UNIT – IV

CHAPTER – 11 : TRANSPORT IN PLANTS

Means of Transport

Three means of transport in plants:

- Diffusion
- Facilitated Diffusion
- Active Transport

Diffusion

- Movement of molecules from high concentration to low concentration without semi-permeable membrane.
- Slow process
- No expenditure of energy
- Diffusion depends upon: Concentration gradient, Permeability of the membrane, Temperature, Pressure and Size of the substance.

Facilitated Transport

- In facilitated diffusion, the membrane proteins are involved. They provide a site for hydrophilic molecules to pass through the membrane and no energy is required.
- Proteins involved in the process form channels which may always be opened or controlled. Facilitated diffusion is very specific.
- *Porins*: Proteins that forms huge pores in the outer membranes of plastids, mitochondria, etc. They are different kinds;
- *Aquaporins*: Proteins that facilitate diffusion of water molecules
- Transport can be of 3 types:
  - *Symport* – both molecules move in the same directio
  - *Antiport* – both molecules move in opposite directior
  - *Uniport* – independent movement of molecules
- When all proteins involved are saturated, it leads to maximum transport.

Active transport

- Requires special proteins which are very specific and sensitive to inhibitors.
- Requires energy to pump molecules against the concentration gradient.
- When all proteins involved are saturated, it leads to maximum transport.

Water Potential (ψ_W)

- Greater the concentration of water in a system, greater is its kinetic energy and greater is the water potential.
- It is measured in Pascal (Pa)
- If two systems are in contact, then there is movement of water from the solution with greater water potential to lower water potential.
- Solute potential (ψ_s) – Magnitude of lowering of water potential wh solute is added to the water
- Pressure Potential (ψ_p) – Magnitude of increase of water potential w pressure greater than atmospheric pressure is applied to pure water or a solution
- Water potential of pure water is zero.
- Solute potential is always negative and water potential is always positive.
- $\psi_w = \psi_s + \psi_p$

Osmosis

- Water diffuses from region of its higher concentration to its lower concentration through semi-permeable membrane.
- Diffusion of water across a semi-permeable membrane
- Direction and rate of osmosis depends upon pressure gradient and concentration gradient.
- **Osmotic pressure** – External pressure applied to prevent the diffusion of water

  It depends upon solute concentration.
- Numerically, osmotic pressure is equal to osmotic potential
- Osmotic pressure has positive sign. Osmotic potential has negative sign.

Types of Solutions:

- **Isotonic solution**
  - Concentration of external solution is equal to Concentration in cytoplasm
  - There is no net gain, hence No change in cell size.
- **Hypotonic solution**
  - Concentration in cytoplasm is greater than the Concentration of external solution.
  - So water enters into the celsl and Cells swell.
- **Hypertonic solution**
  - Concentration of external solutions is greater than the Concentration in cytoplasm.
  - Hence water moves from cells to external solution and Cells shrink.

- **Plasmolysis**
  - It occurs when cell is placed in hypertonic solution, because water moves out from cytoplasm and vacuole. Hence Cell membrane shrinks away from the cell wall.
  - As water moves in, cytoplasm builds up a pressure against the cell wall. This pressure is called **turgor pressure** and cells enlarge.

Imbibition

- Diffusion in which water is absorbed by solids, causing them to enormously increase in volume.
- Imbibition is along the concentration gradient and depends upon affinity between adsorbent and liquid being adsorbed.
- Examples − Imbibition of water by seeds that causes seeding to emerge (of soil, swelling of wooden door during rainy season, swelling of raison when soaked in water.

Long Distance Transport of Water: It occurs by three processes, Diffusion, Mass flow system and Translocation through conducting vascular tissues. There are two types of conducting tissues, namely;

Xylem: Transports water, salts, nitrogen and hormones. From roots to the other parts and it is unidirectional.

Phloem: Transports organic and inorganic solutes. It occurs from the source (leaves) to the sink (storage part) and it is multidirectional.

Absorption of Water by Plants

- Water is absorbed through roots by diffusion.
- Root hairs (slender, thin-walled extensions of root epidermal cells) increase the surface area for absorption.
- Once absorbed by root hairs, water moves into deeper layers by 2 pathways − Apoplast Pathway or Symplast Pathway.

Apoplast Pathway:

- Movement occurs through the intercellular spaces or walls of the cells, without entering the cytoplasm. Movement is fast. Most of the water flow in roots occurs via apoplast, except at the casparian strip.

Symplast pathway:

- Water enters the cell through the cell membrane and travels intracellularly through plasmodesmata. Movement is slow. At the casparian strip region, water moves through the symplast.

- Most of the water enters through apoplast pathway, endodermis has casparian strips which are made of suberin, it is impervious to water, so water enters the symplast.

There are two forces which are responsible for transporting the water up in a plant; they are root pressure and transpiration pull.

Root Pressure

- Water molecules enter from soil to root hair, then to cortical cells and finally reach xylem vessels.
- Positive pressure created inside the xylem when water transported along the concentration gradients into the vascular system
- *Guttation* – Loss of water in its liquid phase from special openings near tip of grass blades and leaves of herbaceous plants.

Transpiration pull

- Transpiration is a process of loss of water in the form of water vapours from the surface of leaves.
- Transpiration accounts for loss of 99% of water taken by the plant. Loss is mainly through stomata.
- Pull of water as a result of tension created by transpiration is the major driving force of water movement upwards in a plant.
- There are three physical properties of water which affect the ascent of xylem sap due to transpiration pull.
  - *Cohesion* – Mutual attraction between water molecules
  - *Adhesion* – Attraction of water molecules to polar surface
  - *Surface tension* – Attraction of water to each other in liquid phase to a greater extent than to water in gaseous phase

Transpiration

- It occurs manly through openings called stomata. Transpiration provides the transpirational pull which is responsible for the upward movement of water in tall plants.
- Stomata:
  - Open in the day and close during the night
  - Also contribute in the exchange of O_2 and CO_2
  - Opening and closing of stomata is influenced by the turgidity of the guard cells.

