

Academic year: ٢٠٢٥/٢٠٢٤ Subject: **Plant Physiology**

By: Dr. asseel habh

Lecture: ١

-What is Plant Physiology?

Plant Physiology is defined as the science that deals with the functions and events that occur within the plant cells. which included: metabolic processes , water relations , mineral nutrition , growth and development , Movement , growth , transport.

physiological and Biochemical Processes occur in certain combinations: -

- * gaseous exchange: - gets in Stomata .
- * Water transport: - (the phloem).
- * photosynthesis: - gets in (Chloroplast).
- * transmission of ions: - get across plasma membranes .
- * Respiration in plant: - gets in the Mitochondria.

-What is a plant?

Plant knows more than the definition of features as: -

- Its multicultural organism.
- Its non – motile.
- Eukaryotic cells.
- Has cell wall comprised of cellulose.
- Its autotrophic

-Definition of cell :

Cell: - it is a unit of the construction and function of all living organisms .

-What is the difference between a plant cell and an animal cell?

	Animal Cell	Plant Cell
Cell wall	Absent	Present (formed of cellulose)
Shape	Round (irregular shape)	Rectangular (fixed shape)
Vacuole	One or more small vacuoles (much smaller than plant cells).	One, large central vacuole taking up 90% of cell volume.
Centrioles	Present in all animal cells	Only present in lower plant forms.
Chloroplast	Animal cells don't have chloroplasts.	Plant cells have chloroplasts because they make their own food.
Cytoplasm	Present	Present
Ribosomes	Present	Present
Mitochondria	Present	Present
Plastids	Absent	Present
Endoplasmic Reticulum (Smooth and Rough)	Present	Present
Golgi Apparatus	Present	Present
Plasma Membrane	Only cell membrane	Cell wall and a cell membrane
Microtubules/ Microfilaments	Present	Present
	May be found in some cells	May be found in some cells

Animal Cell

Plant Cell

Flagella

Lysosomes

Nucleus

Cilia

Lysosomes occur in cytoplasm.

Present

Present

Lysosomes usually not evident.

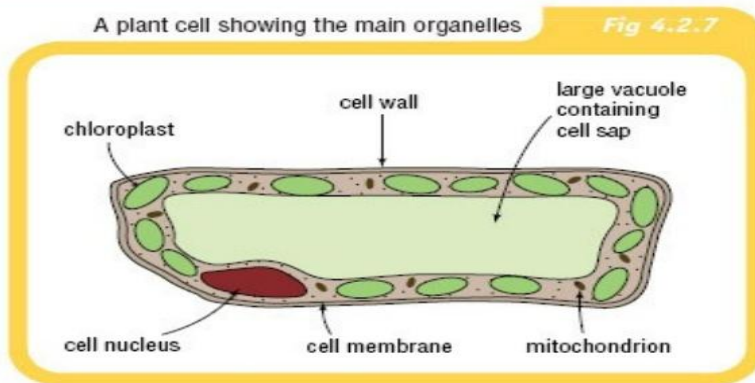
Present

Most plant cells do not contain [cilia](#).

. Draw a plant cell, and label all of the part

A plant cell showing the main organelles

Fig 4.2.7



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Respiration

Introduction:

It is known that large amount of photosynthetic products (carbohydrates) is utilized in respiration to produce energy and organic compounds which utilize in growth and development of plant. During respiration some of the energy produced liberated as a heat, while most of energy is utilized in synthesis of high energy compounds to be used to accelerate of chemical reaction within the cells to synthesize the importance biological molecules such as proteins, lipids, carbohydrates, hormones, flowers, and fruit formation.

The energy compounds:

There are types of reactions;

١-Excergonic reaction: it is a reaction that produces energy after completing.

٢-Entergonic reaction: it is a reaction that require energy for completing.

The energy produced from the excergonic reaction are stored in chemical compound called **energy compound** like ATP, GTP, TTP, UTP.

***Respiration:

Respiration can be defined as oxidation process of carbohydrate resulting in energy and chemical compounds utilized in biosynthesis of important biological molecules such as proteins, lipids, and chlorophylls.

The respiration process includes a series of chemical reactions. The storage carbohydrates should be hydrolyzed to glucose which is the first compound oxidize the hydrogen atoms to form H_2O .

The process of respiration is divided into two stages:

1-The first step which conducted in the absence of O_2 and called **Glycolysis**.

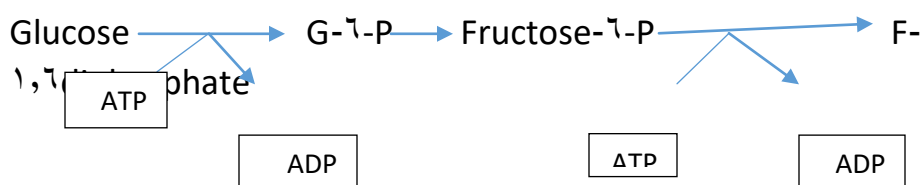
2-The second stage which require O_2 to complete and called **Krebs cycle**.

***Glycolysis:

It is a series of metabolic reaction started with glucose, and ended with lacted compounds. When the process ends with ethyl alcohol and CO_2 it is called **fermentation**. The production of lactate or alcohol (fermentation) is restricted to microorganisms, while in higher plants the process ends with production of **pyruvate** which is the last compound produced before lactate.

The glycolysis process is also called **Embden-Meyerhof-Parnas pathway (EMP)**, to appreciate the scientific efforts of these scientists in discovering the metabolic pathway and their enzymes in this process. The process is located in cytoplasm and does not required O_2 . The process consist of two stages:

1-which include transfer of glucose to fructose 1,6 diphosphate.



2- Splitting of 1,6 fructose diphosphate into 3C compound namely dihydroxy aceton phosphate and glycer aldehyde 1,3 phosphate.

The two compounds above are in equilibrium state and each one can convert to another as needed by the cell.

***Importance of glycolysis:

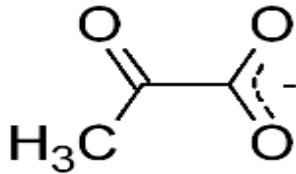
1-it is necessary step for oxidation of carbohydrates.

2-produce the reduced compound NADH +H⁺.

3- Produce ATP.

***Biosynthesis of Acetyl CoA:

When O₂ is sufficient, oxidation decarboxylation of pyruvate take place forming acetyl CoA and NADH+H⁺ as in the equation:



Pyruvate structure

This reaction required the following :

1-Thymine pyrophosphate (TPP).

