono lactone is hydrolysed by the enzyme Lactonase to produce 6 molecules of **Phosphogluconic acid.**
3. Phosphogluconic acid is Oxidatively decarboxylated by an enzyme Phosphogluconic acid dehydrogenase.molecules of NADP are reduced and 6 molecules of CO_2 are released to produce 6 moleculesof **Ribulose -5- phosphate**.
4. 6 moleculesof Ribulose -5- phosphate isomerise into 4 molecules of Xylulose-5-Phosphate and **2 molecules of ribose -5 phosphate** in presence of enzymes **Ribulose phosphate** -3- epimerase and Pentose phosphateisomerase respectively.
5. 2 molecules of **Xylulose-5-Phosphate and 2 molecules of ribose -5 phosphate combine** in presence of Transketolase to form 2 molecules of **Sedoheptulase-7 phosphate** and 2 molecules of **Phosphoglyceraldehyde.**
6. 2 molecules of **Sedoheptulase-7 phosphate and 2 molecules of Phosphoglyceraldehyde combine** in the presence of Transketolaseto form 2 molecules of **Fructose -6-phosphate and 2 molecules of erythrose -4-phosphate.** .
7. 2 molecules of erythrose -4-phosphate reacts with remaining 2 molecules of Xylulose -5-phosphate in presence of transketolase to form 2 molecules of Fructose -6 –phosphate and 2 moleculesof **3-phosphoglyceraldehyde**.
8. One molecule of 3- phosphoglyceraldehyde isomerise **into Dihydroxy acetone phosphate** in presence of enzyme Phosphotriose isomerise.
9. Remaining one molecule of 3- phosphoglyceraldehyde unites with Dihydroxy acetone phosphate in presence of Aldolase to form one molecule **of Fructose-1- 6-diphosphate**. It forms one molecule of Fructose-6- phosphate in presence of phosphotase.
10. 5 molecules of Fructose -6-phosphate produced isomerise into **Glucose-6- phosphate** in presence of Posphohexose isomerise.

<u>Conclusion:</u> - Complete oxidation of a molecule of Glucose produces 12 molecules of $NADPH_2$, which is equal to 36 ATP Molecules.

<u>Significance of Pentose path way:-</u>

1. Pentose path way provides alternative route for Carbohydrate degradation.
2. Pentose path way generates $NADP_2$ which are used as reductants in biosynthetic process when NADPH molecules are generated by Fructose -6 phosphate photosynthesis.
3. It produces Sugars for synthesis of Nucleic acids.
4. It plays an important role in fixation of CO_2
5. It provides Erythrose -4-phosphate, which is required for synthesis of Shikimic acid.

6. It produces number of Tetroses and Pentoses for synthesis of Nucleotides, Nucleosides,Nucleic acids, Anthocyanin etc.

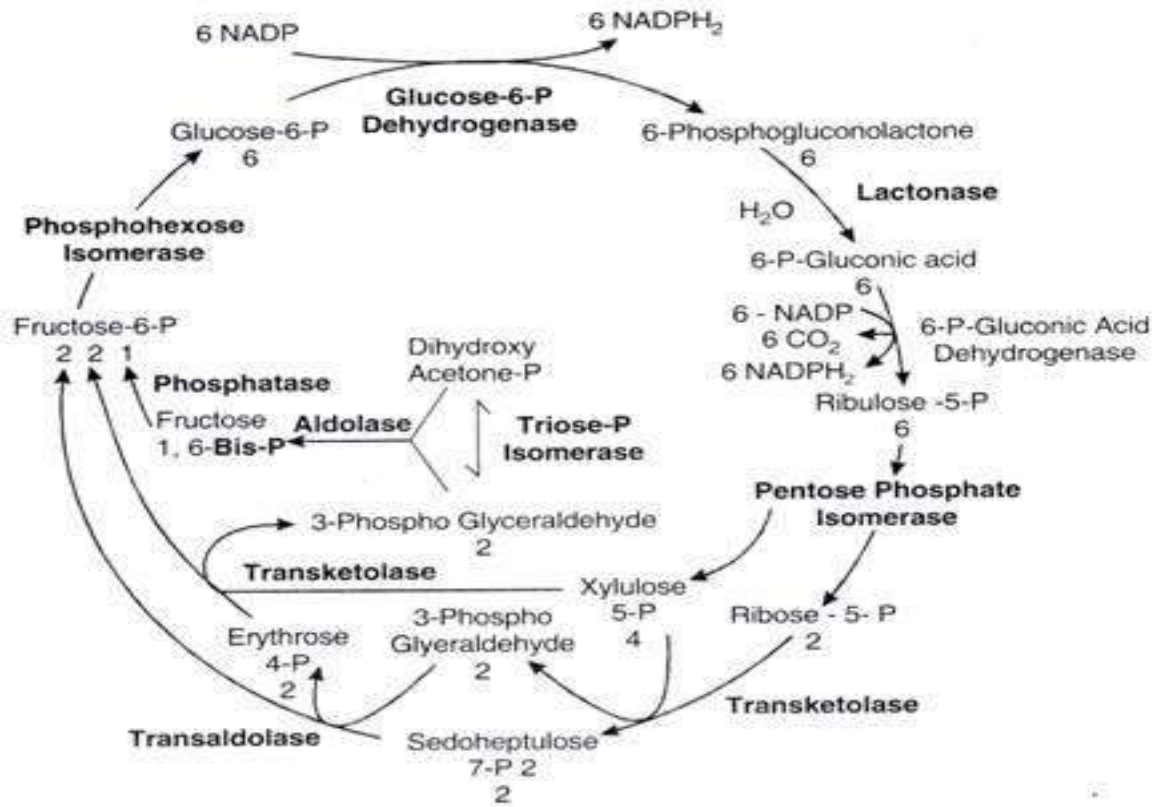


Fig. 16.18. Pentose phosphate pathway.

2 Marks questions

1. Draw labelled diagram of Mitochondrion.
2. What is Pentose Path way? Mention its significance.
3. What is meant by Oxidative phosphorylation?

4. Differentiate between Aerobic and Anaerobic respiration.

10 Marks Questions

1. Explain Glycolytic Path way.
2. Describe Kreb's Cycle/ TCA cycle/ Citric acid cycle.
3. Describe Oxidative Phosphorylation/ Electron transport chain.
4. Give an account of Pentose path way.

Unit 5:Enzymes 5 Hrs

Structure, Nomenclature, Properties, classification; Mechanism of enzyme action and enzyme inhibition.

Enzymes are specific proteinceous substances that catalyse Biochemical reactions. Hence they are known as 'Biocatalyst'. Kuhne in 1878 coined the term 'Enzyme'. While working on the fermentation. In 1926 Robert summer Purified, Crystallized and revealed its proteinaceous nature.

Structure and chemical composition

Based on structure and chemical composition enzymes are grouped into 2 types. They are as follows:-

1) **Simple enzymes:-** Enzymes made up of **Proteins** are called 'Simple enzymes'.

2) **Conjugated enzymes OR Holoenzymes:-** Enzymes made up of **both Protein and Non protein** components are called **Conjugated enzymes OR Holoenzymes** . The protein part of enzymes is called **"ApoEnzymes**". The Non protein part which is tightly bound to Apoenzyme is called "**Prosthetic group**". The non protein part of an enzyme which is not tightly bound is called "**Coenzyme or Cofactor**". The site in Protein part which tightly binds the substrate complex is called "**Active site".**

Nomenclature

The name of an enzyme consists of 2 parts. The first part **indicates the substrate on which an enzyme acts** and the second part indicates the **type of enzyme action.** The names of all enzymes ends with **Suffix 'ase'.**
Ex: Cytochrome oxidase- This indicates that the enzyme **oxidises cytochrome,**

Iso citric acid dehydrogenase- This indicates that an enzyme **removes hydrogen from Iso citric acid .**

Classification of Enzymes:

According to **"Commission on Enzyme of international union of Biochemistry"**, the features of enzyme classification is as follows:-

5. All enzymes are grouped in **6 Major classes**.
6. Each Major class has been divided into **many sub classes**.
7. Each sub class is further subdivided into **sub sub classes**.
8. Each enzyme has specific **code number of 4 digits**. **First** digit indicates **Major class**, **second** digit indicates **sub class**, **third** digit indicates **sub sub class** and **fourth** digit denotes specific **name of enzyme** in which first part indicates **name of substrate** and second part indicates **type of reaction**.

Six major classes are as follows:-

1. **Oxido reductases**: - It catalyses oxidation reduction reactions. It is divided into Oxidase, Peroxidase, Dehydrogenase,Reductase,Oxygenase,Hydroxylase, Catalase.
2. **Transferases:** - It catalyses reactions that involve group transfer. Ex: Transketolase, Transaminase, Transaldolase, Transphosphorylase, Transcarboxylase etc.

3. **Hydrolases; -** It catalyses hydrolytic reactions like Carbohydrases, Lipases.
4. **Lyases: -** It catalyses removal of group from substrate without addition of water.
5. **Isomerases**:-It catalyses isomerisation reactions.
6. **Ligases: -** It catalysesreactions in which 2 molecules are coupled by breaking of pyrophosphate bond by ATP.