Factors affecting transpiration:

- ***External factors***: Temperature, Light, Humidity and Wind speed.
- ***Plant factors / Internal factors***: Number of stomata, distribution of stomata, water status in plants.

Importance of Transpiration

- Creates transpirational pull for transport
- Supplies water for photosynthesis
- Transports minerals from soil to all parts of a plant
- Cools the surface of the leaves by evaporation.
- Keeps the cells turgid; hence, maintains their shape

Uptake of Mineral Nutrients

- Minerals are absorbed from the soil by active transport. They cannot follow passive transport because of two factors;
  - They are charged. Hence, they cannot cross the cell membranes.
  - Concentration of minerals in soil is lesser than the concentration of minerals in roots. Hence, concentration gradient is not present.
- Certain proteins in the membranes of root hair cells actively pump ions from soil to cytoplasm of epidermal cells.

Transport of Mineral Nutrients

- Unloading of mineral ions occur at fine vein endings of the leaves through diffusion.
- Some minerals are also remobilised from old senescing parts N, P K, S. Minerals forming structural components (example Ca) are not remobilised.

- Phloem transports food from source to sink, but this source-sink relationship is reversible depending upon the season. Therefore, phloem transport is bi-directional.

Mass flow Hypothesis:

- This is the well accepted mechanism used for translocation of sugars from the source to the sink.
- Glucose prepared at the source is converted into sucrose. Sucrose is moved to the companion cells, and then to the living phloem sieve tube cells by active transport. This process of loading creates a hypertonic condition in the phloem.
- Water in the adjacent xylem moves into the phloem by osmosis. Osmotic pressure builds phloem sap.
- As hydrostatic pressure on the phloem sieve tube increases, pressure flow begins and sap moves through the phloem to the sink and stored as complex carbohydrates (starch).

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CHAPTER – 12 : MINERAL NUTRITION

Hydroponics:

It was given by Julius Von Sachs. Hydroponic is growing of plants in a defined nutrient solution, in the absence of soil. It helps us to study the effect of adding, removing or varying the concentration of any particular mineral element. Essential elements can be identified by this method, and their deficiency symptoms can be noted.

Criteria for the essentiality of an element are:

- Absolutely necessary for the completion of the life cycle of a plant; necessary for its growth and reproduction.
- Its requirement is specific, and not replaceable by any other element.
- Directly involved in the metabolism of the plant

Categories of Essential Elements

- Essential elements are 17.
- Basically categorised according to:

Their requirements:

- Macronutrients – Present in large amounts in tissues (C, H, O, N, P, S, K, Mg, Ca).
- Micronutrients – Present in small amounts in tissues (Fe, Mn, Cu, Mo, Zn, B, Cl, Ni)

Functions performed in a plant:

- Components of biomolecules (C, H, O, N)
- Components of energy-related chemical compounds (Mg – chlorophyll ; P – ATP)
- Activation / Inhibition of enzymes – Mo (enzyme nitrogenise)
- Elements that activates osmotic potential of cell – K (opening and closing of stomata)

Role of Micro and Macro Nutrients:

Nutrient	Absorbed as	Role
Nitrogen	NO_2^- NO_3^- and NH_4^+	• Required by all metabolically active cells and meristematic tissues.
Phosphorus	$H_2PO_4^-$ or HPO_4^{2-}	• Constitutes cell membranes, proteins, all nucleic acids, and nucleotides • Required for ATP formation.
Potassium	K^+	• Required in abundance by meristematic tissues, buds, leaves, root tips etc. • Maintains anion-cation balance in cells. • Involved in opening and closing of stomata and maintains turgidity of cells.
Calcium	Ca^{2+}	• Meristematic and differentiating tissues. Formation of mitotic spindle, activates enzymes, Synthesis of middle lamella (Ca pectate) of cell wall during cell division
Magnesium	Mg^{2+}	• Activates enzymes of respiration and photosynthesis, involved in DNA and RNA synthesis, constitutes ring structure of chlorophyll.
Sulphur	SO_4^{2-}	• Found in amino acid cysteine and methionine
Iron	Fe^{3+}	• Constitutes proteins involved in electron transport system such as cytochromes and ferredoxin
Manganese	Mn^{2+}	• Activates enzymes involved in photosynthesis, respiration, and nitrogen metabolism.
Zinc	Zn^{2+}	• Synthesis of auxins and activates carboxylases enzymes.

Copper	Cu^{2+}	• Overall metabolism of plants and activates enzymes involved in redox reactions.
Boron	BO_3^{3-} or $B_4O_7^{2-}$	• Involved in pollen germination, in cell elongation and differentiation.
Molybdenum	MoO_2^{2+}	• Involved in nitrogen metabolism, enzymes like nitrogenase and nitrate reductase.
Chlorine	Cl^-	• Involved in water splitting reaction of photosynthesis a Determines solute concentration.

Deficiency Symptoms of Essential Elements

- If essential elements are below their ***Critical concentration*** (amount of nutrients required for normal growth and development of plants), plants show certain morphological and observable characters. Those characters are called as Deficiency symptoms.

Deficiency symptoms:

- ***Chlorosis*** (Loss of Chlorophyll) - leads to yellowing of leaves - N, K, Mg, S, Fe, Mn, Zn, Mo.
- **Necrosis** (Death of Tissue) - Ca, Cu, K, Mg
- ***Delayed flowering*** - N, S, Mo
- ***Inhibition of Cell Division*** - N, K, S, Mo

Toxicity of Micronutrients

- Any mineral ion concentration that reduces the dry weight of tissues by 10% is considered toxic.
- Toxicity of one element may lead to deficiency of other elements since the former may inhibit the uptake of latter.
- For example; Mn competes with Fe, Mg for uptake and also inhibits Ca translocation to shoot apex. Therefore, Mn toxicity symptoms are actually same as deficiency symptoms of Fe, Mg, and Ca.