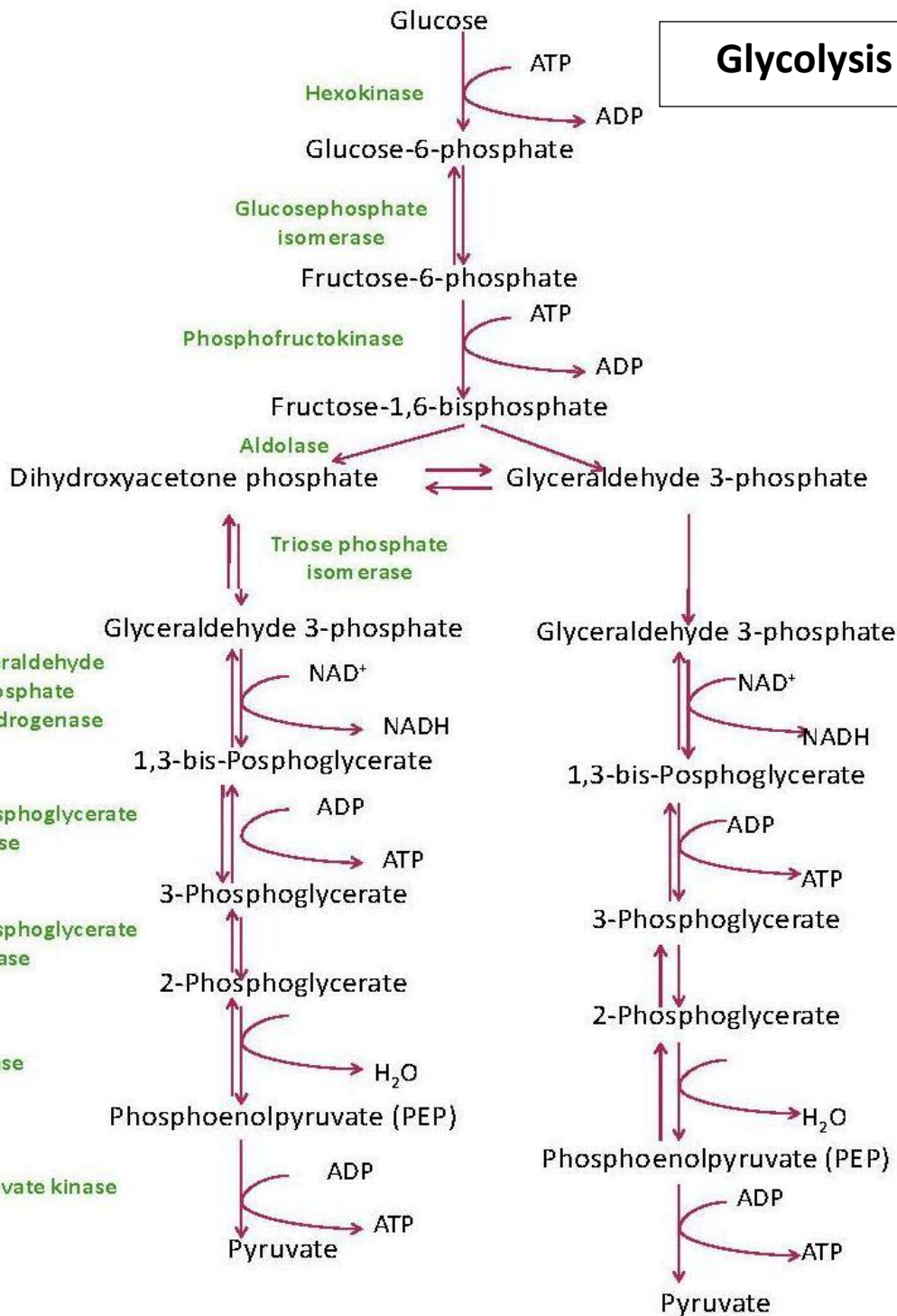
2-Mg⁺

3-CoA

4-Lipoic acid

5-NAD

Glycolysis



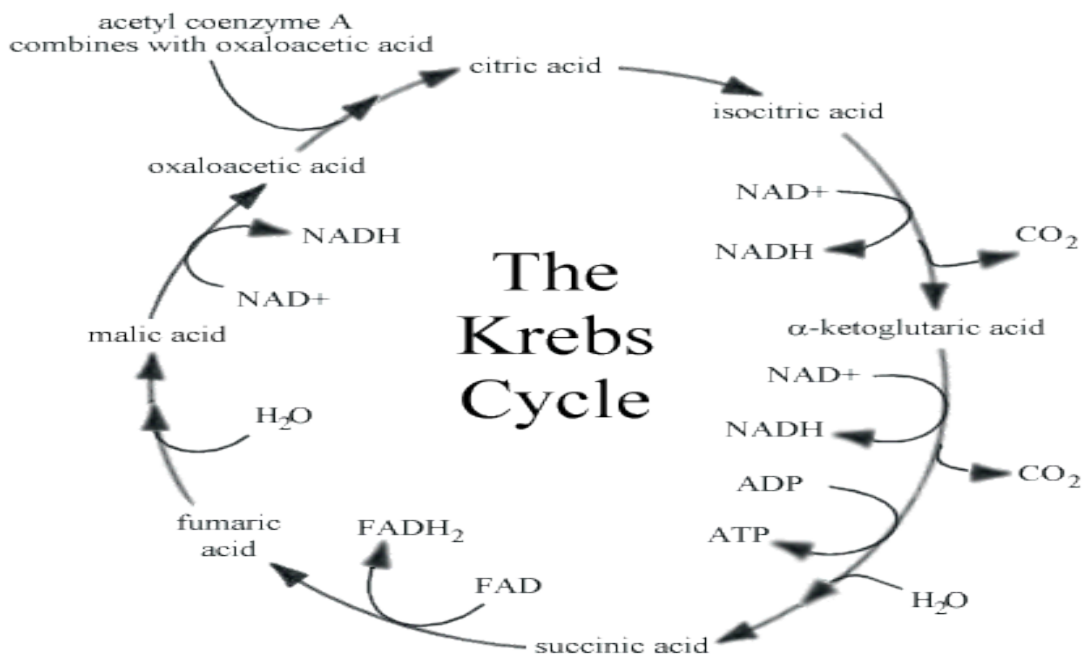
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****Krebs cycle:**

It is also called **citric acid cycle** or **Tricarboxylic acid cycle (TCA)**, it is a cycle since the first compound of the cycle (oxalo acetate OAA) is resynthesized again in the cycle. The cycle is started by the reaction of Acetyl CoA with OAA to form citrate. The citrate convert to cis-aconitate by dehydration reaction. This cis-aconitate is unstable compounds and convert immediately to isocitrate by hydration reaction. And then this cycle continuous to produce malate which converted to OAA forming $\text{NADH} + \text{H}^+$, in the presence of malate dehydrogenase and NAD, thus regeneration of OAA completes the cycle.

Significance of Krebs cycle:

- 1- production of the reduced forms ($\text{NADH} + \text{H}^+$ and FADH_2).
- 2- Production of the energy products GTP.
- 3- The compounds of krebs cycle is involved in the synthesis of important biological molecules such as cytochromes, phytochromes, proteins, vitamins and nucleic acids.



****Electron transport system (ETS) and phosphorylation:**

The system is located in mitochondria, and consists of :

1-CoQ, NAD, and FAD carriers.

2-cytochromes a, a₃, b, and c.

The system start carrying pairs of electrons and H⁺ from the reactions in krebs cycle to NAD, FAD, and CoQ. Then the pairs of electros were received by cytochromes b, c, a , a₃, and combined to O₂ to produce H₂O.

The energy released from the electrons stores in inorganic phosphate bond during the formation of ATP, the NADH+H⁺ goes through the ETS releases 3ATP while the FADH₂ releases only 2ATP.

The production of ATP by electron transport system is called **oxidation phosphorylation.**

****Respiration quotient (RQ):**

$$RQ = \frac{\text{(moles or weight) of CO}_2 \text{ evolved}}{\text{(moles or weight) of O}_2 \text{ consumed}}$$

? What is the importance of RQ:

To determine the type of stored food in seed or fruit consumed during respiration.

1-In seed which are rich with CHO, the respiration equation would equals (one), that means the stored food is CHO.

2-In oily or fatty seeds the equation would equal less than (one), that means the stored food is oil or fatty acid.

3- In seeds or fruit rich with organic acid the equation would equal more than (one), that means the stored food is protein.

*****Factors affecting respiration:**

1-**Temperature:** The temp. has a significant effect on enzyme activity of all enzymes including photosynthesis enzymes.

Maximum respiration rate occurred between 30-40 C°. The effect of temp. on respiration rate increased with increasing temp.

γ-O₂ concentration: under low O₂ concentration, more CO₂ liberated from the plant due to increase of glycolysis rate. But when O₂ increased less CO₂ liberated due to increase of aerobic respiration.

γ-CO₂ concentration : Increased CO₂ concentration decrease the O₂ uptake by the stomata this leads to decrease the respiration rate .

ξ-Photosynthesis: Increasing the photosynthesis causes increase in the respiration rate due to increase in the amount of respiration substrate (sugar).

College of Science Al-Mustanseryea University Dep.: Biology

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Lecture: ٣

Plant Hormones

Plant hormones: are a group of naturally occurring, organic substances which influence physiological processes at low concentration.

Characters of plant hormones:

- ١-integrate many different plant parts.
- ٢-naturally occurring organic substances.
- ٣-affects plant growth and development.
- ٤-works in a very low concentration.

*****Hormones may be classified into these classes:**

A/Promote hormones:

1-Auxins 2-Gibbrelline 3-Cytokinins

B/Inhibit hormones:

1-Ethylen 2-Abscisic acid

*****There are some definitions in plant hormones:**

1-**plant regulators:** are organic compounds other than nutrients that in small amounts promote, inhibit or modify a physiological process in plants.

2-**plant hormones:** are regulators produced by plants which in low concentration regulate plant physiological processes. Hormones usually move within the plant from site of production to a site of action.