Enzymes shows following properties:-

- **Catalytic properties:-**All enzymes are Bio catalysts required in vey small quantities. They accelerate the pace of reaction and remain unchanged, do not disturb the euillibrium of the reaction.
- **Reversibility of reaction: -** Enzymes accelerate the pace of reaction in both directions. Depending upon the reuuirements of the cell and factors present at that particular time.Ex: Starch phosphorylase during day time hydrolase starch to sugar. During night synthesis of starch takes place, light and PH decides the direction of enzymes.
- **Specificity:-** Enzymes are highly specific in their action. A particular enzyme catalyses particular kind of reaction.Ex; Malic dehydrogenase removes hydrogen atom from Malic acid and from any other keto acid.
- **Colloidal nature:-** Enzymes are dispersed in the protoplasm and show colloidal properties. They cannot pass through membrane of colloidon.
- **PH sensitivity:-** Enzymes are active at limited range of pH . They are denatured by strong acids or alkali.
- **Heat sensitivity**: - Enzymes are active at high temperature (60 to 70 degree Celsius in dried condition they are stable. Called Thermoliable. **Reversibility:** Enzymes accelerate the pace of reaction in both directions. Depending upon the requirements of the cell. And factors present at that particular time.
- **Inhibition of enzyme action;-** When active sites of an enzymes is blocked , it become inactivated. The chemical compound that inactivates the enzyme is called '**Enzyme poison**".

Enzyme activity on the substrate is affected by number of factors as follows:-

1. **Enzyme concentration: -** Increase in concentration of enzymes will increase the rate of reaction catalysed by it in presence of enough concentration of substrate.
2. **Substrate concentration: -** Decrease in concentration of substrate molecules lower than rate of reaction, as many active sitesof enzymes are unoccupied.
3. **Temperature:-**Activity of the enzymes is minimum at low temperature ie,.0 degree C. It is optimum at normal temperature; maximum at 45 degree C. Beyond 60 degreeC enzyme activity is retarded.
4. **PH: -** Enzymes function efficiently at particular hydrogen ion concentration. Pepsin require low PH, Trypsin require high PH. Beyond its own optimum range they show reduced activity.
5. **Water:-**Enzymes are active when supplied with sufficient water. In absence of water activity of enzyme is suppressed.
6. **Enzyme inhibitors:-** The organic substances which inhibit the enzyme activity on the substrate molecule by blocking Active sites of enzymes are **called enzyme inhibitors.**It may be **Competative** where the organic substance are structurally similar to the substrate molecule, compete with substrate to occupy active site.they pre occupy the active site, substrate will be unable to bind, enzyme activity is inhibited.or **Non competative** The organic substances which are not structurally similar to the substrates, do not occupy Active site and do not compete with the substrate , But inhibit enzyme activity by destroying the structure of an enzyme protein or alter reactive group of an enzyme.

MECHANISM OF ENZYME ACTION

To explain mechanism of enzyme action many theories have been proposed. They are: - **1) Lock and Key and mechanism: 2) Induced fit theory** 3) **Ping pong theory or Double displacement theory**

1) **Lock and Key and mechanism:** - This theory has been proposed by Fischer in 1898. According to this theory all enzymes have rigid, active, unfolded surface called as **Active site.** It can fix to particular substrate molecule to form **Enzyme substrate complex.** Rapid reaction takes place, product is released from the enzyme and the enzyme become free without any change. This theory explains the specificity of the enzymes as particular lock can be opened by a particular key which is specially designed to open it.

2) Induced fit theory: - This theory was proposed by Koshland in 1969.According to this theory Active site of the enzyme is not rigid and it has 2 groups. These are A) Substrate supporting catalytic groups.and 2) Substrate breaking group. The substrate interacts strongly with the enzyme; alter the active site so that perfect fitting with the substrate takes place to carry out reaction.

3) Ping pong theory or Double displacement theory:-In Bisubstrate reaction, substrate molecule alternately binds to an enzyme, releases the product and free enzyme. This mechanism is called as "Ping pong mechanism. EX: Transamination reaction.

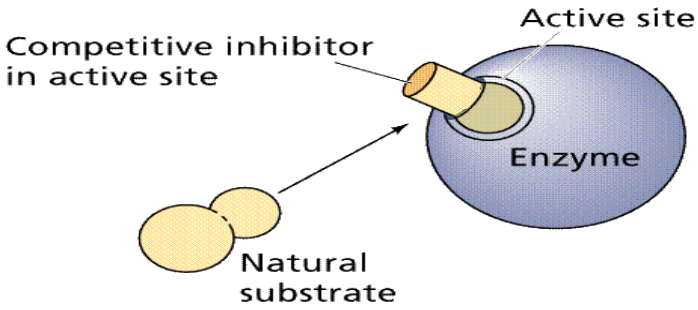
In a reaction involving Glutamic acid and Oxalo acetic acid as substrate, the enzyme is transaminase, has Pyridoxyl phosphate as prosthetic group. In the first step Glutamic acid bind with the prosthetic of enzyme donates amino group and released as a product Alpha keto Glutaric acid. In the second step Oxalo acetic acid binds to the enzyme which has amino group bound to it from first substrate. Now substrate accepts amino group transferred from the first substrate and releases Aspartic acid as product.

Enzyme inhibition:-

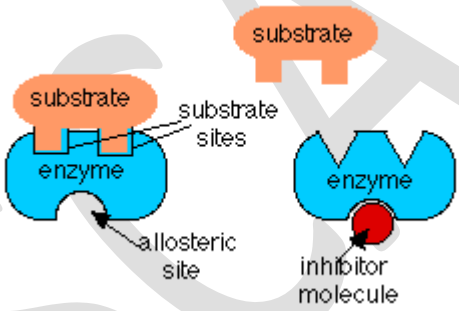
When active sites of enzymes are blocked, it becomes inactivated. The chemical compound that inactivates the enzyme is called '**Enzyme poison**".

The organic substances which inhibit the enzyme activity on the substrate molecule by blocking Active sites of enzymes are **called enzyme inhibitors. There are 2 types of inhibitors, Namely** Competative **inhibitors Non competitive inhibitors and Allosteric inhibitors (End product inhibitors).**

1. **Competative inhibitors: - In Competitive type** the organic substances are structurally similar to the substrate molecule, compete with substrate to occupy active site, they pre occupy the active site, substrate will be unable to bind, enzyme activity is inhibited. Ex: Enzyme Succinic acid dehydrogenase catalyses conversion of Succinic acid to Fumaric acid. Due to structural similarity between Succinic acid and Malonic acid reaction does not takes place.



2. **<u>Non competitive inhibitors</u>:- In Non competitive** type the organic substances which are not structurally similar to the substrates, do not occupy Active site and do not compete with the substrate , But inhibit enzyme activity by destroying the structure of an enzyme protein or alter reactive group of an enzyme such as –COOH, -NH_2 group etc.
3. **<u>Allosteric inhibitors (End product inhibitors or Feed back inhibition)</u>:-** when series of reactions are catalysed by number of enzymes in sequence, the **accumulation of final end product** may **cause inhibition in the activity** of the first enzyme of the series. This inhibition due to final end product which is different in structure from the Substrate of the enzyme is called **"Allosteric or Feed back inhibition.**
   Allosteric enzyme has 2 types of sites for enzyme action. They are**: Active site and Allosteric site.**
   Fig



Allosteric site is present away from the active site. When final end product fits in the Allosteric site, it changes the shape of an enzyme and makes it unfit to form Enzyme substrate complex. Allosteric inhibition is **reversible.** When the **concentration of final end product falls,** it leaves allosteric site and **activity of an enzyme starts.**

<u>2 MARKS QUESTIONS</u>

1. What is an Enzyme? Give an Example.
2. Differentiate between Apo enzyme and Co-enzyme.
3. What is enzyme Inhibitor? Give example.
4. Mention Theories relating to Enzyme action.
5. Mention any 2 properties of Enzyme.

<u>5 MARKS QUESTIONS</u>

1. Explain Lock and Key mechanism.
2. List properties of Enzyme action.
3. Give an account of Enzyme inhibitors.
4. Describe Induced Fit theory and double displacement / Ping pong theory.

10 MARKS QUESTIONS

1. Describe mechanism of Enzyme action with suitable theories.

Unit 6:Nitrogen metabolism 4 Hrs

Biological nitrogen fixation; Nitrate Metabolism, Synthesis of amino acids, Reductive and Transamination.

NITROGEN METABOLISM

Nitrogen is an important Macro element required by plants for their nitrogem metabolism. It is the main source of compounds like Ammonia, Proteins , Nucleic acids ,Chlorophyll etc.

The process of conversation of Molecular Nitrogen of the atmosphere into Nitrogenous compounds of the soil to make it available for absorption by plants is called 'Nitrogen fixation'. It can be grouped into 2 types . Namely, 1.**Physical nitrogen fixation. 2. Biological Nitrogen fixation.**

1. PHYSICAL NITROGEN FIXATION

Conversion of Atmospheric nitrogen into usable form by lightning and rainfallis called Physical nitrogen fixation.

During thunder and lightning gaseous nitrogen is oxidized to nitrogen peroxide which combines with rain water to form nitrous and nitric acid . In the soil with calcium and Potassium form calcium nitrate and Potassium nitrate which are absorbed by plants.