Nitrogen Metabolism

Nitrogen Cycle:

- **Nitrogen fixation**: The process of conversion of nitrogen (N_2) into ammonia (NH_3)
- **Ammonification**: The process of decomposition of organic nitrogen of plants and animals into ammonia.
- **Nitrification:** The ammonia so formed may volatilise and re-enter the atmosphere, or some of the ammonia may be converted into nitrate by soil bacteria.
- $$2NH_3 + 3O_2 \xrightarrow{Nitrosomonas/Nitrococcus} 2NO_2^- + 2H^+ + 2H_2O$$
  $$\underset{\text{nitrite}}{2NO_2^-} + O_2 \xrightarrow{Nitrobacter} \underset{\text{nitrate}}{2NO_3^-}$$
  These are the steps involved in **nitrification**.
  The nitrate so formed can be easily absorbed by the plants, and transported to leaves. In leaves, nitrate is reduced to ammonia to form the amine group of amino acids.
- **Denitrification**: Process of reduction of the nitrate present in soil to nitrogen. Carried out by bacteria like *Pseudomonas* and *Thiobacillus.*

Biological Nitrogen Fixation

- Reduction of nitrogen to ammonia by living organisms is called Biological Nitrogen Fixation.
- Certain prokaryotes (bacteria) are able to fix nitrogen because the enzyme nitrogenase is present exclusively in them.
  $N \equiv N \xrightarrow{\text{nitrogenase}} NH_3$
- Nitrogen-fixing microbes can be classified as follows:
  - Free living : Aerobic (*Azotobacter*), Anaerobic (*Rhodospirillum*), Cyanobacteria (*Nostoc, Anabaena*).
  - Symbiotic – with leguminous plants (*Rhizobium*), with non-leguminous plants (*Frankia*).
- It needs three biological components :
  - A reducing agent to transfer hydrogen atom to dinitrogen ($N \equiv N$)
  - ATP to provide energy
  - Enzyme system , Nitrogenase, Mo- Fe protein and leghaemoglobin.
- Leg haemoglobin: It is a pink colour pigment similar to haemogolobin of vertebrates and functions as an oxygen scavanger and protects nitrogenase from oxygen.

$$N_2 + 8e^- + 8H^+ + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16P_i$$

Nodule Formation

- Root hair comes in contact with *Rhizobium*. It becomes curved and deformed due to the chemical secretion.
- Plant forms an infection thread, grows inside and delivers bacteria to the cortical tissue.
- Bacteria produce cytokinin and auxin which is produced by the plant to stimulate cell division and enlarge to form nodules.
- Nodules form contact with vascular tissues and get food.
- Formation of root nodules and nitrogen fixation occur under the control of nod genes of legumes and *nod*, *nif* and *fix* genes of bacteria.

Synthesis of amino acids

- Ammonia formed by nitrogen fixation is used for the synthesis of amino acids.
- There are 2 processes by which amino acids are synthesized
  - ***Reductive amination***
    - NH4+ reacts with - ketoglutaric acid and forms glutamic acid.
    - It is catalysed by glutamate dehydrogenase enzyme.
  - ***Transamination***
    - Amino group of one amino acid is transferred to keto group of a keto – acid.
    - Glutamic acid is the main amino acid which transfers its amino group (NH2) to form 7 other amino acids by the enzyme transaminase.
  - ***Amides***
    - By the replacement of OH- of the amino acid by NH_2 radical.
    - Asparagine and glutamine are amines formed from aspartic acid and glutamic acid In the presence of enzyme asparagines synthetase and glutamine synthetase.

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CHAPTER – 13 : PHOTOSYNTHESIS IN HIGHER PLANTS

Photosynthesis is a Physic o – chemical process, uses light energy to synthesis organic compounds (sugar).

Importance of photosynthesis:

- Primary source of food
- Release O_2 to atmosphere

Early Discoveries

- Joseph Priestly: Candle with bell jar and mouse experiment – He concluded that air is necessary for the growth of a plant. He discovered the fact that plants restore oxygen in the air.
- Jan Ingenhousz: Experiment with aquatic plant in light and dark – He concluded that sunlight is essential for plant processes that purify the air.
- Julius Von Sachs: Green parts of plant make glucose and store as starch.
- T.W. Engelmann: Spilt light using prism into 7 colours (VIBGYOR) - Green algae *Cladophora* placed in a suspension of aerobic bacteria - Bacteria were used to detect the sites of O_2 evolutions.
- Cornelius van Niel: He did experiment with purple and green bacteria and demonstrated photosynthesis is a light dependent process with hydrogen from H_2O reduces CO_2 to carbohydrates. He concluded that oxygen comes from H_2O, and not from CO_2. Finally, the correct equation for photosynthesis was discovered.

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

Site of Photosynthesis

- Green leaves, green stems and floral parts (sepal)
- Chloroplast - found in mesophyll cells of leaves
- In chloroplast – the membrane system is responsible for trapping the light energy and also for the synthesis of ATP and NADPH. Where stroma has enzymes for the reduction of CO2 in to carbohydrates (sugars)

Pigments Involved in Photosynthesis

- 4 types of pigments may be present in leaves:
  - Chlorophyll a
  - Chlorophyll b
  - Xanthophylls
  - Carotenoids

- An absorption spectrum is the graph plotted against the fraction of light absorbed by the pigment.
- An action spectrum is the rate of a physiological activity plotted against the wavelength of light.
- Photosystems are pigments that are organized in the thyllakoid membrane in to two different photosystems (PS 1 & PS 11)
- Each PS has one specific chlorophyll – a, and many other accessory pigments bound by proteins.
- Chlorophyll – a forms the reaction centre (actual reaction takes place) other pigments form the light harvesting complex (LHC) called antennae.
- PS 1 reaction centre is p700 (chlorophyll –a absorbs light at 700 nm)
- PS 11 reaction centre is p680 (chlorophyll –a absorbs light at 680 nm)

Light Reaction (Photochemical Phase)

- This phase directly depends on light. The pigments absorb light energy and produce ATP.
- Includes:
  - Light absorption
  - Water splitting
  - Oxygen release
  - Formation of ATP and NADPH, which is then used in the biosynthetic phase
- Pigment molecules bound to the proteins form LHC (light harvesting complexes). LHC are located within two photosystems – PSI and PSII
- Each photosystem has two parts:
  - Reaction centre – consisting of chlorophyll a molecule
  - Antennae – consisting of accessory pigments, which increase the efficiency of photosynthesis by absorbing different wavelengths of light
- Reaction centre is different in both photosystems:
  - PSI – P700; since chlorophyll a has absorption peak at 700 nm here
  - PSII – P680; since chlorophyll a has absorption peak at 680 nm here.