3-**growth regulators or growth substances:** are regulators that affect growth.

4-**growth hormones:** are hormones that regulate growth.

5-**flowering regulators:** are regulators that affect flowering.

6-**flowering hormones:** are hormones that initiate the formation of floral primordia or promote their development.

******Auxins(Indol acetic acid – IAA)******

1-First plant hormones to be discovered.

2-very simple chemical structure, dramatic influences on growth.

3-early on it was believed to be the master (plant hormone)

4-growth promoting hormone.

5-Auxin found in embryo of seed, young leaves, meristem of apical buds.

****there are some physiological effects influenced by Auxins:**

1-cell enlargement of stems, leaves and roots.

1-cell and organ differentiation.

2-flower initiation and development, fruit set, fruit growth, and embryo growth.

3-abscission of leaves, flowers and fruits.

4-direction of growth (tropism of stems or roots).

5-apical dominance.

6-parthenocarpy in some plants.

7-enlargement and cell division of callus tissue culture.

****Tropism:** it is defined as the movement of plant organ towards the environmental stimulus such as light, gravity, water and chemical stimulus. There are several types of tropism:

1-**photo tropism:** it is bending of plant towards the light source due to translocation of auxin to the shaded side. The increased concentration in the shaded side causes increase in cell enlargement and growth of the cell in this region and cause bending.

2-**Eotropism:** movement of roots towards the earth center due to earth gravity. This happens due to accumulation of auxin in the lower region. Roots are different from stems in their response to auxin. High concentration of auxin in roots causes inhibition instead of stimulation. Root is positive geotropism while stem is negative geotropism.

3-**Apical dominance:** it is phenomenon in which apical bud dominate over the lateral bud and doesn't allow it to grow. This happens when the auxin in the apical bud translocated to lateral buds and increases their auxin concentration. The high concentration of auxin inhibited growth of lateral buds.

Scientists found the presence of several compound of indol in nature which have similar function of IAA such as Indole pyruvic acid, Indol acetonitril and Indol acetaldehyde.

These compounds may be metabolized and change to IAA in plants.

There are two kinds of auxin in plants:

1- Free auxin, which can be isolated by diffusion.

2- Bound auxin, which cannot be isolated by diffusion.

There are some compound similar to auxin and these compounds have the ability to bind with auxin and inactivated it, these are called **antiauxins**.

*****Destruction of Auxin:**

Two means of destruction of IAA in plants appear to dominate :

- 1- Enzymatic oxidation.
- 2- Photo oxidation

*****Gibberellins (GA)*****

Gibberellins are belonged to terpenoids group which synthesized from isoprene units. GA consist of 4 isoprene units and differ among each other in the position and number of methyl, carboxyl and hydroxyl groups and in the number of saturated in the first ring.

*****positions of GA synthesis in the plants:**

- 1- Juvenile leaves. 2-roots. 3-buds. 4-embryo and fruits.

GA are broken down slowly in plant. Also it can be transformed into inactive form by conjugation with sugar or protein molecules.

*****GA movement in plants:**

GA moved through phloem and xylem.

****GA present in plant in two forms:**

- 1- Free GA which are the active form.
- 2- Bound GA in this case, GA bound to sugar by glycoside linkage or proteins. It was believed that the bound form is sort of storage process used by plant.

****Anti Gibberellins:**

It is also called growth retardant compounds:

- 1- cycocel. 2-phosphon. 3-cultar.

All these compounds caused dwarf of the plants and increased plant tillering.

*****Mechanisms of action of GA:**

- 1-Activation of cell division in shoot apex.
- 2-stimulate cell elongation.
- 3-increase the plasticity of cell wall and thus enlarge the cells of stem.
- 4-activation of genes responsible for the synthesis of hydrolytic enzyme in the endosperm during seed germination.

****physiological effect of GA:**

- 1- Control genetic dwarfism: genetic dwarfism is caused by gene mutation in some crop cultivars such as corn, peas.
- 2- Stimulation of flowering and growth of flower branches:
 - A/ in some plants growth of leaves become very dense and the branch of flower are stunted (rosette). This happens in long day plants which doesn't receive enough light.
 - B/ in other plants the flowering branch is elongated abnormally because the plant doesn't received enough cold temperature.
- 3- Inhibition of root formation in cutting and callus:

GA stimulates translocation of nutrients from the region of roots formation in the cutting and callus to other parts causing inhibition.
- 4- Stimulate germination of seed which required dark conditions:

Some seeds require dark conditions to germinate. Treatment of seeds with GA causes germination in light condition.
- 5- GA stimulates male flower in some plants such as cucumber. Other GA stimulate female flower.
- 6- Stimulate the synthesis of enzymes in endosperm of germinated seeds such as α -amylase, β -amylase, proteases, ribonucleases.
- 7- Breaking the dormancy of seeds and buds:

Dormancy means inability of seeds to germinate and buds to grow in presence of favorable environment (moisture, temperature and light). When the seeds or buds treated with cold temperature (4°C) for a definite period, both of them germinate. It was found that GA can substitute cold temperature and caused germination of seeds and growth of buds.

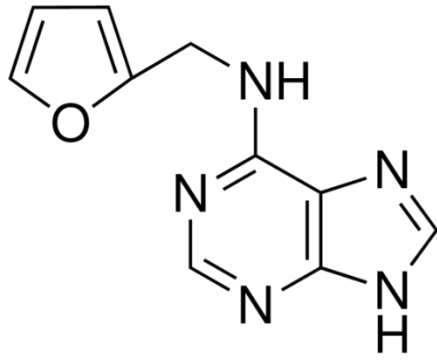
****Cytokinins****

Are plant hormones, they are derivatives of the nitrogenous base adenine, and consist of purine ring. Cytokinin were previously named as kinin.

Cytokinins were discovered when scientists found that some compounds containing adenine have the ability to induce cell division. At that time the first compound discovered by the scientists were named **kinin**. However animal physiologists used the term kinin to include hormones related to polypeptides group, there for scientists used the term **phytokinin** and later replaced it to **cytokinin**.

Thirteen out of eighteen cytokinins have been extracted and purified from higher plants. Some of these compounds bound with \circ carbon sugar and sometimes with phosphate to form nucleotides and nucleosides. **Zeatine** is one of the most important cytokinin compounds in plants.

Several types of the isolated cytokinins have been synthesized outside the plant and named as synthetic cytokinins. These compound have the same physiological effect as natural cytokinins.



Cytokinin structure

***Physiological effect of cytokinins:

cytokinins were found to synthesize in roots and translocate to other part of the plant by xylem. Rate of movement of cytokinins is slower than the auxins and Gas.

The most important physiological effects are :

1-**cell division:** cytokinins are found to be essential for cell division in plant tissue culture. However, the continuity of growth of tissue required the presence of IAA with cytokinins. It was found that IAA is necessary for nucleus division, while cytokinin is required for cytoplasm division.

2-**cell enlargement:** it was found that cytokinins stimulate cell enlargement as IAA and GA.

3-**Root initiation and growth:** it was found that cytokinins in presence of IAA stimulate the formation of roots in callus tissues.

4-**Shoot initiation and growth:** it was known that the parenchyma cells of callus do not differentiate into organs or tissues when there is a balance between IAA and cytokinin, but when the ratio of cytokinin/ IAA increased, the differentiation of parenchyma cells started to form buds and shoots.

5-**Breaking dormancy:** scientists revealed that growth of lateral buds breaking the dormancy of apical dominance could not be controlled by IAA alone but in combination with cytokinin in certain ratio.

6-**prevention of aging and senescence:** cytokinins are found to inhibit aging and senescence due to the following reasons:

A/ prevents the formation of hydrolytic enzymes such as nucleases, proteases which cause senescence and aging.

B/ withdraw of nutrient from the surrounding tissues to the region in which the cytokinin accumulates.

γ- Enzyme formation: scientists believe that cytokinins stimulate the metabolic reactions which lead to synthesis of enzymes and not to the effect on the genes responsible for the synthesis of the enzymes as was happened in case of IAA and GA.

*****Abscisic acid(ABA)*****

This hormone is isolated in 1960 from fruit of cotton crop and named Abscission II. In subsequent years several types of this hormones have been isolated from plants and it is considered as growth inhibitor hormone.