2 .BIOLOGICAL NITROGEN FIXATION

The Process of conversion of atmospheric nitrogen into usable form by soil micro organisms is called Biological nitrogen fixation.It takes place by 3 methods as fallows**:-**

1. Symbiotic Nitrogen fixation

2. Non-symbiotic Nitrogen fixation. 3.Associative Nitrogen fixation.

I Symbiotic Nitrogen fixation

The process of conversion of atmospheric nitrogen to usable forms by Micro organisms when they are present in symbiotic association is called ymbiotic Nitrogen fixation.
Ex : Nitrogen fixation by bacteria Rhizobium when present in Leguminous root nodules.

Mechanism of Nodule formation

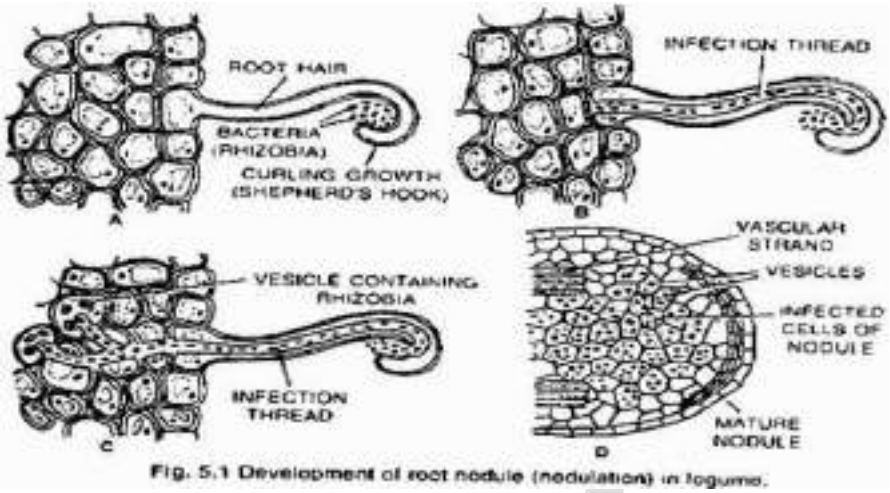


Fig. 5.1 Development of root nodule (nodulation) in legume.

Nodules are small ,knob like protruberances formed by species of Rhizobium . Bejernick isolated it first from Roots of leguminous plants . Prasmukifirst studied mechanism of nodule formation . It involves fallowing steps:-

1. Specific Leguminous root stimulate specific Rhizobium to develop symbiotic association.EX: Pea stimulates Rhizobium leguminosarum , Bean roots stimulates Rhizobium phaseoli etc .
2. Rhizobium secrete growth harmone IAA which induce curling of root hair that help in attachment of Rhizobium to binding site of Root hair.
3. Rhizobium secretes Cystase enzyme which help in entry of Rhizobium into Root hair.
4. Root hair develops infection thread . It carries the bacteria ,grow across cortical cell , reaches innermost cortical cell releases rhizobium into il.
5. Rhizobial cell induce cortical cell to proliferate. Thus root nodules are formed.

   Rhizobium divide ,loose cell wall,become vacuolated ,bulged ,branched cells called bacteriods. These fix nitrogen as plant matures.

   Mechanism of symbiotic Nitrogen fixation.

   symbiotic Nitrogen fixation Rhizobium in root nodules of leguminous plants requires fallowing factors:-

   Symbiotic Nitrgen fixation by Rhizobium in root nodules of leguminous plants requires fallowing factors :-

   1. **6 electrons** :- Ferrodoxin of Photosynthetic electron transport chain donates electrons.
   2. **6 Hydrogen atoms +12ATP** :- Pyruvic acid metabolism donates Hydrogen atoms and ATP molecules ,Respiratory metabolites also supply ATP .
   3. **Nitrogenase enzyme** :- **'NIF'** gene of Rhizobium codes for it..

   N+ 6e +6H +12 ATP---------Rhizobium----------2 NH+12ADP+ 12Pi

   The process of symbiotic nitrogen fixation takes place as follows:-

   1. Reduced Ferrodoxin donates electrons to oxidized Fe- protein complex, then this complex become reduced.
   2. Reuduced Fe protein complex reacts with ATP and become ATP activated Fe- protein complex. It donates electrons to MO-Fe protein complex.

3. Mo-Fe Protein complex receives electrons from ATP activated Fe- protein Complex and reduced. It transfer electrons to nitrogen.
4. Nitrogen combines with hydrogen to form free Ammonia . It get converted into Amino acids in the root nodules . Amino acids diffuses into soil and become available for the plants.

In Rhizobium Nitrogenase enzyme needs anaerobic condition to fix molecular Nitrogen .Leg haemoglobin in the root nodule absorbs oxygen and keeps Rhizobium in oxygen free state.
[Leg haemoglobin is a protein produced by symbiotic interaction of rhizobium and Legume Root]. Haeme component of protein is formed by Rhizobium globulin by legume root].

Amino acid synthesis

Amino acids are building blocks of proteins. carboxyl group amino acids synthesis takes place in 2 steps. They are :- 1.**Reductive amination 2. Trans amination**

1 .Reductive amination : The process of conversion of in organic Nitrogen into organic Nitrogen by Amination and Reduction at alpha keto group of organic acid is called **Reductive amination**.
In organic Nitrogen, a the form of nitrogen Ammonia is produced by Biological nitrogen fixation or obtained from the soil or by reduction of nitrogen.
Inorganic nitrogen reacts with alpha keto glutaric acid in presence of an enzyme glutamic dehydrogenase and NADPH to form Amino acid.

Keto glutaric acid + NADPH + NH----------Glutamic acid + NADPH +Ho

2 Transamination: The transfer of an amino group from Glutamic acid to keto position of corresponding keto acid in presence of an enzyme transaminase and co enzyme pyridoxyl phosphate is called **"Transamination ".**
The co enzyme Pyridoxyl phosphate acts as a carrier of amino group . It picks amino group from donar amino acid and converts into pyridoxyl amine phosphate. It transfers this amino group to the acceptor keto acid forming new amino acid and itself is converted into pyrodoxyl phosphate.

II Non symbiotic Nitrogen fixation

The process of conversion of molecular Nitrogen of the atmosphere into free Ammonium ions by free living bacteria is known **as Non symbiotic nitrogen** fixation. EX; Azatobacter ,clostridium, Pseudomonas, Chlorobium , Rhodospirullum etc .

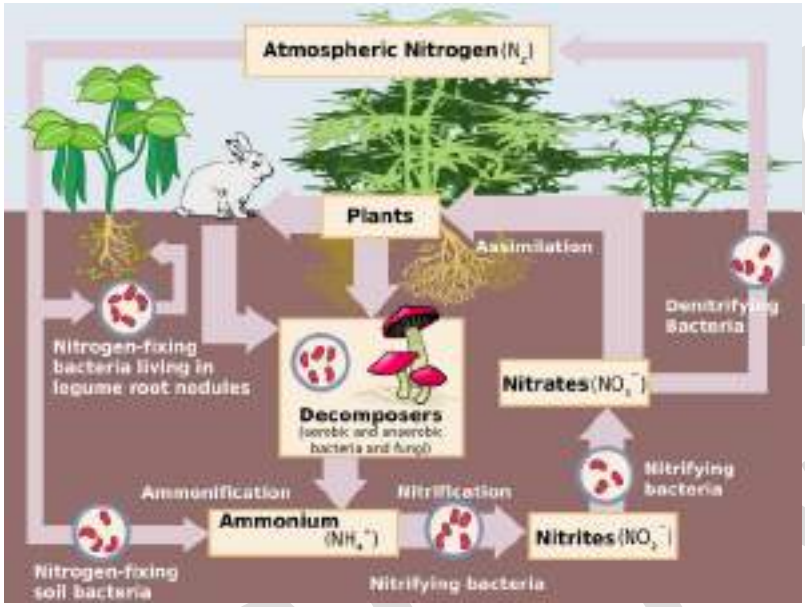
III Associative Nitrogen fixation

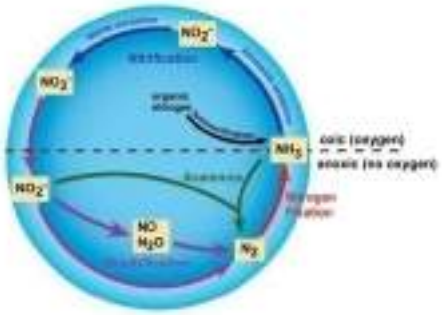
The process of conversion of molecular nitrogen of the atmosphere into free Ammonium ions by free living bacteria when present in intimate association with roots of higher plants is known as **" Associative Nitrogen fixation."**
It is an association between bacteria and roots of cereals , grasses without development of nodule like structure. In this type bacteria live in Rhizosphere [transition zone between soil & root] .the bacteria fix Nitrogen and supply to root, in return roots provide carbon di oxide , & carbohydrates to bacteria.
Ex: Beijerinckia ----Roots of Sugar cane ,
Azospirullum -------Roots of cereals

Azatobacter paspali---------Roots of tropical grass.

NITROGEN CYCLE

The cyclic movement of Nitrogen between organic and inorganic form to maintain its balance in nature is called" Nitrogen cycle".





Nitrogen cycle involves fallowing steps :-

8. Air is a reservoir for nitrogen. It is made avilable for plants during lightning and rain fall by physical means and through soil microbes by biological nitrogen fixation.
9. Nitrates are utilized by green plants to synthesise nutrients .[proteins].
10. Animals feed on plants , Nutrients are passed to animals . These excrete nitrogenous wastes. These are converted into Nitrites by Ammonification.
11. Dead bodies of plants and Animals are decomposed into nitrogenous wastes.
12. Nitrites are converted into nitrates by nitrification.