Photo-Phosphorylation

- The process of formation of ATP in chloroplast in the presence of sunlight
- Photo-phosphorylation is of two types:
  - Non-cyclic photo-phosphorylation
  - Cyclic photo-phosphorylation

Non-Cyclic Photo-Phosphorylation

- PSII absorbs 680 nm wavelength of red light, causing electrons to become excited and these electrons are then accepted by an electron acceptor, which sends them to an electron transport system.
- Electron transport system transfers the electrons to PSI.
- Electrons in PSI are simultaneously excited on receiving a wavelength of 700 nm.
- From the electron acceptor, electrons are transferred to the molecule of $NADP^+$.
- Addition of these electrons reduces the $NADP^+$ to NADPH+ H^+.
- Since the electrons lost by PSII do not come back to it, this process of formation of ATP is called non-cyclic photo-phosphorylation.

Cyclic Photo-Phosphorylation

- In this scheme, only PSI is functional. Hence, the electrons are circulated within the photosystem.
- This results in a cyclic flow of electrons.
- This scheme could possibly be occurring in stroma lamellae because it lacks both PSII and NADP reductase enzyme.
- This cyclic flow results only in the synthesis of ATP, and not of NADPH + H^+.

Splitting Of Water

- Water splitting complex is associated with PSII.
- Manganese, chlorine, etc., play an important role.
- The light-dependent splitting of water is called photolysis

$$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$$

- Electrons formed are used for replacing the electrons lost from P680.
- P680 absorbs light and becomes as a strong oxidizing agent and splits a molecule of water to release oxygen. Oxygen is liberated as a by-product of photosynthesis.
- Protons are used for the formation of reducing power NADP to $NADPH^+$.

Differences between Non-cyclic and Cyclic Photophosphorylations:

	Non- cyclic Photophosphorylation	Cyclic Photophosphorylation
1.	Photolysis of water takes place.	No photolysis of water occurs.
2.	Both PS I and PS II are involved.	Only PS 1 is involved.
3.	Electrons are not cycled.	The electrons released by PS I come back to PS I itself.
4.	Both ATP and NADPH are produced.	Only ATP is formed.
5.	Oxygen is liberated	Oxygen is not liberated.

Chemiosmotic Hypothesis

- It is the mechanism of ATP synthesis in thylakoid of chloroplast.
- When electrons are transported through the electron transport system (ETS) and protons accumulate inside the thylakoid membrane due to photolysis of water.
- Now electrons are passed through PS and protons are transported across the membrane.

Chemiosmosis requires;

- A thylakoid membrane
- A protein pump
- A protein gradient
- ATP synthase enzyme.

Dark Reaction / Biosynthetic Phase:

- Next stage is the biosynthetic phase. In this, ATP and NADPH are used for synthesising the food / Glucose.
- This stage is also called the dark phase as it is independent of light.
- It takes place in the stroma of chloroplasts.
- In some plants, the first product of CO_2 fixation is a 3-carbon compound called 3-phosphoglyceric acid (PGA). These plants are said to adopt the C_3 pathway.
- In other plants, the first CO_2 fixation product is a 4-carbon compound called oxaloacetic acid. These plants are said to adopt the C_4 pathway.

Calvin Cycle (C_3 Cycle)

- The path of carbon in the dark reaction was traced by Melvin Calvin using radioactive carbon (^{14}C).
- The primary acceptor of CO_2 was found to be a 5-carbon ketose sugar called Ribulose bisphosphate (RuBP). RuBP is used in a cyclic manner (regenerated) and a sugar is synthesised.
- 3 phases of Calvin cycle: Carboxylation, Reduction and Regeneration of RuBP

1. Carboxylation:
    - Ribulose 1, 5-bisphosphate combines with CO_2, and fixes it to a stable organic intermediate 3C compound called 3-phosphoglycerate (2 molecules). 3 PGA is the first stable product of this cycle.
    - Reaction catalysed by the enzyme RuBisCO (RuBP Carboxylase-Oxygenase)

2. Reduction
    - Here, two molecules each of ATP and NADPH are required for fixing one molecule of CO_2.
    - This stage contains a series of reactions.
    - Glucose is formed as a result of this series of reactions.
3. Regeneration
    - RuBP regenerates to enable the cycle to continue uninterrupted.
    - 1 ATP molecule is required.
4. For the formation of one molecule of glucose, six molecules of CO_2 need to be fixed; hence, six cycles are required.
5. ATP required:
   For fixing 1 molecule of CO_2 − 3 (2 for reduction and 1 for regeneration)
   For fixing 6 molecules of CO_2 − 3 × 6 = 18 ATP
6. NADPH required:
   For fixing 1 molecule of CO_2 − 2 (for reduction)
   For fixing 6 molecules of CO_2 − 2 × 6 = 12 NADPH
7. Thus, the synthesis of 1 molecule of glucose requires 18 ATP and 12 NADPH.