ABA is synthesized in mature leaves and translocated to shoot apex through leaf petiole.

*****physiological effects of ABA:**

- 1- It was found that one of the most important phenomenon in ABA is the drastic increase in its concentration shortly following expose of plants to flooding, drought, mechanical injuries and deficiency in mineral nutrients. The concentration of the ABA subside down very quickly in plants exposed to drought stress to normal level after irrigation.
- 2- **Regulation of stomatal opening and closing:** it was observed that when the plant leaves is treated with ABA, the stomata close after 10-15 minutes. The reason is that ABA causes leakage in K^+ from guard cells and thus the guard cells lose its turgidity and the aperture closed.
- 3- **Abscission and senescence of leaves and fruits:** it was observed that higher concentration of ABA stimulates juvenile leaves and fruit dropping. Concentration of ABA in mature leaves was 200% more

than that in juvenile leaves. Senescence is also accelerated due to the inhibition of GA by ABA.

- ξ- **Bud dormancy:** most of plant species form buds which grow later to leaves or flowers. Buds of most plant species may enter dormancy under unfavorable condition such as drought, high and low temperature and salinity. The dormancy regulated by endogenous hormonal levels.

***Mechanism of action for ABA:

- 1- Causes changes in electrical potential across the plasma membrane which lead to afflux or influx of K^+ across the membrane.
- 2- Inhibition of RNA and protein synthesis.
- 3- Inhibits the action of IAA, GA and cytokinin.

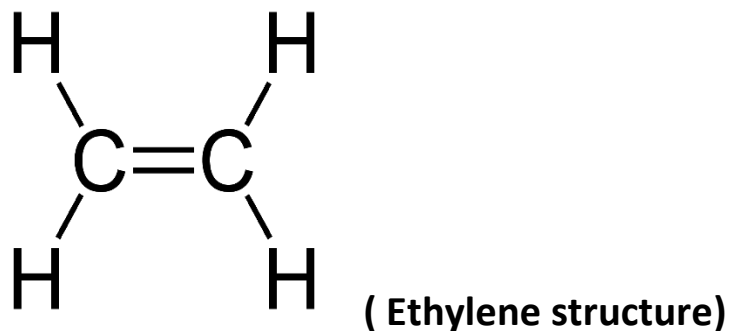
**Biosynthesis of ABA :

- 1-The biosynthesis is occurred in plastids.
- 2-the precursor of ABA synthesis is acetyl CoA.
- 3-The pathway is similar to GA³ biosynthesis but ended in farnesyl pyrophosphate (1° c).

Ethylene

- 1-it is a growth retardant hormone.
- 2-gas under natural condition.
- 3-simple chemical structure compared to other hormones.
- ξ-found in a very low concentration in plants.
- ο-it affects essential physiological process alone or in combination with auxins.

↳ Ethylene is produced from the α-amino methionine.



****factors affecting the activity of ethylene:**

↳ high CO₂ concentration.

↳ decrease in temperature.

*****physiological effects:**

- ↳ **Fruit ripening** : respiration was found to increase rapidly in most of the fruit then decreased the end of fruit maturation, this type of respiration is called climacteric respiration. It was found that ethylene is increased 100 times during climacteric respiration than during immature fruits.
- ↳ **Apical dominance**: it was revealed that ethylene is strongly inhibited the lateral buds and this result due to translocation of auxin from young leaves and apical meristems to the nodes. The higher accumulation of auxins in the nodes stimulates ethylene production in the buds which inhibits their growth.
- ↳ **Geotropism**: previously we mentioned that geotropism is taken place due to accumulation of auxin (IAA) in the lower part of the roots causing inhibition of growth in this region recently it was found that the effect was not related directly to IAA but to ethylene which is stimulated by the presence of IAA.

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*****Water movement:**

One objective of plant physiology is to understand the dynamic of water as it flows into and out of cells or from the soil, through the plant, into the atmosphere.

Movement of substances from one region to another is commonly referred to as **translocation**. Mechanisms for translocation may be classified as either *active* or *passive*, depending on whether metabolic energy is expended in the process. It is sometimes difficult to distinguish between active and passive transport, but the translocation of water is clearly a passive process. Although in the past many scientists argued for an active component, the evidence indicates that water movement in plants may be indirectly dependent upon expenditure of metabolic energy. Passive movement of most substances can be accounted for by one of two physical processes:

Either **bulk flow** or **diffusion**. In the case of water, a special case of diffusion known as **osmosis** must also be taken into account.

****Diffusion:**

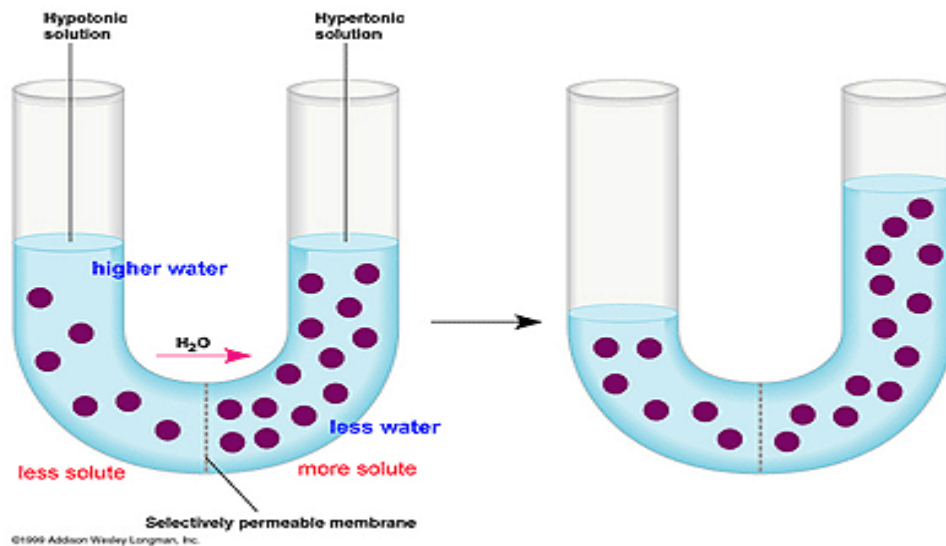
Diffusion is the net movement of molecules from an area of greater concentration to an area of lesser concentration. Diffusion by random movement continues until the distribution of molecules becomes even throughout the solution. The rate of diffusion depends on:

- ١- The size of the molecules (larger molecules move slower).
- ٢- The temperature of the solution (higher temperature cause faster movement).
- ٣- The solubility of the molecules in the solvent (molecules that do not dissolve do not diffuse).

Diffusion is a significant factor in the uptake and distribution of water, gases, and solutes throughout the plant. In particular, diffusion is an important factor in the supply of carbon dioxide for photosynthesis as well as the loss of water vapor from leaves.

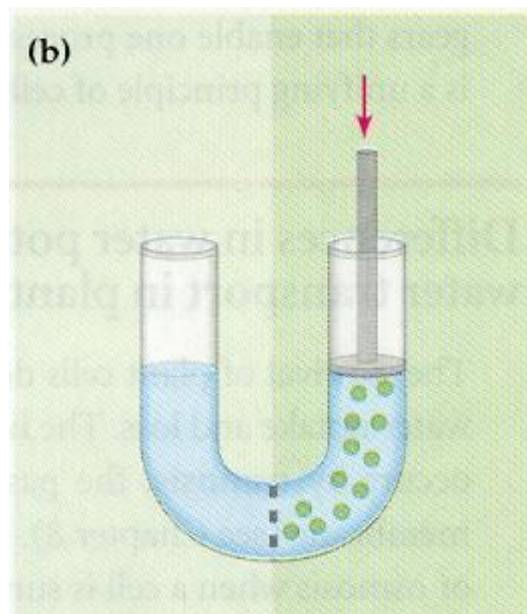
****Osmosis is the diffusion of water across a selectively permeable membrane:**

The diffusion of water through a selectively permeable membrane has a special name **osmosis**. To appreciate the importance of osmosis, consider a membrane that is permeable to water but impermeable to glucose. When such a membrane separates two halves of a container, each having a different concentration of glucose, water diffuses by osmosis into the side having the higher glucose concentration and the lower water concentration. The net movement of water stops either when both sides of the container have the same concentration of glucose and water or when the force of gravity equals the force of water movement, whichever occurs first. Note that the side that began with a higher concentration of glucose increases in volume. This relative increase in volume can contribute to the movement of water and solute through a plant.