13. Nitrates are converted into gaseous nitrogen by denitrification [bacteria pseudomonas denitrificans , Thiobacillus bring about Denitrification].
14. Gaseous Nitrogen is made available for plants throughnitrogen fixation by physical and biological methods.

Thus Nitrogen cycle goes on continuously in nature.

2MARKS QUESTIONS

1. What are 'Nif' genes? Mention their significance.
2. Define Non Associative nitrogen fixation with example.
3. What is meant by Trans amination and Reductive amination.
4. What is meant by Symbiotic Nitrogen fixation? Give an example.

5 MARKS QUESTIONS

5. Explain Nitrogen cycle.
6. Describe Amino acid synthesis.

10 MARKS QUESTIONS

1. Describe Biological nitrogen fixation.

Unit 7(4 Hrs)

Plant growth regulators: Auxins, Gibberellins, Cytokinins, Ethylene ,ABA and their role in agriculture and horticulture.

Phytohormones

The term 'Hormones' is derived from Greek word where 'hormo' means to ' Stimlae'. Thiamann coined the term. phytohormones are organic substances synthesised in minute concentration in one part of the plant body and transported to another part where they control growth and other physiological functions.

Classification of Phytohormones

Natural phyto hormones are classified into 2 groups. they are

- **Growth Promotors**:- The hormones which accelerates the growth and development in plants are called 'Growth promotors'. Ex: Auxins, Gibberlins, Cytokinins.
- **Growth Inhibitors**:- The hormones which retard or inhibit the growth and development in plants are called' Growth inhibitors.Ex: Ethylene , Abscissic acid.

Growth Promotors

Auxins (In Greek auxein means to grow).

- In 1880 Charles Darwin and his son Francis Darwin found that the sensation of unilateral illumination p by the coleoptile tip of Canary Grass.
- In 1910Boysen-Jensen showed that the sensation of phototropism picked up by coleoptile tip could be transmitted to sub-apical region.
- 1928 Went discovered that the hormone travelled from tip or apex towards the base. The growth promoting substance was named by him as auxin .
- In 1931 Kogl and Haagen-Smith isolated three chemicals from human urine.They were named as auxin a, auxin b, and hetero-auxin.

- In 1934 Kogl found that hetero-auxin is the real plant auxin and is chemically indole 3-acetic acid or lAA. It is an universal natural auxin It is also present in urine of human beings suffering from pellagra, a disease caused by deficiency of niacin.
- In 1934 Kogl discovered related chemicals indole 3-acetaldehyde, indole 3-acetonitrile, indole 3-butyric acid (IBA), phenyl acetic acid and 4-chloro indole acetic acid. All of them have auxin like activity.
- Auxin is synthesised in shoot apices, leaf primordia and developing seeds from amino acid tryptophan. Auxin passes from shoot tip to the region of elongation.
- The raw material used in synthesis of auxin is called auxin precursor. It is tryptophan for IAA.
- Certain compounds inhibit action of auxin. They are called anti-auxins, e.g., p-chloro phenoxy isobutyric acid (PCIB). TIBA (2, 3, 5 triiodobenzoic acid.

Synthetic Auxins:

Many synthetic auxins are also being manufactured. The important ones are 2: 4 D (2: 4-di-chlorophenoxy acetic acid), 2 : 4 : 5-T (2 : 4 : 5-tri-chlorophenoxy acetic acid), IBA (indole 3-butyric acid), NAA (naphthalene acetic acid). MCPA (2-methyl 4- chloro-phenoxyacetic acid), Dicamba (2-methoxy 3-, 6-di-chlorobenzoic acid). IBA is both natural and synthetic. Synthetic auxins move in all directions inside plants.

Bioassay of Auxins: It is testing of a biological activity like growth response of a substance by employing a living material like plant or plant part.

1. Avena Curvature Test is based on experiments of Went 10° curvature is produced by auxin concentration of 150 µg/litre at 25° C and 90% relative humidity. The test can measure auxin upto 300 pg/litre.

2. Root Growth Inhibition: Sterilized seeds of Cress are allowed to germinate on moist filter paper. As the roots reach a length of 1 cm , root lengths are measured. 50% of the seedlings are placed in a test solution while the remaining are allowed to grow over moist paper.Lengths of the roots are measured after 48 hours. It is seen that the seedlings placed in test solution show very little root growth while root growth is normal in control seedlings.

Functions of Auxins:

1. Respiration: Auxins stimulate respiration by increasing availability of respiratory substrate.

2. Metabolism: Application of auxin enhance metabolism due to mobilisation of plant resources.

3. Solutes: Auxins increase storage of solutes inside the cells.

4. Cell Enlargement: Cell enlargement is caused by solubilisation of carbohydrates, loosening of wall micro-fibrils, synthesis of more wall materials, increased membrane permeability and respiration.

5. Cambial Activity: Degree of cambial activity is directly proportional to auxin concentration. Auxin also controls xylem differentiation.

6. Cell Division: Auxin promotes division in the cells of vascular cambium.

7. Tissue Culture: In tissue culture, the development of callus or mass of undifferentiated cells is promoted by auxin.

8. Root Formation: Auxin promotes root initiation.

9. Apical Dominance: Apical dominance is the phenomenon by which presence of apical bud does not allow the nearby lateral buds to grow. When the apical bud is removed, the lateral buds sprout.

10. Inhibition of Abscission: Auxin delays abscission of young leaves and fruits. auxin promotes the abscission of mature or older leaves and fruits.

11. Tropic Movements: Differential distribution of in-dole 3-acetic acid produces phototropism and geotropism.

12. Sex: Auxins have a feminizing effect on some plants.

13. Seedless Fruits: Auxin promotes development of parthenocarpic fruits . e.g., Banana.

14. Ethylene: Higher concentration of IAA induces synthesis of ethylene.

15. Membrane Potential: It produces a negative potential on the cell membrane.

Uses of Auxins:

1. Rooting: Auxins stimulate root formation on the stem cutting, e.g., IBA, IBA-alanine, NAA.

2. Parthenocarpy: Application of auxins (e.g., IAA, IBA) and conjugate auxins (e.g., IBA-alanine) to un-pollinated pistils make them develop into seedless fruits or parthenocarps which carry a better market price than the normal fruits having seeds.

3. Weedicides: Chemicals which kill weeds growing in the fields. Application of 2: 4-D and 2:4: 5-T removes broad leaved weeds in cereal crops and lawns because they do not affect mature monocotyledons while Dalapon (2-2 di-chloropropionic acid) kills grasses in broad leaved crops.

4. Flowering:NAA and 2, 4-D are often employed for inducing flowering in Litchi and Pineapple.

5. Storage: Methyl ester of NAA prevents the sprouting of Potato tubers kept in storage.

6. Pre-Harvest Fruit Drop: In low concentration 2, 4-D is useful in preventing pre-harvest fruit drop of Orange and Apple.

7. Vegetable Crops: Chlorophenoxy propionic acid enhances the quality of vegetable crops by preventing flower formation.

8. Fruits: Auxins enhance sweetening of fruits, e.g., IBA.

9. Prevention of Lodging: Naphthalene acetamide (NAAM) prevents lodging or falling of crop plants during windy season.

10. Dwarf Shoots: Application of naphthalene acetic acid increases the number of dwarf shoots and number of fruits.

Gibberellins

- Gibberellins known in Japan since 1800 where certain rice plants were found to suffer from bakane or bakanae (foolish seedling) disease.
- In 1918 Hori and Kurosawa in 1926 found that it is caused by a fungus, Gibberella fujikori.
- Yabuta in 1935 named it gibberellin . Yabuta also prepared crystalline form of gibberellin which actually consisted of six gibberellins.

- 1955 Brian et al isolated in pure form Gibberellic acid or GA_3 . Cross in 1961 worked out the structure of gibberellic acid, GA_3 .

It is chemically $C_{19}H_{22}O_6$. GA_3 is one of the most intensively studied gibberellin. Until now 125 different gibberellins have been identified. Many of them occur naturally in plants and fungi. Gibberella fujikori has as many as 15 gibberellins.

Bioassay of Gibberellins

1. Dwarf Pea: Seeds of dwarf pea are allowed to germinate till the formation of coleoptile. GA solution is applied to some seedlings. Others are kept as control. After 5 days, epicotyl length is measured. GA stimulates epicotyl growth with a concentration as low as 1 Nano gram.

2. Barley Endosperm: Endosperms are detached from embryos, sterilized and allowed to remain in 1 ml of test solution for 1-2 days. There is a build-up of reducing sugars. The content of reducing sugar is proportional to gibberellin concentration. Reducing sugars are not formed in control experiment where endosperms are kept in plain water.

Functions of Gibberellins:

1. Stem and Leaf Growth: Gibberellins help in cell growth of stem, leaves and other aerial parts. Thus they increase the size of stem, leaves, flowers and fruits.

2. Dwarf Shoots: Gibberellins induce intermodal growth in some genetically dwarf varieties of plants like Pea and Maize.

3. Bolting: Gibberellins induce sub-apical meristem to develop faster. This causes elongation of reduced stem or bolting in case of rosette plants. Ex: Henbane, Cabbage, and root cropsEx: Radish

4. Dormancy: Gibberellins overcome the natural dormancy of buds, tubers, seeds, etc. and allow them to grow.

5. Seed Germination: During seed germination, gibberellins stimulate the production of some messenger RNAs and then hydrolytic enzymes like amylases, lipases ribonucleases and proteases in cereals. The enzymes solubilize the reserve food and it is transferred to embryo axis for its growth.