C_4 Pathway (Hatch and Slack Pathway)

- Occurs in plants like maize, sugarcane − plants adapted to dry tropical regions. The leaves of C_4 plants have Kranz anatomy. These plants show 2 types of photosynthetic cells , mesophyll cells and bundle sheath cells. Chloroplasts are dimorphic i.e., those is the mesophyll cells are granal and in bundle sheath Cells are agranal.
- C_4 plants can tolerate high temperature and high light intensity, show greater productivity of biomass, and lack photorespiration.
- Primary CO_2 acceptor: Phosphoenol pyruvate (PEP) − a 3-carbon molecule.
- PEP Carboxylase fixes CO_2 in the mesophyll cells. It forms the 4-carbon compound oxaloacetic acid (OAA), and then other 4-carbon compounds malic acid.
- These compounds are transported to the bundle sheath cells. There, C_4 acid breaks down to form C_3 acid and CO_2, and carbon dioxide enters the C_3 cycle).
- C_3 acid, so formed, is again transported to the mesophyll cells and regenerated back into PEP.
- C_3 cycle cannot directly occur in the mesophyll cells of C_4 plants because of the lack of the enzyme RuBisCO in these cells.
- RuBisCO is found in abundance in the bundle sheath cells of C_4 plants.

Photorespiration

- It is a process in which there is no formation of ATP or NADPH, but there is utilization of ATP with release of CO_2. It is also considered a wasteful process.
- Photorespiration is responsible for the difference between C_3 and C_4 plants.
- At high temperature and high oxygen concentration, In C_3 plants, RuBP carboxylase function as oxygenase.

- RuBP oxidized into phosphoglycerate (3C) and phosphoglycolate (2C)
- 75% of carbon lost during oxygenation of RuBP
- There is loss of photosynthetically fixed carbon and no energy rich compounds are formed, so photorespiration is a wasteful process.

Differences between C_3 and C_4 Plants:

	C_3 plants	C_4 plants
1.	Photosynthesis occurs in mesophyll tissues.	Photosynthesis occurs both in mesophyll and bundle sheath cells.
2.	The carbon dioxide acceptor isRuBisco.	The carbon dioxide accepter is PEP carboxylase.
3.	Krantz anatomy is absent.	Krantz anatomy is present
4.	The 1st stable compound formed is 3C compound called 3-Phospho Glyceric Acid (PGA).	The 1st stable compound is 4-carbon Oxaloacetic acid (OAA).
5.	The optimum temperature is 20-25oC	The optimum temp. is 35 – 44oC.
6.	Photorespiratory loss is high.	Photorespiration does not take place.

Factors affecting rate of Photosynthesis:

Blackmans law of limiting factors.
When a physiological process is controlled by a number of factors, the rate of reaction depends on the lowest factor, so the factor which is the least/ limiting will determine the rate of Photosynthesis.

Photosynthesis is influenced by internal (plant) factors and external factors.

Light.
- Quality and intensity of light
- Wavelength of light between 400 nm 700 nm is called photosynthetically active radiation (PAR). High intensity of light destruct chlorophylls.

Temperature.
- High temperature denatures enzymes of biosynthetic phase and low temperature inactivates.

Carbon dioxide concentration.
- In C3 plants upto 500 and in C4 plants upto 360

Availability of water.
- Less water leads to - water stress, stoma closes, less carbon dioxide, reduce leaf expansion and less photosynthetic area.

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CHAPTER – 14: RESPIRATION IN PLANTS

Cellular Respiration

- It is the process of oxidation / breakdown of food materials within the cell to release energy. Respiratory substrate to be oxidised during respiration is usually glucose, but these can also be proteins, fats or organic acids.
- In plants respiration gas exchange occurs through stomata and lenticels.
- Overall cellular respiration is:
  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy (36 ATPs)

Types of respiration:

- Aerobic respiration
- Anaerobic respiration

	Aerobic respiration	Anaerobic respiration
1.	**It occurs in the presence of oxygen.**	**It occurs in the absence of oxygen.**
2.	**Respiratory substrate (glucose) is completely oxidised.**	**Partially oxidised.**
3.	**Products are CO_2, H_2O and 36 ATPs.**	**Products are ethyl alcohol / lactic acid, CO_2, 2 ATPs.**
4.	**Energy is released in large quantities.**	**Lesser quantity of energy.**
5.	**Cytoplasm and Mitochondria are the sites of break down.**	**Only cytoplasm is the site of break down.**

Mechanism of respiration :

- Glycolysis – it is common to both aerobic and anaerobic respiration
- Citric acid cycle / Krebs cycle - Aerobic respiration in mitochondria
- Electron transport system – in the inner membrane of mitochondria
- Both aerobic and anaerobic respiration starts with Glycolysis.
- In aerobic respiration Glycolysis is followed by Citric acid cycle and ETS (both occur in mitochondria).
- In anaerobic respiration Glycolysis is followed by formation of ethyl alcohol / lactic acid in the cytoplasm.

Fermentation :

Incomplete oxidation of pyruvic acid, under anaerobic respiration forms lactic acid/ ethyl alcohol. It occurs in bacteria, yeast and striated muscles.

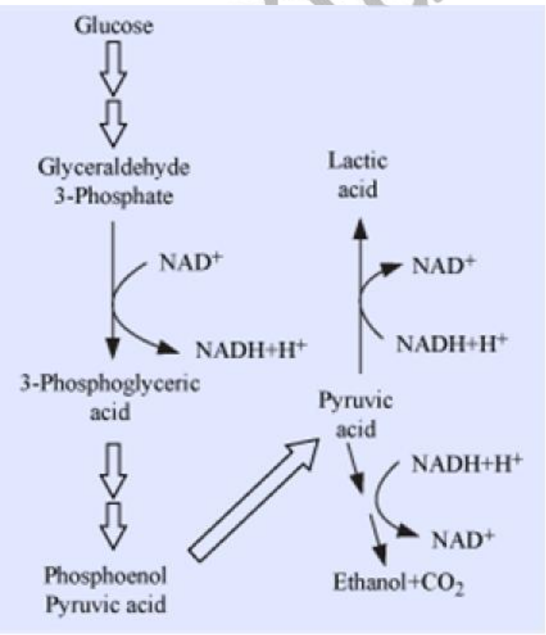
In yeast fermentation:

- Pyruvic acid → Ethanol + CO_2
- Enzymes involved – Pyruvic acid decarboxylase, Alcohol dehydrogenas.