Osmosis is demonstrated by the movement of water through a selectively permeable membrane in a U-tube.

This example of osmosis hints at another feature of the process. Immediately before osmosis begins, the dilute solution in the tube on the left side of the membrane has a higher water and lower glucose concentration compared to the lower water but higher glucose concentration on the right side of the membrane. The concentration difference means water on the left side has a greater potential to move across the membrane. Its movement, however, can be prevented if a piston is placed on the right side with just enough pressure to keep the volume constant. A pressure gauge on the piston measures the force required to maintain a constant volume. This pressure, which is called **osmotic pressure**, is a measure of the ability of osmosis to do work in a system, such as moving water through a plant.

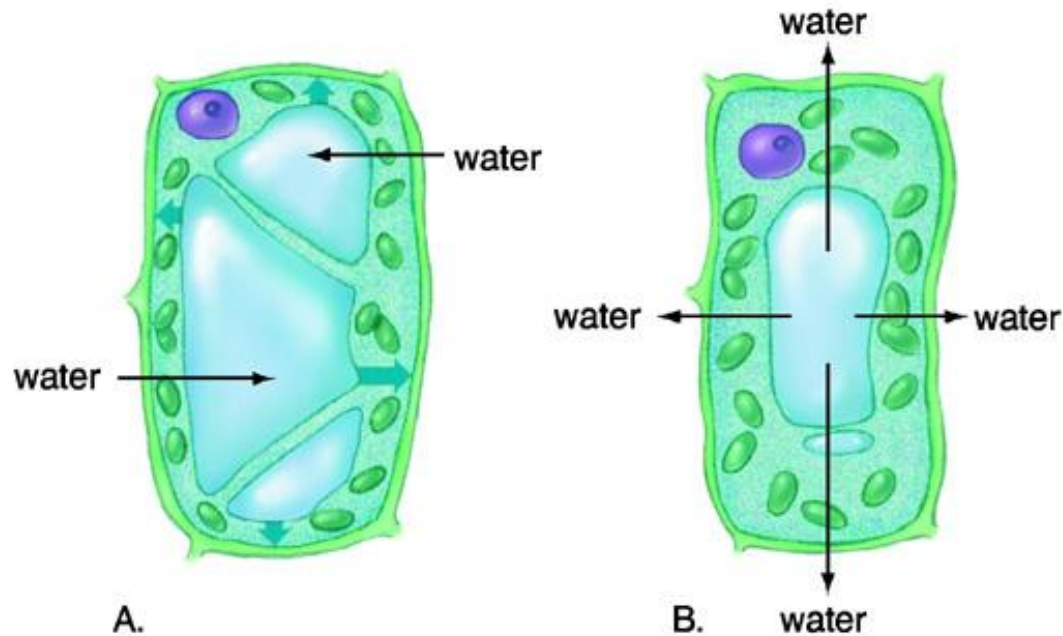


Higher water potential in the left-hand solution causes water to move into the right-hand solution. the amount of pressure that is necessary to maintain constant volume on the right equals the force of water movement across the membrane.

Most plants and indeed plants cells are surrounded by an environment with a lower concentration of solute and higher concentration of water. This difference in solute concentrations results in water entering a plant, which usually has a lower water potential than the surroundings. The cells and the plant absorb as much water as they can hold. Remember that the outward pressure of the cell membrane against the cell walls is called turgor pressure because it keeps the cells turgid.

Turgor pressure is vital to plants in many ways. During growth, cell expansion is caused by turgor pressure on cell walls that have become relaxed. Turgor pressure also keeps herbaceous (nonwoody) plants upright, supports the fleshy stalks and leaves of trees and shrubs. Changes in turgor pressure also cause movements in plants, such as the opening and closing of stomata and the curling of grass leaves. Cells lose turgor when they are placed in a dry environment or high-salt solution. The continued loss of turgor causes the cell membrane and protoplast to shrink away from the cell wall. Dryness causes most loss of turgor in plants.

Osmotically induced shrinkage of the cytoplasm is called plasmolysis. This phenomenon occurs in crop and garden plants when salt accumulates in the soil from extensive use of hard (i.e., mineral-rich) water. It also occurs when people apply too much fertilizer, causing a high concentration of salt outside the plant. As a result, water exits the plant via osmosis and diffuses to a region of lesser water concentration (i.e., water potential) compared to inside the plant. The loss of turgor in these plants causes their leaves and stems to wilt. Key to turgor pressure is the cellular import and export of molecules other than water. This occur via membrane transport.



A. A turgid cell. Water has entered the cell by osmosis, and turgor pressure is pushing the cell contents against the cell walls. B. Water has left the cell, and turgor pressure has dropped, leaving the cell flaccid.

****Water potential can be used to predict the flow of water through a plant:**

Like solutes, water also has potential energy to flow to where it is less concentrated. The potential energy of water has a special name: **water potential**. Water tends to move down a water-potential gradient that is, from a region of high water potential to a region of low water potential. By general agreement, the water potential of pure water is zero.

This means that the water potential of a solution has a negative value because the water is less concentrated than in pure water.

Three key points: 1- the water potential of pure water is zero.

2- water flows down a water potential gradient, toward the more negative water potential.

3- the addition of solutes to a solution lowers the water potential.

****Water potential is the sum of its component potentials:**

Water potential may also be defined as the sum of its component potentials:

$$\Psi = \Psi_p + \Psi_s$$

The symbol Ψ_p represents the **pressure potential**. It is identical to P and represents the hydrostatic pressure in excess of ambient atmospheric pressure. The term Ψ_s represents the **osmotic potential**. Note the change in sign (osmotic pressure $\pi = -\Psi_s$). As pointed earlier, osmotic potential is equal to osmotic pressure but carries a negative sign.

Osmotic potential is also called **solute potential** because it is the contribution due to dissolved solute. The term osmotic(or solute) potential is preferred over osmotic pressure because it is more properly a property of the solution.

We can see from the equation that the hydrostatic pressure and osmotic potential are the principal factors contributing to water potential. A third component, the **matric potential** (M), is often included in the equation for water potential. Matric potential is a result of the adsorption of water to solid surfaces. It is particularly important in the early stages of water uptake by seeds (called **imbibition**) and when considering water held in soils. There is also a matric component in cells, but its contribution to water potential is relatively small compared with solute component. It is also difficult to distinguish the matric component from osmotic potential.

****Absorption of water****

Mechanism of absorption of water:

In higher plants water is absorbed through root hairs which are in contact with soil water and from a root hair zone a little behind the root tips. When roots elongate, the older hairs die and new root hairs are developed so that they are in contact with fresh supplies of water in the soil.

Mechanism of water absorption is of two types:

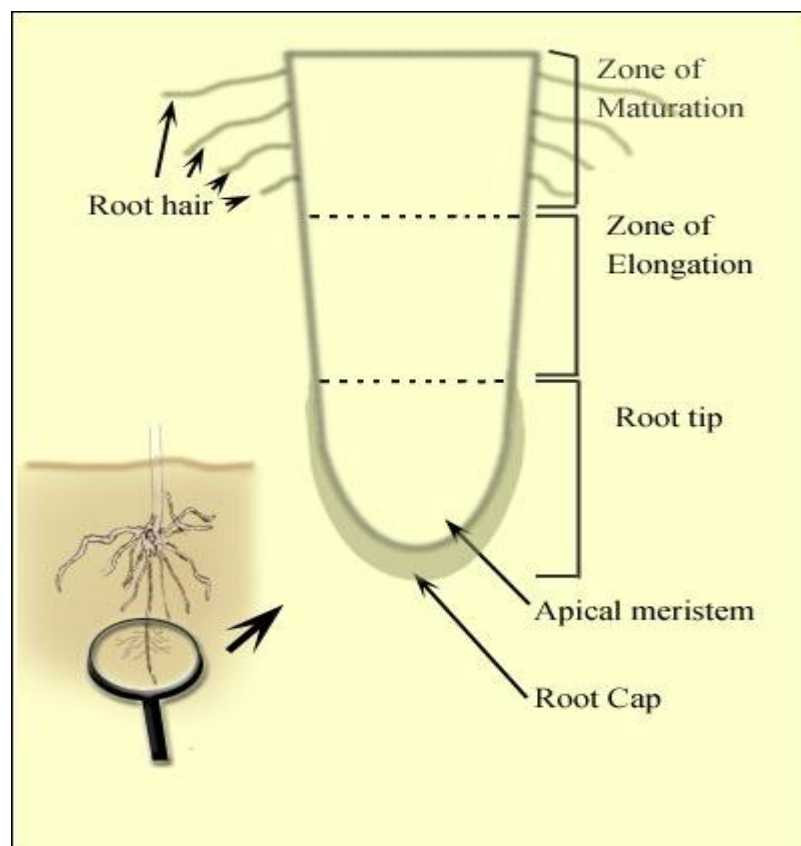
1- **Active absorption** of water. In this process the root cells play active role in the absorption of water and metabolic energy released through respiration is consumed.