6. Fruit Development: They induce parthenocarpic fruit formation .e.g., Apple, Pear.

7. Flowering: They promote flowering in long day plants during non-inductive periods.

8. Vernalization: Vernalization or low temperature requirement of some plants can be replaced by gibberellins.

9. Sex Expression: Gibberellins promote the formation of male flowers on genetically female plants of Cannabis. They can also replace female flowers with male flowers on monoecious plants of cucurbits.

10. Curvatures: Gibberellins are responsible for phototropic and geotropic responses of shoot tips in Sunflower.

Uses of Gibberellins(Applications)

1. Fruit Growth: Application of gibberellins increases the number and size of several fruits, e.g., Grape, Tomato.

2. Parthenocarpy: Seedless fruits can be produced by application of gibberellins to un-pollinated flowers.

3. Malt: Gibberellins (e.g., GA_3) increase the yield of malt from barley grains.

4. Overcoming Dormancy: Gibberellins is used for breaking seed and bud dormancy. They induce germination of positively photoblastic seeds of Tobacco and Lettuce in complete darkness.

5. Delayed Ripening: GA_7 delays senescence so that fruit can be left on the tree for longer period .(It extends period of marketing. Ripening of Citrus fruits can be delayed with the help of gibberellins. This is useful in storing the fruits).

6. Flowering: Gibberellins can be used in inducing off season flowering in many long day plants & plants requiring vernalisation.

7. Sugarcane: Spraying of sugarcane crop with gibberellins increases length of stem and yield of sugarcane to as much as 20 tonnes/acre.

8. Early Maturity: Juvenile conifers sprayed with mixture of GA_4 and GA_7 reach maturity quite early resulting in early seed production.

Cytokinins:

- Cytokinins is aplant growth hormones which are basic in nature, either amino purine or phenyl urea derivatives, that promote cytokinesis (= cell division) either alone or in conjunction with auxin.
- The first cytokinin was discovered from degraded autoclaved Herring sperm DNA by Miller 1955.
- It is called kinetin (6-furfuryl amino-purine). Kinetin does not occur naturally. It is a synthetic hormone.
- The first natural cytokinin was obtained from unripe maize grains or kernels by Letham (1964). It is known as zeatin (6-hydroxy 3-methyl trans 2-butenyl amino-purine).It also occurs in coconut milk.
- Up to now 18 types of cytokinins have been discovered. Some of them are constituents of transfer RNAs.
- Roots seem to be the major source of cytokinin synthesis. From roots the cytokinins pass upwardly through xylem.
- cytokinin synthesis also takes place in other areas where cell divisions are occurring like endosperm region of seeds, growing embryos and developing seeds, young fruits, developing shoots buds, etc. Coconut milk is a rich source of cytokinin.

Bioassay of Cytokinins:

1. Tobacco Pith Culture: Out of two tobacco pith cultures, one is supplied with cytokinin while the other is not. Increase in fresh weight of the tissue over the control is a measure of stimulation of cell divisions and hence cytokinin activity. The test can measure cytokinin concentration between 0.001-10 mg/litre. It takes 3-5 weeks.

2. Retardation of Leaf Senescence: It is a rapid bioassay technique. Leaf discs are taken in two lots. In one lot cytokinin is provided. After 48-72 hours, the leaf discs are compared for chlorophyll content. Cytokinin retards the process of chlorophyll degradation. The test is sensitive in concentration of 1 pg/litre.

3. Excised Radish Cotyledon Expansion: The test was developed by Letham. Excised Radish cotyledons are measured and placed in test solution as well as ordinary water (as control). Enlargement of cotyledons is an indication of cytokinin activity.

Functions of Cytokinins:

1. Cell Division: Cytokinins are essential for cytokinesis .

2. Cell Elongation: Cytokinins cause cell elongation.

3. Morphogenesis: Cytokinins are essential for morphogenesis or differentiation of tissues and organs. In 1957 Skoog and Miller, reperted that buds develop when cytokinins are in excess while roots are formed when cytokinins are in less.

4. Differentiation: Cytokinins induce formation of new leaves, chloroplasts in leaves, lateral shoot formation and adventitious shoot formation. They also bring about lignification and differentiation of inter-fascicular cambium.

5. Senescence (Richmond-Lang Effect): Cytokinins delay the senescence of leaves and other organs by mobilisation of nutrients.

6. Apical Dominance: It promotes apical dominance.

7. Seed Dormancy: They help to overcome seed dormancy of various types, including red light requirement of Lettuce and Tobacco seeds.

8. Resistance: Cytokinins increase resistance to high or low temperature and disease.

9. Phloem Transport: They help in phloem transport.

10. Accumulation of Salts: Cytokinins induce accumulation of salts inside the cells.

11. Flowering: Cytokinins can replace photoperiodic requirement of flowering..

12. Sex Expression: Cytokinins promote femaleness in flowers.

13. Parthenocarpy: In 1965 Crane reported induction of parthenocarpy through cytokinin treatment.

Uses of Cytokinins(Applications)

1. Tissue Culture: Cytokinins are essential for tissue culture as it responsible for cell division and also involved in morphogenesis. It is provided through the addition of coconut milk or yeast extract medium.

2. Shelf Life: Application of cytokinins to marketed vegetables can keep them fresh for several days. (Shelf life of cut shoots and flowers is prolonged).

3. Resistance: Cytokinin helps plants in developing resistance to pathogens and extremes of temperature.

4. Overcoming Senescence: Cytokinins delay senescence of intact plant parts.

Growth Inhibitors

I.Ethylene

- Ethylene is a gaseous hormone which stimulates transverse or isodiametric growth but retards the longitudinal one.
- In 1910 Cousins found that ripe oranges produced a volatile substance that promoted ripening of unripe bananas.
- In 1934 R. Gane found that the ripening causing volatile substance was ethylene.

- In 1935 Crocker recognised Ethylene as a plant hormone.
- Ethylene is produced in plants from the amino acid methionine. It is formed in almost all plant parts— roots, leaves flowers, fruits, and seeds.

Functions of Ethylene:

1. Growth: Ethylene inhibits longitudinal growth but stimulates transverse or horizontal growth and swelling of axis.

2. Gravity: It decreases the sensitivity to gravity. Roots become Apo-geotropic while stems turn positively geotropic. Leaves and flowers undergo drooping. The phenomenon is called epinasty.

3. Senescence& Abscission: It brings the senescence of leaves and flowers. Abscission of leaves, flowers, fruits.

5. Apical Dominance: Ethylene promotes apical dominance and prolongs dormancy of lateral buds.

6. Breaking of Dormancy: It breaks the dormancy of buds, seeds and storage organs.

7. Abscisic Acid: Abscisic acid is formed in the leaves under conditions of water stress is mediated through ethylene.

8. Growth of Rice Seedling: Ethylene promotes rapid elongation of leaf bases and internodes in deep water rice plants. As a result leaves remain above water.

9. Root Initiation: In low concentration ethylene helps in root initiation, growth of lateral roots and root hairs.

10. Fruit Ripening: It aids in ripening of climacteric fruits and dehiscence of dry fruits. Climacteric fruits are fleshy fruits which show a sudden sharp rise of respiration rate at the time of ripening (respiratory climacteric). They are usually transported in green or unripe stage. Ethylene is used to induce artificial ripening of these fruits. Ex: Apple, Mango, Banana, etc.

11. Flowering: It stimulates flowering in Pineapple, Mango and also causes fading of flowers. This helps in synchronizing fruit set.

12. Sex Expression: Ethylene has a feminizing effect on sex expression. The genetically male plants of Cannabis can be induced to produce female flowers in the presence of ethylene.

Uses of Ethylene(Applications)

The uses of ethylene are as follows:-

1. Fruit Ripening: Ethylene lamps are now s used for stimulating colour development and ripening of some fleshy fruits, e.g., Banana, Mango, Apple, and Tomato.

2. Feminising Effect: External supply of very small quantity of ethylene increases the number of female flowers and hence fruits in Cucumber.

3. Sprouting of Storage Organs: Rhizomes, corms, tubers, seeds and other storage organs can be made to sprout early by exposing them to ethylene.

4. Thinning: Better growth of fruits excess flowers and young fruits are thinned with the help of ethylene. Ex: Cotton, Cherry, and Walnut.

II.Abscisic Acid

- Abscisic Acid is also called stress hormone because the production of hormone is stimulated by drought, water logging and other adverse environmental conditions.
- In 1963 Addicott isolated this hormone from Cotton bolls. Abscisic acid is known as Dormin as it induces dormancy in buds, underground stems and seeds.
- Abscisic acid is a mildly acidic growth hormone which functions as a general growth inhibitor by counteracting other hormones such as auxin, gibberellins, and cytokinins or reactions mediated by them.
- It is produced in many parts of the plants and abundantly inside the chloroplasts of green cells and later transports to all parts of the plant through diffusion and through phloem and xylem.