- Only 7% of energy of glucose is released during fermentation.
- Yeasts poison themselves to death when alcohol concentration reaches about 13%.

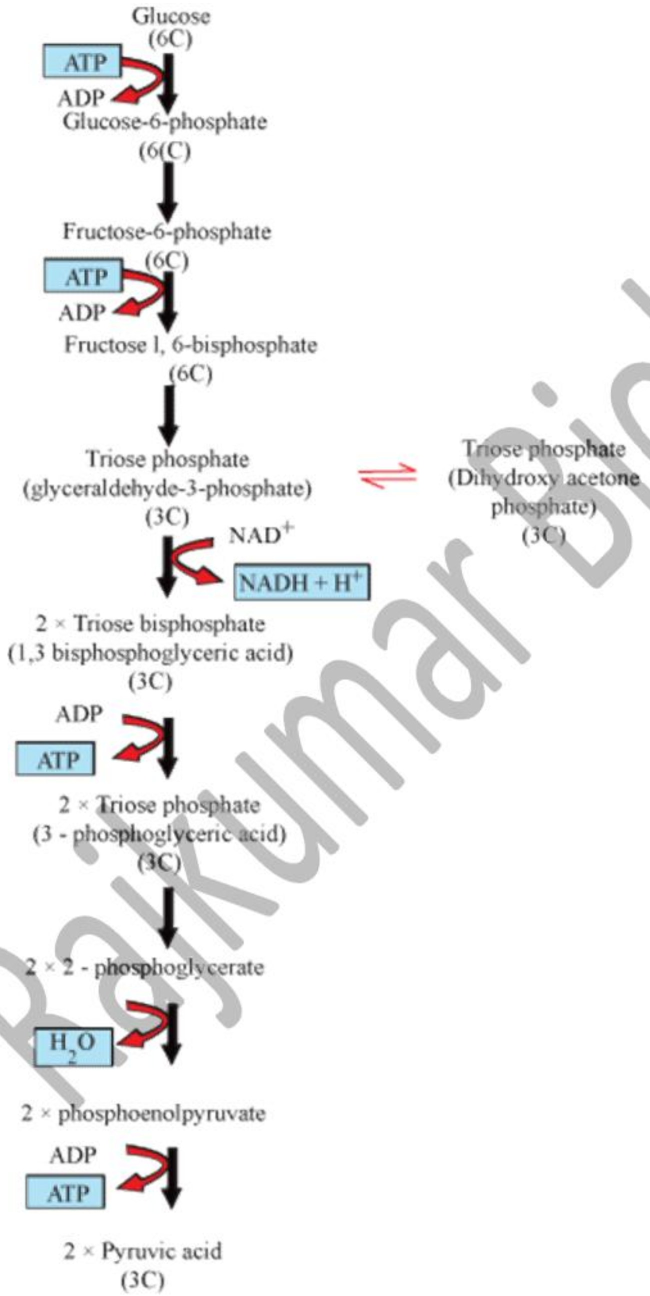
In bacterial fermentation:

- Pyruvic acid → Lactic aci .
- Enzyme involved – Lactate dehydrogenase.
- While doing severe exercise similar reaction occurs in animal muscles in anaerobic conditions.



Glycolysis :

- It is the process of breaking down of glucose to pyruvic acid.
- It was given by Embden, Meyerhof and Parnas
- A chain of 10 reactions converts glucose into pyruvate.
- Net ATPs produced = 4 (produced) − 2 (consumed) = 2 ATPs



Steps of glycolysis

- The pyruvate, so produced, may undergo:
  - Lactic acid fermentation
  - Alcoholic fermentation
  - Aerobic respiration (Krebs cycle)

Aerobic Respiration

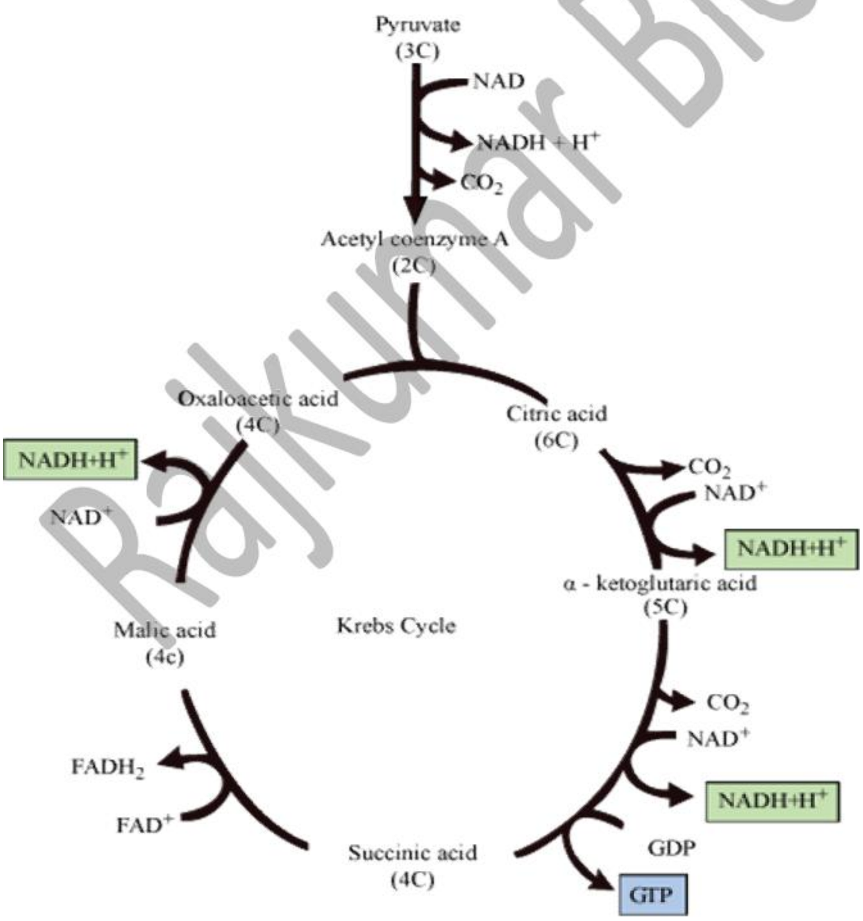
Citric acid cycle / Tricarboxylic acid cycle / Kreb's cycle:

- **TCA cycle** – it takes place in the mitochondrial matrix – it is the process of complete oxidation of pyruvate by stepwise removal of all hydrogen atoms, which leaves three molecules of CO_2
- **Electron Transport Chain and Oxidative phosphorylation** – it takes place in the inner membrane of the mitochondria – it is the process of synthesis of ATP fron $NADH_2$ and $FADH_2$.