Active absorption may be of two kinds:

A/ Osmotic absorption i.e., when water is absorbed from the soil into the xylem of the roots according to the osmotic gradient.

B/ Non-osmotic absorption i.e., when water is absorbed against the osmotic gradient.

↳ **Passive absorption** of water. It is mainly due to transpiration, the root cells do not play active role and remain passive.



Root tip structure

*****Active osmotic absorption of water:**

First step in the osmotic absorption of water is the Imbibition of soil water by the hydrophilic cell walls of root hairs. Osmotic Pressure(O.P.) of the cell sap of root hairs is usually than the O.P. of the soil water. There for the diffusion pressure deficit(D.P.D.) in the root hairs become higher and water

from the cell walls enters into them through plasma-membrane by osmotic diffusion. When water enters into xylem from pericycle, a pressure is developed in the xylem of roots which can raise the water to a certain height in the xylem. This pressure is called as **root pressure**.

*****Active non-osmotic absorption of water:**

Sometimes, it has been observed that absorption of water takes place even when the O.P. of the soil water is higher than the O.P. of cell-sap. This type of absorption which is non-osmotic and against the osmotic gradient requires the expenditure of metabolic energy probably through respiration. Following evidences support this view:

↳-the factors which inhibit respiration also decrease water absorption.

↳-poisons which retard metabolic activities of the root cells also retard water absorption.

↳-auxins (growth hormones) which increases metabolic activities of the cells stimulate absorption of water.

****Passive absorption of water:**

Passive absorption of water takes place when rate of transpiration is usually high. Rapid evaporation of water from the leaves during transpiration creates a tension in water in the xylem of the leaves. This tension is transmitted to water in xylem of roots through the xylem of stem and the water raises upward to reach the transpiring surface . As a result, soil water enters into the cortical cells through root hairs to reach the xylem of roots to maintain the supply of water. The force for this entry of water is created in leaves due to rapid transpiration and hence, the root cells remain passive during this process.

****External factors affecting absorption of water:**

↳-Available soil water:

Sufficient amount of water should be present in the soil in such form which can easily be absorbed by the plants. Usually the plants absorb **capillary water** i.e., water present in films in between soil particles. Other forms of water in the soil e.g., **hygroscopic water, combined water, gravitational water** etc. are not easily available to plants.

γ-Concentration of the soil solution:

Increased con., of soil solution (due to the presence of more salts in the soil) results in higher osmotic pressure. If the O.P. of soil solution will become higher than the O.P. of cell sap in root cells, the water absorption particularly the osmotic absorption of water will be in **alkaline soils** and **marshes**.

γ-Soil air:

Absorption of water is retarded in poorly **aerated soils** because in such soils deficiency of O_2 and consequently the accumulation of CO_2 will retard the metabolic activities of the roots like respiration. This also inhibit rapid growth and elongation of the roots so that they are deprived of the fresh supply of water in the soil. Water logged soils are poorly aerated and hence, are physically dry. They are not good for absorption of water.

ξ-soil temperature:

Increase in soil temperature up to about $30^\circ C$ favors water absorption. At higher temperature water absorption is decreased. At low temp., also water absorption decrease so much so that at about $5^\circ C$ it is almost checked. This is probably because at low temp. :

1/ the viscosity of water and protoplasm is increased .

2/permeability of cell membranes is decreased.

3/metabolic activities of root cells are decreased.

4/growth and elongation of roots are checked.

***Absorption of mineral and salts:

Previously, it was thought that the absorption of mineral salts from the soil took place along with the absorption of water but it is now well established

that the mineral salt absorption and water absorption are two different processes.

Mineral salts are absorbed from the soil solution in the form of ions. They are chiefly absorbed through the meristematic regions of the roots near the tip. However, some mineral salts may also be absorbed at other locations on the root surface or over the entire root surface including zone of elongation and root hairs that depends upon the high availability of such minerals around them and/or strong tissue demand at such locations. Some mineral salts can also be absorbed by leaves of the plants during foliar application of chemical fertilizers on them.

Plasma membrane of the root cells is not permeable to all ions. It is selectively permeable. All the ions of the same salt are not absorbed at equal rate but there is unequal absorption of ions.

The further process of the absorption of mineral salts may be of two types:
1/ Passive and 2/ Active.

1/Passive absorption of mineral salts:

First step in the absorption of mineral salts is the process of Ion-Exchange which does not require metabolically energy but greatly facilitates mineral salt absorption.

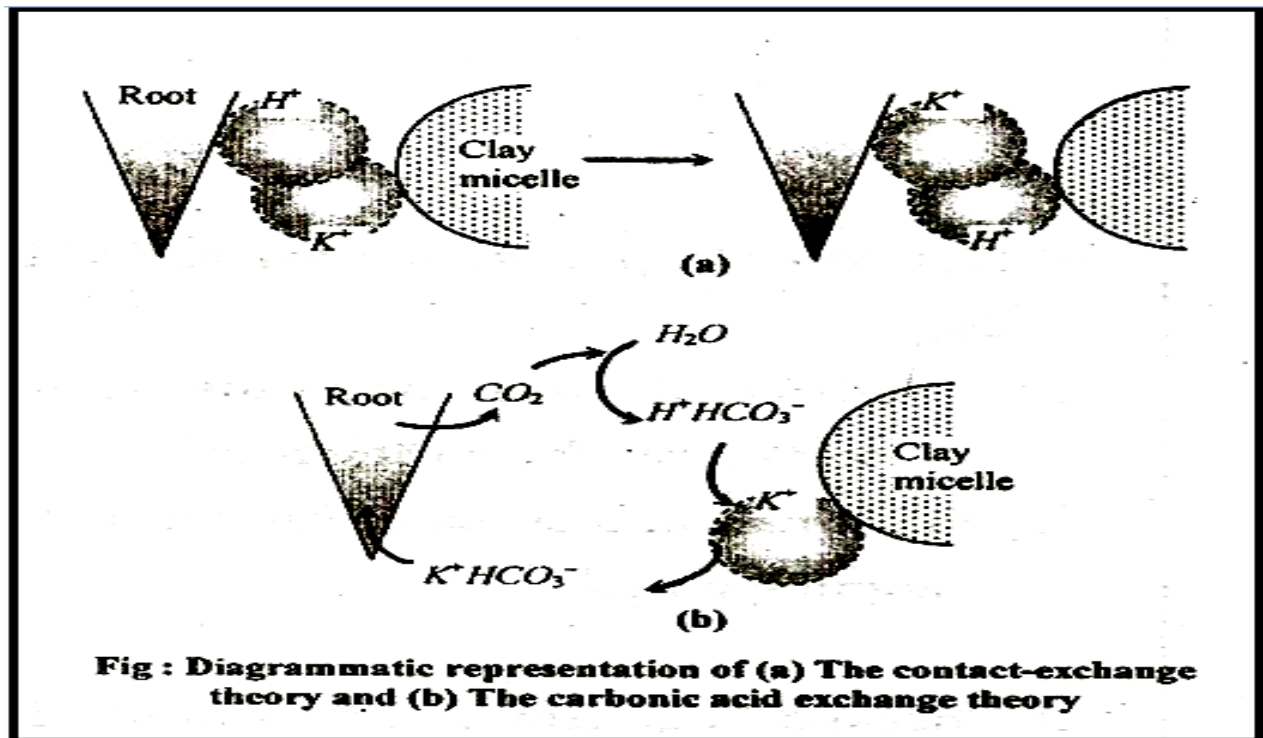
Ion-Exchange: The ions adsorb on the surface of the walls or membranes of root cells may be exchanged with the ions of same sign from external solution. For example, the cation K^+ of the external soil solution may be exchanged with H^+ ion adsorbed on the surface of the root cells. Similarly, an anion may be exchanged with OH^- ion. There are two theories regarding the mechanism of ion exchange:

1-Contact Exchange theory

According to this theory, the ions adsorbed on the surface of root cells and clay particles (or clay micelles) are not held tightly but oscillate within small volume of space. If the roots and clay particles are in close contact with each other, the oscillation volume of ions adsorbed on root –surface may overlap the oscillation volume of ions adsorbed on clay particles, and the ions adsorbed on clay particle may be exchanged with the ions adsorbed on root-surface directly without first being dissolved in soil solution.