Functions of Abscisic Acid

1. Bud Dormancy: Abscisic acid induces dormancy of buds..

2. Seed Dormancy: It causes seed dormancy .

3. Stoppage of Cambium Activity: Abscisic acid stops mitosis in vascular cambium towards the approach of winter.

4. Abscission: Abscisic acid promotes abscission of flowers and fruits.

5. Leaf Senescence: Its excessive presence stops protein and RNA synthesis in the leaves and stimulates their senescence.

6. Transpiration: Abscisic acid is rapidly synthesised during desiccation and other stresses. it results in closure of stomata and prevents transpiration.

7. Resistance: Abscisic acid increases resistance of plants to cold and other types of stresses. It is, therefore, also known as stress hormone.

8. Starch Hydrolysis: Abscisic acid inhibits gibberellin mediated amylase formation during germination of cereal grains.

9. Flowering: In small quantities, abscisic acid is known to promote flowering in some short day plants Ex: Strawberry.

10. Rooting: It promotes rooting of stem cuttings Ex:Bean.

11. Membrane Potential: ABA induces a positive surface potential on cell membrane.

13. Controlled Growth: It is antagonist to gibberellins and counteracts the effect of other growth promoting hormones.

Uses of Abscisic Acid(Applications)

1. Antitranspirant: Application of minute quantity of abscisic acid to leaves shall reduce transpiration to a great extent through partial closure of stomata. It conserves water and reduces the requirement of irrigation.

2. Flowering: It is useful in introducing flowering in some short day plants kept under un-favourable photoperiods.

3. Rooting: Use of abscisic acid promotes rooting in many stem cuttings.

4. Dormancy: Abscisic acid is used in prolonging dormancy of buds, storage organs and seeds.

2 MARKS QUESTIONS

1. What are Growth Promotors? Give example.
2. What are Growth inhibitors? Give example.
3. What is meant by Rich mond long effect?
4. Mention 2 applications of ABA.
5. Mention 4 important role of Ethylene.
6. Mention the persons who discovered Auxins and Gibberlins.
7. What are phyto harmones? Mention the types.
8. Mention Natural and Synthetic Harmones.

5 MARKS QUESTIONS

1. List role of Auxins. Any 5
2. List role of Gibberlins. Any 5
3. List role of Cytokinins. Any 5
4. Mention Role and applications of Ethylene.
5. Mention Role and applications of Abssisic acid.

10 MARKS QUESTIONS

1. Give an account of Physiological role and applications of Auxins.
2. Describe Physiological role and applications of Gibberlins.
3. Explain Role and applications of Growth inhibitors.

Unit 8 (4 Hrs)

Plant response to light and temperature ,Photoperiodism , Phytochromes, Florigen concept, Vernalization.

Photoperiodism:

Introduction:

The plants in order to flower require a certain day length i.e., the relative length of day and night which is called as photoperiod. The response of plants to the photoperiod for flowering is called as **photoperiodism.**

The phenomenon of photoperiodism was first discovered by Garner and Allard (1920, 22) He observed that the Biloxi variety of Soybeans (Glycine max) and 'Maryland Mammoth' variety of tobacco (Nicotiana tabacum) could be made to flower only when the daily exposure to the light was reduced below a certain critical duration.After many complex experiments concluded that **'the relative length of the day is a factor of the first importance in the growth and development of plants'.**

Depending upon the duration of the photoperiod, they classified plants into three categories.

(1) Short Day Plants (SDP):

These plants require a relatively short day light period (usually 8-10 hours) and a continuous dark period of about 14-16 hours for flowering .These plants are also known as long-night-plants .Ex:- Maryland Mammoth variety of tobacco (Nicotiana tabacum) Biloxi variety of Soybeans (Glycine max), Cocklebur (Xanthium pennsylvanicum).

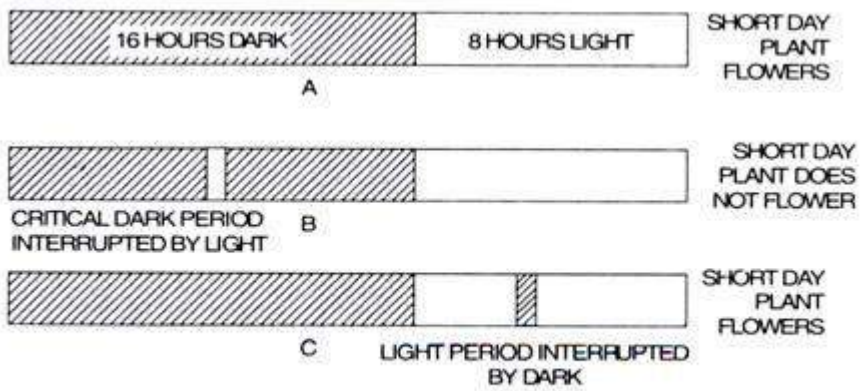


Fig. 18.1. Effect of a brief exposure of red light during dark and interruption of light period by dark on flowering in a short day plant.

i. In short day plants the dark period is critical and must be continuous. If this dark period is interrupted even with a brief exposure of red light, it will not flower.

ii. The inhibitory effect of red light can be overcome by a subsequent exposure with far-red light (730-735 mu wavelengths).

iii. Interruption of the light period by dark does not have inhibitory effect on flowering in short day plants (Fig. 18.1 C).

iv. Prolongation of the continuous dark period initiates early flowering in short day plants.

(2) Long Day Plants (LDP):

These plants require a longer day light period (usually 14-16 hours) in a 24 hours cycle for subsequent flowering. These plants are also called as **short night plants** .Ex: Spinacea (spinach) Beta vulgaris (Sugar beet).

i. In long day plants the light period is critical.

ii. A brief exposure in the dark period or the prolongation of the light period stimulates flowering in long day plants.

(3) Day Neutral Plants:

These plants flower in all photoperiods ranging from 5 hours to 24 hours continuous exposure. Ex: Tomato, cotton, sunflower, cucumber and certain varieties of peas and tobacco.

During recent years certain intermediate categories of plants have also been recognised. They are,

A)Long Short Day Plants:

These are short day plants but must be exposed to long days during early periods of growth for subsequent flowering. Some of the examples of these plants are certain species of Bryophyllum.

B)Short-Long Day Plants:

These are long day plants but must be exposed to short days during early periods of growth for subsequent flowering. Some of the examples of these plants are certain varieties of wheat (Triticum) and rye (Secale).

Photoperiodic Induction:

Plants may require one or more inductive cycles for flowering. An appropriate photoperiod in 24 hours cycle constitutes one inductive cycle. If a plant which has received sufficient inductive cycles is subsequently placed under un-favourable photoperiods, it will still flower. Flowering will also occur if a plant receives inductive cycles after intervals of un-favourable photoperiods (i.e., discontinuous inductive cycles). This persistence of photoperiodic after effect is called as photoperiodic induction.

i. An increase in the number of inductive cycles results in early flowering of the plant. For instance Xanthium (a short day plant) requires only one inductive cycle and normally flowers after about 64 days. It can be made to flower even after 13 days if it has received 4-8 inductive cycles. In such cases the number of flowers is also increased.

ii. Continuous inductive cycles promote early flowering than discontinuous inductive cycles.Ex: Biloxi soybean (SDP) —2 inductive cycles; Salvia occidentalis (SDP) — 17 inductive cycles; Plantago lanceolata (LDP)—25 inductive cycles.

Florigen concept.

The photoperiodic stimulus is perceived by the leaves. As a result, a floral hormone is produced in the leaves, then trans located to the apical tip, causing the initiation of floral primordia.

Floral hormone has been named as florigen. But it is quite evident that this hormone is a material substance which can be trans located from leaves to the apical tips situated at other parts of the plant resulting in flowering.

According to Corbesier and Coupland, 2005 'florigen' to be a macromolecule,may possibly be a RNA or protein molecule which is trans located from the leaf to the apical tips (or meristems) via phloem in photo-induced plants.

Grafting experiments in cocklebur plants have even proved that the floral hormone can be trans located from one plant to another.

(That the photoperiodic stimulus is perceived by the leaves can be shown by simple experiments on cocklebur (Xanthium pennsylvanicum), a short day plant. Cocklebur plant will flower if it has previously been kept under short-day conditions. If the plant is defoliated and then kept under short day condition, it will not flower. Flowering will also occur even if all the leaves of the plant except one leaf have been removed. If a cocklebur plant intact of defoliated, is kept under long day conditions it will not flower . But,

if even one of its leaves is exposed to short day condition and the rest are under long day photoperiods, flowering will occur.The photoperiodic stimulus can be transmitted from one branch of the plant to another branch. For example, if in a two branched cocklebur plant one branch is exposed to short day and other to long day photo period, flowering occurs on both the branches.Flowering also occurs if one branch is kept under long day conditions and other branch from which all the leaves except one have been removed is exposed to short day condition. If one branch is exposed to long photoperiod and the other has been defoliated under short day condition, flowering will not occur in any of the branches).

Nature of the Floral Hormone:

'Grafting experiments in cocklebur plants have even proved that the floral hormone can be trans located from one plant to another. For example, if one branched cocklebur plant, which has been exposed to short day conditions is grafted to another cocklebur plant kept under long day conditions, flowering occur on both the plants.

The floral hormone has been transmitted to the receptor plant through graft union. But if a cocklebur plant is grafted to another similar plant both of which have been kept under long day conditions, flowering will not occur on either of the two plants .It has also been indicated that the floral hormone may be identical in short-day and long- day plants. For example, grafting experiments between certain long-day plants and short-day plants have shown that flowering occurs on both the plants even if one of them has been kept under non-inductive photoperiods.