Formation of Acetyl Coenzyme A

$$\text{Pyruvic acid} + \text{CoA} + \text{NAD}^+ \xrightarrow[\text{pyruvate dehydrogenase}]{\text{Mg}^{2+}} \text{Acetyl CoA} + \text{CO}_2 + \text{NADH} + \text{H}^+$$

Krebs cycle / Tricarboxylic acid cycle / Citric acid cycle:

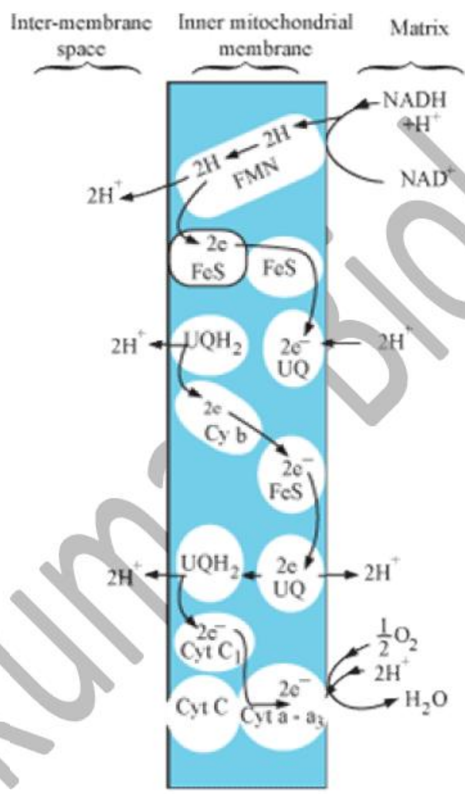


- Overall equation:

$$\text{Pyruvic acid} + 4NAD^{+} + FAD^{+} + 2H_2O + ADP + Pi \xrightarrow[\text{Matrix}]{\text{Mitochondrial}} 3CO_2 + 4NADH + 4H^{+} + FADH_2 + ATP$$

Electron Transport Chain (ETS)

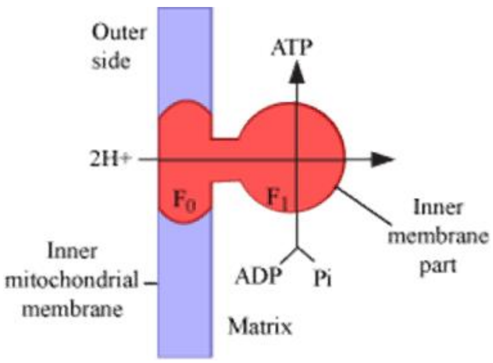
- $NADH_2$ and $FADH_2$ are oxidised to release the energy stored in them in the form of ATPs.
- Electrons are passed from one carrier to another, and finally to oxygen, resulting in the formation of water.



Electron Transport System (ETS)

- Oxidation of 1 NADH produces 3 ATPs.
  Oxidation of 1 $FADH_2$ produces 2 ATPs.

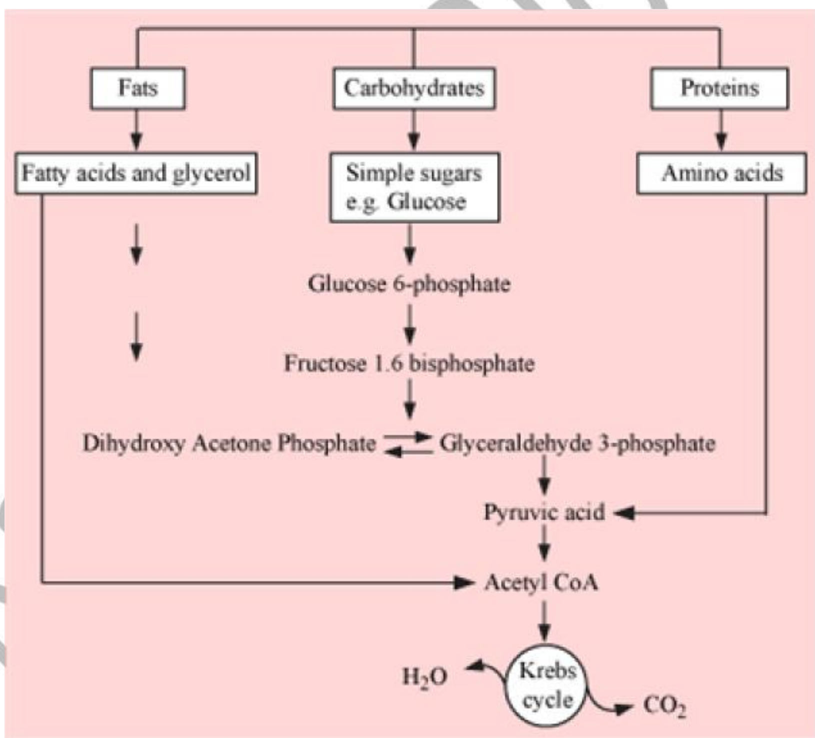
Oxidative Phosphorylation

o 

Respiratory Balance Sheet

- Glucose + $6O_2$ + 36ADP + 36Pi → $6CO_2$ + $6H_2O$ + 36ATP

Amphibolic Pathway: Involved in both anabolism and catabolism



Respiratory Quotient (RQ)

- It is the ratio of the volume of CO_2 evolved to the volume of O_2 consumed during respiration.