2-Carbonic Acid Exchange theory

According to this theory, the CO_2 released during respiration of root cells combines with water to form carbonic acid (H_2CO_3). Carbonic acid dissociates into H^+ and an anion HCO_3^- in soil solution. These H^+ ions may be exchanged for cations adsorbed on clay particles.



****Donnan's Equilibrium:**

The accumulation of ions inside the cells without involving expenditure of the met energy can be explained to some extent by Donnan's equilibrium theory. (also known as the **Donnan effect, Donnan law, Donnan equilibrium, or Gibbs-Donnan equilibrium**).

According to this theory, there are certain pre-existing ions inside the cell which cannot diffuse outside through membrane. Such ions are called as in diffusible or fixed ions which may be in the form of charged carboxyl ($-\text{COO}^-$) and amino ($-\text{NH}_3^+$) groups of proteins or charged groups of other

macromolecules in the cell. However, the membrane is permeable to both anions and cations of the outer solution.

Suppose, there are certain fixed anions in the cell which is in contact with the outer solution containing anions and cations. Normally equal number of anions and cations would have diffused into the cell through an electrical potential to balance each other, but to balance the fixed anions more cations will diffuse into the cell. This equilibrium is known as Donnan's equilibrium. In this particular case, there would be an accumulation of cations inside the cell if however, there are fixed cations inside the cell, the Donnan's equilibrium will result in the accumulation of anions inside the cell.

When the concentration of mineral salts is higher in the outer solution than in the cell sap of the root cells, the **mineral** salts are absorbed according to the **concentration** gradient by simple process of **diffusion**. This is called as **passive absorption** because it does not require expenditure of metabolic energy. It is known that during passive absorption, the mineral salts may diffuse through cell membranes directly through lipid bi-layer.

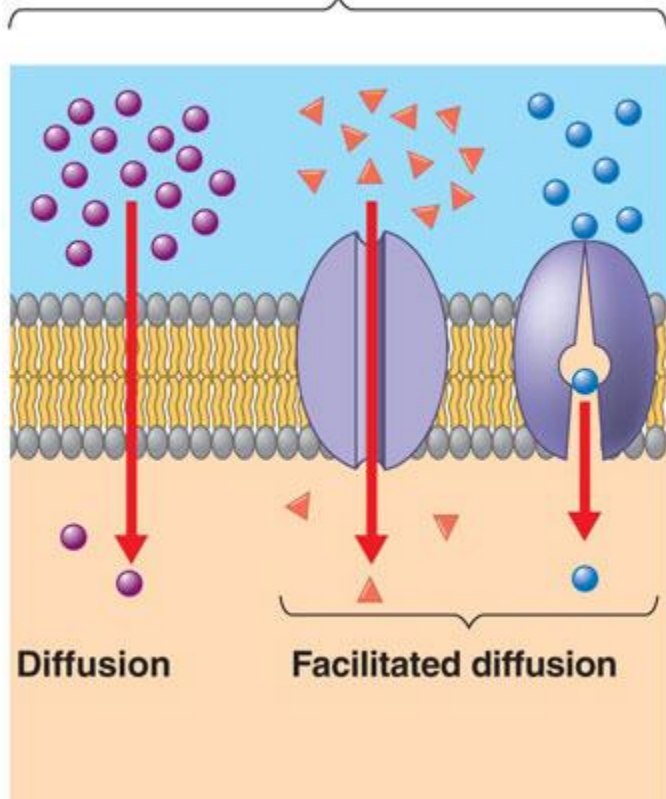
B/ Active absorption of mineral salts:

This cannot be explained by simple diffusion or Donnan's equilibrium and has led people to believe that absorption and accumulation of mineral salts against the concentration gradient is an active process which involves the expenditure of metabolic energy through respiration following evidences favor this view:
1- the factors like low temp., deficiency of O_2 , metabolic inhibitors etc. which inhibit metabolic activities like respiration in plants inhibit accumulation of ions.

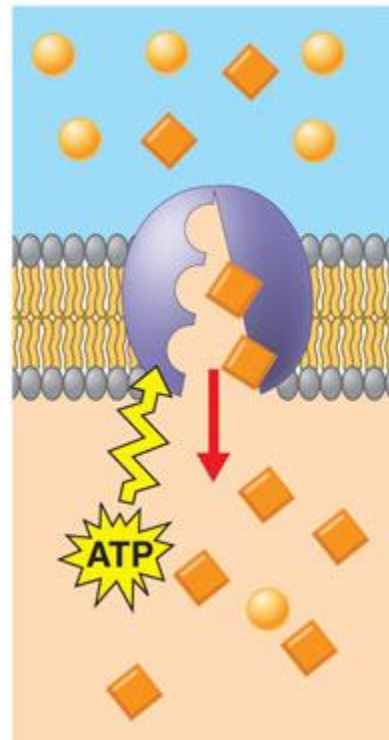
2- rate of respiration is increased when a plant is transferred from water to salt solution (salt respiration) .

It has often been observed that the cell sap in plants accumulates large-quantities of mineral salts ions against the concentration gradient. For example in alga *Nitella* the cell accumulated K^+ and phosphate ions to such an extent that their concentrations were hundreds times greater than in the pond water in which the plant was growing. The mineral salts move mainly through membrane **ion-selective protein channels** or transmembrane **carrier proteins**, carrier on channel mediated passive transport of mineral salts across the membrane is also called as facilitated diffusion.

Passive transport



Active transport



Academic year: ٢٠٢٥/٢٠٢٤ Subject: **Plant Physiology**

By: Dr. asseel habh

Lec:٥

Photosynthesis

Photosynthesis is considered the most important process for all living organisms (except for anaerobic bacteria which can fix CO_2 without using hydrogen of H_2O as a source of proton). Photosynthesis is simply a light-driven series of chemical reactions that convert the energy-poor compound, CO_2 , to energy-rich sugars. In plants, photosynthesis also splits water and release Oxygen(O_2). The photosynthesis organisms produce about ٥٠ million ton of sugar annually by this process. Photosynthesis needs the following essential requirements:

- ١-Source of light energy
- ٢-Source of energy capture
- ٣-Means for energy storage

In plants photosynthesis can be summarized into the following general equation:



Light energy: To understand photosynthesis , we must know a little about the properties of light.

In ١٩٠٥, Einstein proposed that light consist of packets of energy called **photons**, which are the smallest divisible units of light. The intensity (i.e. brightness) of light depends on the number of photons. Light intensity is important in photosynthesis because each photon carries a fixed amount of energy that is determined by the photons wavelength.

Wavelengths of visible light are measured in nanometers. The longer the wavelength, the less energy per photon. Sunlight consist of a spectrum of colors of light having different wavelengths and energy.

Light energy is defined as waves of fine particles called photons or quantum. Atom of any element requires one quantum for excitation and one molecule of any element requires 6.02×10^{23} (Avogadro number) of quantum for excitation.

Photosynthetic pigments: Studied conducted by plant physiologists indicated that the pigments absorbed light energy and transfer it to chemical energy are the chlorophylls which occurred in the plastids. The pigments are classified as follow:

1/Chlorophylls: the quantity of chlorophyll is 10 times more than carotenoids and it includes the following types:

a/ chlorophyll a : occurred in all photosynthetic plants and maximum absorption of light appeared at 430 and 660 nm wave lengths.

b/ chlorophyll b : occurred in all higher plants and green algae and maximum absorption of light appeared at 453 and 640 nm wave lengths.

c/ chlorophyll c : occurred in brown algae.

d/ chlorophyll d : occurred in red algae.

e/ chlorophyll e : occurred in some plant species.