Phytochrome:

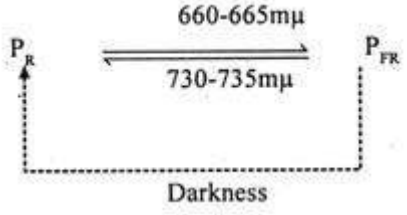
Proteinaceous pigment that inhibits flowering in Short day plants and Stimulates flowering in Long day plants by interruption in dark period is called "Phytochrome".

- **Vierstra and Quail in 1983 reported Successful purification of intact native phytochrome from etiolated oat seedlings**.
- The native phytochrome is a **soluble protein** with a molecular weight of about 250 kDa. It's a **homodimer** of two identical polypeptides each with a molecular weight of about 125 kDa.
- Each polypeptide has a prosthetic group called as **chromophore** which is covalently linked to the polypeptide via a sulphur atom (Thioether Linkage) in the cysteine residue of the polypeptide. The protein part of the phytochrome is called as **apoprotein**. Apoprotein along with chromophore constitute holoprotein

i. The pigment phytochrome exists in two different forms:

(i) **Red light** absorbing from which is designated as $\mathbf{P_R}$ and
(ii) **Far-red light** absorbing form which is designated as $\mathbf{P_{FR}}$**.**
ii. These two forms of the pigment are photo chemically inter convertible.

iii. When **P_R** form of the pigment absorbs red light (660-665mp), it is converted into **P_{FR} form.**
iv. When **P_{FR}** form of the pigment absorbs far-red light (730-735mp), it is converted into **P_R** form.
v. The **P_{FR}** form of the pigment gradually **changes into P_R** form **in dark**.



- Brief exposure with red light during critical dark period inhibits flowering in short-day plants.
- This inhibitory effect can be reversed by a subsequent exposure with far-red light.
- The prolongation of the critical light period or the interruption of the dark period stimulates flowering in long-day plants.
- During the day the P_{FR} form of the pigments is accumulated in the plant which is inhibitory to flowering in short-day plants but is stimulatory in long–day plants.
- During critical dark period in short-day plants, this form gradually changes into P_R form resulting in flowering.A brief exposure with red light will convert this form again into P_R form thus inhibiting flowering.
- Reversal of the inhibitory effect of red light during critical dark period in SDP by subsequent far-red light exposure is because the P_{FR} form after absorbing far-red light (730-735mμ) will again be converted back into P_R form.

TYPES OF PHYTOCHROMES IN PLANTS

There are two major types of phytochromes in plants, (i) type I and (ii) type II.

The type I predominates in etiolated seedlings. Type I phytochrome is encoded by PHY A gene while type II is encoded by PHY B, PHY C, PHY D and PHY E genes.

The type II in green plants and seeds (such as oat seeds). There are minor differences in molecular weight and spectral properties of these two types of phytochromes.

Importance of Photoperiodism:

(i) The knowledge of photoperiodism has been of great practical importance in hybridisation experiments.

(ii) Although the floral hormone ‘florigen’ has not yet been isolated, the isolation and characterization of this hormone will be of utmost economic importance.

(iii) The phenomenon of photoperiodism is an excellent example of physiological preconditioning where an external factor i.e., the photoperiodic stimulus, induces some physiological changes in the plant .

(Phytochrome Mediated Photo responses in Plants:

1. Photoperiodism.2. Seed germination.3. Elongation of leaf, petiole, stem. 4. Hypocotyl hook unfolding.5. Unfolding of grass leaf. ,6. Sex expression. 7. Bud dormancy.8. Plastid morphology.9. Plastid orientation.11. Rhizome formation.12. Bulb formation.13. Leaf abscission.14. Epinasty.15. Succulency16. Enlargement of cotyledons.17. Hair formation along cotyledons.18. Formation of leaf primordia. 19. lower induction.20. Differentiation of primary leaves.21. Formation of tracheary elements.22. Differentiation of stomata.23. Change in rate of cell respiration.24. Formation of phenylalanine deaminase.25. Synthesis of anthocyanins.26. Increases in protein systhesis.27. Increase in RNA synthesis.28. Changes in the rate of fat degradation.29. Changes in the rate of degradation of reserve proteins.30. Auxin catabolism.31. Incorporation of sucrose into plumular tissue.32. Permeability of cell membranes.33. Lipoxygenase metabolism).

Vernalization: **Introduction;**

Many plants do not come to flower before they experience a low temperature. These plants remain vegetative during the warm season, receive low temperature during winter, grow further and then bear flowers and fruits. Requirement of low temperature prevents precocious reproductive development in autumn.

It allows the plant to reach vegetative maturity before reproduction can occur. The condition occurs in winter varieties of some annual food plants (e.g., Wheat, Barley, and Rye), some biennial (e.g., Cabbage, Sugar beet, Carrot) and perennial plants (e.g., Chrysanthemum).

The annual winter plants also possess spring varieties. The spring varieties are planted in spring. They come to flower and bear fruits prior to end of growing season.

If the winter varieties are sown similarly, they fail to flower and produce fruits before the end of growing season. They are planted in autumn, form seedlings in which form they cover winter. The seedlings resume growth in spring. They bear flowers and fruits in summer.

Definition:

Lysenko (1928), a Russian worker that **the cold requiring annual and biennial plants can be made to flower in one growing season by providing low temperature treatment to young plants or moistened seeds.**He called the effect of this chilling treatment as "**vernalization"**. Vernalization is, therefore, a process of shortening of the juvenile or vegetative phase and hastening flowering by a previous cold treatmen.

Site for Vernalization:

The stimulus of vernalization is perceived only by the meristematic cells, e.g., shoot tip, embryo tips, root apex, developing leaves, etc.

Requirements of Vernalization:

(i) Low Temperature: Low temperature required for vernalization is usually 0°—5°. It is 3°—17° in case of biennial Henbane (Hyoscyamus niger). Low temperature treatment should not be immediately followed by very high temperature (about 40°C) otherwise the effect of vernalization is lost. The phenomenon is called de-vernalization.

(ii) Period of Low Temp. Treatment: It varies from a few hours to a few days.

(iii) Actively Dividing Cells: Vernalization does not occur in dry seeds. The seeds must be germinated so that they contain an active embryo. For this the seeds are moistened before exposing them to low temperature. In whole plants, an active meristem is required.

(iv) Water: Proper protoplasmic hydration is must for perceiving the stimulus of vernalization.**v) Aerobic Respiration** and **(vi) Proper Nourishment.**

Mechanism of Vernalization:

The stimulus received by the actively dividing cells of shoot or embryo tip travels to all parts of the plant and prepare it to flower. The stimulus has been named as vernalin. It can be passed from one plant to another through grafting in case of Henbane but not in others. However, the chemical has not been separated. In some plants cold treatment can be replaced by gibberellins.

Vernalization prepares the plant to flower. The induction of flowering depends upon the presence of other favourable conditions. Photoperiodism, however, not only prepares the plant to flower but also brings about flowering. Thus, Henbane is a long-day plant which also requires cold treatment. Unless and until both are provided the plant will not come to flower,

Importance of Vernalization:

(i) Vernalization can help in shortening the juvenile or vegetative period of plant and bring about early flowering. It is not only applicable to temperate plants but also to some tropical plants, e.g., Wheat, Rice, Millets, Cotton.

(ii) It increases yield, resistance to cold and diseases, and

(iii) Kernel wrinkles of Triticale can be removed by vernalization.

2 Marks Questions

1. What is Photoperiodism?
2. What is Vernalisation? Mention its significance.
3. What are Phytochromes?

5 Marks Questions

1. Explain Vernalisation.

2. Write a note on Phytochrome.
3. Give an account of Photoperiodism.
4. Describe Florigen concept.

Unit 9

Dormancy: a brief account of seed dormancy (1 Hour)

Seed Dormancy:

Dormancy is a delaying mechanism which prevents germination of seed**.**

DEFINITION:-Seed dormancy is the innate inhibition of germination of a viable seed even when placed in most favourable environment for germination.

Bewlay and Black (1994) have divided seed dormancy into two categories, seed coat based and embryo based. Germination inhibitors occur in both.

Types of Seed Dormancy:

Harper (1977) recognizes three types of seed dormancy depending on the how each of them arises: viz., innate, enforced and induced. **The seed dormancy is of following types:**

i. **Innate dormancy:- Innate dormancy** may be imposed chemically by the presence of inhibitory compounds either in the seed coat or in the embryo. In some cases environmental conditions such as chilling, fluctuating temperature of specific photoperiods.

ii. **Enforced dormancy:- Enforced dormancy** occurs when seed is deprived of its requirements for germination, for example, by the absence of sufficient moisture, oxygen, light or a suitable temperature.

iii. **Induced dormancy:- Induced dormancy** is caused by the unfavourable conditions.

Causes of Seed Dormancy:-

1. Immaturity of Embryo: Embryo is immature at the time of seed shedding. The seed will remain dormant till the embryo becomes mature, e.g., Anemone nemorosa, Ranunculus ficaria.

2. light: Light sensitive seeds do not germinate in absence of light; whereas light hard seeds do not germinate on the exposure to light.