- RQ = 1 (When carbohydrate is used as substrate)
  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy

- RQ is less than 1 for fats.

  2 $C_{51} H_{98} O_6$ +145 O_2 - --> 102CO_2 + 98H_2O + Energy

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

- RQ is 0.9 for proteins.
- RQ is more than 1 for organic acids.
- RQ is infinite in case of anaerobic resp. because CO_2 is evolved but O_2 is not consumed.

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CHAPTER – 15: PLANT GROWTH AND DEVELOPMENT

Growth:

- It is a characteristic of living beings in which an irreversible permanent increase in size of an organ or its parts occur or an increase in the size of a cell.

Types of Growth Rate

- Growth rate can be defined as the increase in growth per unit time.
- Plants show two types of growth—Arithmetic and Geometric—according to the increase shown by the growth rate.
    - *Arithmetic growth* - Only one daughter cell continues to divide while others differentiate or mature. Example – root elongating at a constant rate.

    - *Geometric Growth* - Initial growth is slow (lag phase), followed by a rapid increase in growth (log/exponential phase), and followed by a phase where growth slows down (stationary phase). Example – all cells, tissues and organs show this type of growth

Conditions for Growth

- Include: water, oxygen, nutrients and temperature.

Differentiation, Dedifferentiation and Redifferentiation:

- **Differentiation**
    - In this process, cells derived from root apical and shoot apical meristems and cambium differentiate and mature to perform specific functions.
- **Dedifferentiation**
    - Process in which living differentiated cells regain their capacity to divide
- **Redifferentiation**
    - Process in which differentiated cells that have lost their ability to divide are reformed from dedifferentiated cells and have the ability to perform specific functions.

Development:

- Development – changes in the life cycle.
- Plasticity – different kinds of structure in response to environment or phases of life.
- Eg. Heteropylly in cotton and coriander. In these plants, leaves have different shapes based on the phase of life cycle as well as the habitat.
- Development can also be termed as – growth + differentiation
- Development is controlled by intrinsic as well as extrinsic factors.
  - Intrinsic – Genetic factors and plant growth regulator
  - Extrinsic – light, temperature, water, oxygen, etc.

Plant Growth Regulators / Phytohormones:

Classification based on their nature of action:

- Plant growth promoters. – Auxins, Gibberellins and Cytokinins.
- Plant growth inhibitors - Absissic acid (ABA)

- Ethylene may fit in either of the two groups, but is largely an inhibitor.

Types of phytohormones:

- Auxins
- Gibberellins
- Cytokinins
- Ethylene
- Abscisic acid

Auxins

Discovery :– auxins were discovered by Charles Darwin and Francis Darwin.
Isolation :– they were isolated from tips of coleoptiles of oat seedlings by F.W.Went as IAA and IBA.
Effects: –

- Initiate rooting in stem cuttings, plant propagation.
- Promote flowering, prevent fruit anf leaf drop.
- Promote abscission of older mature leaves.

Uses:-

- Induce parthenocarpy
- Widely used as herbicides (2,4 – D)
- To kill dicotyledonous weeds
- Prepare weed free lawns.
- Controls xylem differentiation and helps in cell division

Gibberellins

Discovery : E. Kurosawa identified gibbereilins present in a fungal pathogen *Gibberella fujikuroi*
Isolation: Infected rice seedlings when treated with sterile filtrates of fungus
Effects:

- GA'S are acidic.
- Increase in length, cause fruits to elongate and improve its shape.
- Delay senescence, extend the market period.
- GA3 used to speed up malting process in brewing

Uses:

- Spraying sugarcane crop with this
- Increases length of stem
- Fastens maturity period.
- Promotes bolting

Cytokinins

Discovery : Skoog and Miller
Isolation: Crystallized it promoting active substance named it kinetin from coconut milk, corn – kernels.
Effects:

- They are synthesized where rapid cell division takes place
- Produce new leaves, chloroplasts in leaves, lateral shoot growth and adventitious shoot formation.

Uses:

- Help overcome apical dominance
- Promote nutrient mobilization which helps in the delay of leaf senescence

Ethylene (gaseous hormone):

Discovery : Cousins confirmed the release of a volatile substance from ripened oranges that hastened the ripening of stored un ripened bananas
Effects:

- Promotes senescence and abscission
- Highly effective in fruit ripening
- Enhances the respiration rate
- Breaks seed and bud dormancy
- Initiates germination in peanut seeds.
- Sprouting potato tubers, promotes root growth root hair formation

Uses:

- Used to initiate flowering, for synchronizing fruit, induces flowering, regulates physiological processes.
- Hastens fruit ripening, accelerates abscission and Promotes female flowers.

Abscisic Acid (ABA):

Discovery: Researchers.
Isolation: 3 kinds of inhibitors - Inhibitor – B, abscission ll & dormin.
Effects:

- Regulates abscission dormancy
- ABA stimulates the closure of stomata
- Increases tolerance, seed development
- Maturation, dormancy, withstand desiccation

Uses:

- There are no. of events in a plant
- Where more than one PGR interact to affect that event, example - Dormancy in seeds / buds abscission, senescence, apical dominance.

Photoperiodism

- It is the response of plants to periods of day/night
- Some plants require periodic exposure to light to induce flowering. Duration of dark period is equally important for flowering.

Long Day Plants − Plants that require exposure to light for a period exceeding critical duration to induce flowering.

Short Day Plants − Plants that require exposure to light for a period less than this critical period to induce flowering.

Day Neutral Plants − Plants where there is no correlation between exposure to ligh duration and induction of flowering.

Vernalization

- It is the phenomenon of dependence of flowering on exposure to low temperature.
- Example − Biennial plants
  These are monocarpic plants that flower and then die in second season. Some examples are sugar beet, cabbage, carrot, etc.

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