****Differences between chlorophyll a and b :**

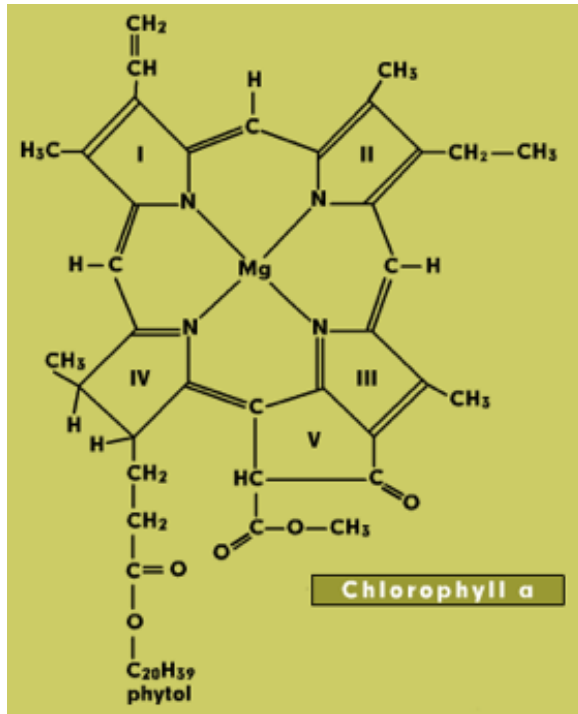
Chlorophyll a	Chlorophyll b
$C_{55}H_{72}O_6N_4Mg$	$C_{55}H_{70}O_6N_4Mg$
Molecular weight 892,32 gm	Molecular weight 876,32 gm
Carbon no.3 attach to methane(CH ₃)	Carbon no.3 attach to aldehyde(CHO)
Best solvent is Ether	Best solvent is methyl alcohol

Maximum absorption at 120 and 70 nm

Maximum absorption at 160 and 80 nm

Chlorophyll structure:

The chlorophyll structure is roughly resembled a “tennis racket” having a large head called **porphyrin** and a long handle or tail called **phytol**. The phytol (the tail) is a long chain alcohol containing one double bond and esterifies with carboxyl group on C_v atom of the chlorophyll molecule.



**other pigments:

1-**Carotenoids**: they are lipid compounds that are distributed widely in both animals and plants and range in color from yellow to purple.

2-**Xanthophylls**: they are more abundant in nature than carotenes and located in chloroplast. They are carotenes containing oxygen.

The function of carotenoids :

a/protect chlorophylls against photo oxidation in excessive light.

b/absorption of light and transfer it to chlorophylls.

c/causes phototropism in plants.

****photophosphorylation:**

The process by which the plant can produce ATP in the presence of light and it happens in the plastids and through the light reactions. There are two types of photophosphorylation:

1/ Non-cyclic photophosphorylation:

The ATP is produced when the electron transfers from cytochrome b to cytochrome f. The process requires the contribution of both photosystem in order to ensure the flow of the electrons through the carrier system.

2/Cyclic photophosphorylation:

This process happens when the plastids exposed to wave length of light more than 700 nm causing P₆₈₀ excited only. In this case, non-cyclic photophosphorylation is stopped, NADP⁺ is not available and CO₂ fixation is retarded. Under these circumstances the available electrons in photosystem II transfer through the carriers to photosystem I which transfer them to Fe-S acceptor.

The ferredoxin is unable to transfer the electrons to form NADPH₂ due to the absence of NADP⁺. However it was found that the ferredoxin is possibly transferred the electron to cytochrome b₆ which in turn pass the electron back to P₆₈₀.

****Function of light reactions:**

1-production of O₂ which is necessary for life continues.

2-formation of NADPH₂ which is necessary for metabolic reactions including dark reaction.

3-formation of ATP which is very necessary for metabolic reactions including dark reaction.

*****Dark reactions:**

The famous plant biochemist Dr. Calvin from university of California used the above technique and found that phosphoglyceric acid (PGA) was the first

compound produced from the fixation of CO₂ in to a carbon compound named Ribulose diphosphate according to the following reaction:

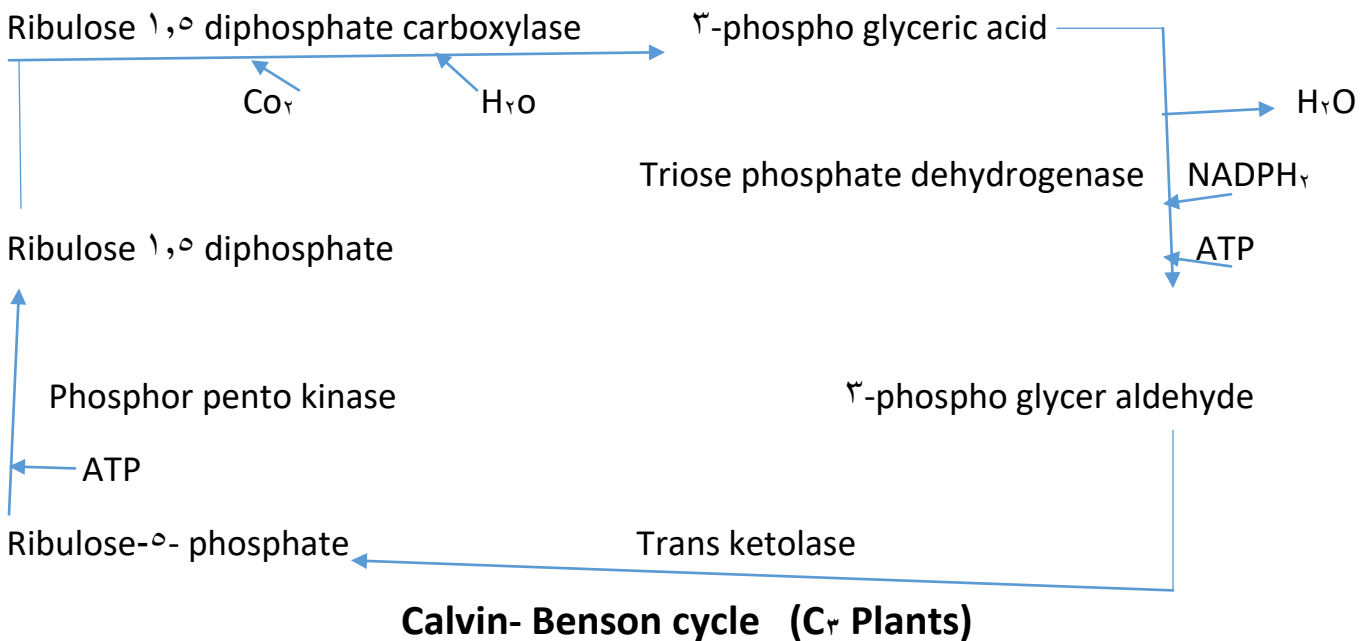


The enzyme catalyzed this reaction is **Ribulose diphosphate carboxylase** which is proved to be biosynthesized in chloroplast. It has been shown that one mole of CO₂ requires 3 moles of ATP and 3 moles of NADPH₂. The dark reactions which known to be a cyclic have collectively named **Calvin cycle**.

****Methods of CO₂ fixation:** studies revealed the presence of 3 kinds of CO₂ fixation in plants. Accordingly, the plants were divided into 3 groups:

1* C₃ plants:

The plants with 3C compound as a primary initial CO₂ fixation product such as wheat, tomato and date palm. The compound is **PGA**.



C₄ Plants:

The plants with C₄ compound as a primary initial CO₂ fixation product such as corn and sugar cane. The compound is **oxaloacetate**.

CO₂ gas is fixed first in the phosphoenolpyruvate (PEP) which is present in the chloroplasts of the mesophyll cells forming a C₄ compound named oxaloacetate. The oxaloacetate converts into malate which moves to enter the chloroplast of the sheath cells, then converts to pyruvate and CO₂. The CO₂ is re-fixed again in Calvin cycle while the pyruvate enters the chloroplast of the mesophyll cells to convert into PEP.