3. Temperature: Generally the low temperatures promote and high temperatures inhibit the germination. In the Indian desert many weed seeds must pass through very high temperature (60°-70C) of sand in day and at the same time low temperatures (5°-10°C) of night before they are stimulated for germination.

4. Impermeable Seed Coat:- The seed coat is impermeable to water and gases, e.g., Apple, Chenopodium.

5. Hard Seed Coat:- The seed coat is mechanically resistant and does not allow the embryo to grow, e.g., Amaranthus, Lepidium.

6. Germination Inhibitors:- Germination inhibitors causing seed dormancy are abscisic acid, phenolic acid, ferulic acid, coumarin, short fatty acids and cyanogenic chemicals. They occur in the seed coats and cotyledons of the embryos. e.g., Apple, Peach, Ash, Cucurbita, Iris, Xanthium.

METHODS OF BREAKING DORMANCY

Seed dormancy can be broken and make seed to germinate by 2 methods . They are :- I) Natural method and II) Artificial method

I)Natural methods to Break Seed Dormancy:

In nature seed dormancy is broken automatically due to:

(i) Development of growth hormones to counter growth inhibitors,

(ii) Leaching of germination inhibitors,

(iii) Maturation and after-ripening of embryo,

iv) Weakening of impermeable and tough seed coats by microbial action, abrasion, passage through digestive tract of animals, etc.

II) Artificial Breaking of Seed Dormancy:

1. Scarification:- Hard, impermeable seed coat is weakened or ruptured by filing, chipping, hot water and chemicals.

2. Stratification:- Seeds are moistened and exposed to oxygen for variable period at low or high temperature.

3. Counteracting Inhibitors:-Inhibitors are destroyed by dipping seeds in KNO_3, thiourea, ethylene chlorohydrin and gibberellin.

4. Shaking and Pressure:-Vigorous shaking and hydraulic pressure are used to weaken seed coats.

Importance of Seed Dormancy:

1. Perennation:-Seed dormancy allows seeds to pass through drought, cold and other un-favourable conditions.

2. Dispersal:- It is essential for dispersal of seeds.

3. Germination under Favourable Conditions:-Seeds germinate only when sufficient water is available to leach out inhibitors and soften the seed coats.

4. Storage:- Dormancy is responsible to store grains, pulses and other edibles for making them available throughout the year and transport to the areas of deficiency.

2 Marks Questions

1. What is Seed dormancy? Mention its types.
2. Mention Causes of Dormancy.
3. List methods to break dormancy.
4. Mention importance of seed dormancy.
5. What is Scarification and Stratification.

5 Marks Questions

1. Explain causes for Dormancy.
2. Describe methods of breaking Dormancy.

Unit 10 (2 Hrs)

Plant movements: (phototropism, geotropism, hydrotropism and seismonasty)

PLANT MOVEMENTS

Movement of plant body from one place to another or the reorientation of plant organs is called plant movements.

- Movement of entire plant body from **one place to another place** is called **movement of locomotion.**
- **Reorientation** of various organs in the plant which is anchored to the soil is called **movement of curvature.**
- Movement of curvature may be **accompanied by growth** called **Growth movements** or **not accompanied by growth** called **Variation movements.**
- When the movements are not induced by **external stimuli** it is called **autonomic movement.**
- When the movements are induced by **unidirectional external stimuli** it is called **Paratonic movement.**

CLASSIFICATION OF PLANT MOVEMENTS

PLANT MOVEMENTS

1. MOVEMENTS OF LOCOMOTION

AUTONOMIC:

a) Ciliary

b) Cyclosis

PARATONIC

a) Photactic

b) Chemotactic

c) Termotactic

2. MOVEMENTS OF CURVATURE

I. GROWTH MOVEMENT

AUTONOMIC : a) Nastic b) Nutational

PARATONIC:

a) Phototropic b) Geotropic, c) Hydrotropic

II .VARIATION MOVEMENT

AUTONOMIC : a) Gyration

PARATONIC: a) Nyctinastic ,b) Seismonastic

PARATONIC MOVEMENT OF GROWTH

Bending movement of the plant organ due to unilateral application of stimulus is called "Tropism"

1. **Georopism: -**

Bending movement of the plant organ due to unilateral application of Gravitational stimulus is called **"Geotropism".** If the plant organ bend towards stimulus of gravity is called**" Pasistive Geotropism**". If the plant organ bend away from stimulus of gravity is called **"Negative Geotopism".**

Generally roots are positively geotropic and stem is negatively geotropic.If the plant organ is exposed to diffuse application of gravitational stimulus, it never shows any type of movement**.** This can be explained with the help of an instrument called **"Clinostat**". It consists of clock with an axis in which metallic pot with sapling is fixed.

- When the clock is not working, stem tip bends towards light and grow away from stimulus of gravity. This proves bending movement of stem away from light ie,. Negative geotropism.
- When the clock is in working condition, the pot along with seedling rotates one round per hour. During the rotation stem tip receives equal stimulus of gravity and stem tip instead of bending upwards grows horizontally.

- **Phototrpism: -** -

AIM: - To show the Positive Phototropism of Stem.

REQUIREMENT:-
Bending movement of the Plant organ due to unilateral application of stimulus of light is called "**Phototropism"**. If the Plant organ bends towards the stimulus of light, it is said to be 'Positively phototropic', if the Plant organ bends away from the stimulus of Light, it is called "Negatively Phototropic".

PRINCIPLE:-
Unequal distribution of Auxin in the stem of the plants or root tip of the Plants causes differential growth.

PROTOCOL:-
Keep the Seedling pot inside the phototropic chamber. Phototropic chamber is a light proof box with a small window on one side of the wall to allow light rays.

OBSERVATION:-
Stem tip bend towards the window, i.e., towards, the source of light.

INFERENCE:-
This shows positive phototropic nature of stem. Unilateral application of stimulus of light to the stem tip results in unequal distribution of Auxines, where more Auxin concentration towards the shade side induces greater stem elongation. As a result of this Plant bend towards the light side. i.e. Stem tip bends towards the window due to stimulus of light.

c)HYDROTROPISM: Movements in response to external stimulus of water is called Hydrotropism

AIM: - To show Hydrotropic movement of roots.

REQUIREMENTS:-Shallow box with perforation at the bottom, Saw dust, Water soaked seed.

INTRODUCTION:- Bending movement of the root due to unilateral application of stimulus of water is called "**Hydrotropism**". Roots are sensitive to amount of moisture and show tendency to grow towards source of moisture and are said to be **positively hydrotropic** .Unequal distribution of Auxines at the root tip due to unilateral stimulus of water causes bending movement.

PRINCIPLE:- The root grows towards the stimulus of water in the soil. Hydrotropic force is greater than the geotropic force.

PROTOCOL:-

- Porous Clay funnel (perforated Porcelain funnel), covered around with a filter paper, is placed on wide mouthed bottle filled with water.
- Porous funnel is filled with dry saw dust and water soaked seeds are arranged near the pores.
- Frequently sprinkle water to help seed germination**.**

OBSERVATION:-

As seeds germinate, instead of growing vertically down wards in response to force of gravity, move out through the pores towards moist filter paper, and grow downward along the side of the paper into the bottle.

INFERENCE:-Roots thus show movements towards moisture. ie Positive Hydrotropism of root and Hydrotropic force is greater than geotropic force.

d)THIGMOTROPISM:Movements in response to stimulus of touch is called Thigmotropism. Ex: Tendril .

VARIATION MOVEMENTS

The movement of plant organ which is not associated with growth is called variation movement.

a) GYRATION: Indian telegraph plant shows Trifoliate leaves ,one terminal leaf let is larger and two lateral leaf lets are smaller. During day time smaller lateral leaf lets show peculiar upward and downward movement at 180 deg resembling gyration(Dancing). It is completed in two minutes. This movement is called **Gyration.**

PARATONIC VARIATION MOVEMENT

1.NYCTINASTIC MOVEMENT:

Movement of leaves and flowers which take up sleep position.

a) If nastic movement is due to presence or absence of **light** ,it is called **as Photonastic movement. Ex: oxalis.**

b)If the nastic movement is due to **temperature**, it is called **"Thermonastic movement".**

Ex : Tulip

2.<u>SEISMONASTIC MOVEMENT</u>:-

Movement of leaves and flowers which **take up sleep position** is called **Nastic movements. The movement brought about by mechanical stimuli such as contact with foreign body such as fast wind, Rain drops etc .is called seismonastic movement**. The extent of seismonostic movement depends upon factors like intensity of stimulus, Vigor and Age of the plant and time elapsed since the last stimulus. Ex: leaves of Mimosa pudica,Stigmas and Stamens of many plants

A) **In Mimosa pudica** If terminal leaf let is touched stimulus travels down through xylem to pulvinule , leaf lets close in pair , then it passes to other pinna and finally reaches pulvinus base resulting in drooping of whole leaf after few minutes it recover from shock come back to normal position.

B) **In Mimulus,Martynia, Bignonia stigma lobes encirclethe pollen grains as soon as it falls over them.**

C) **In Opuntia,Protulaca, Berberis stamens respond instantly when touched by the body of an insect.**

<u>2 Marks Questions</u>

1. **What is Tropism? Mention its types.**
2. **What is Seismonasty? In which plant you find it.**

<u>5 Marks Questions</u>

1. Explain Phototropism.
2. Describe an experiment to demonstrate Geotropism.
3. Give an account of Seismonastic movement.
4. Write a note on Hydrotropism

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