**College of Science** **Al-Mustanseryea University** **Dep.: Biology**

**Academic year: 2017-2018** **Subject: Plant Physiology**

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## Lecture: 1

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
- A sporophyte is the diploid multicellular stage in the life cycle of a plant or alga. It develops from the zygote produced when a haploid egg cell is fertilized by a haploid sperm and each sporophyte cell therefore has a double set of chromosomes, one set from each parent. All land plants, and most multicellular algae, have life cycles in which a multicellular diploid sporophyte phase alternates with a multicellular haploid gametophyte phase

The plant belongs to the plant kingdom {Plantae}, which include: -

1- Angiosperms (Flowering Plant)
2- Gymnosperms plant.
3- Mosses .

The division of the modern varieties of fungus TO (Red algae) and (Green algae).

What is 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: -

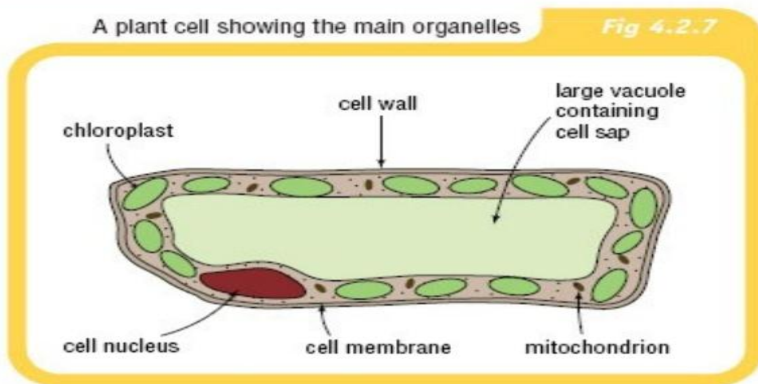
* gaseous exchange: - gets in Stomata .
* Water transport: - ( the phloem).
* photosynthesis: - gets in (Chloroplast).
* transmission of ions: - get across plasma membranes .
* RESPIRATION IN PLANTS : - gets in the Mitochondria.

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

| | 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 |
| **Flagella** | May be found in some cells | May be found in some cells |
| **Lysosomes** | Lysosomes occur in cytoplasm. | Lysosomes usually not evident. |
| **Nucleus** | Present | Present |
| **Cilia** | Present | Most plant cells do not |

| Animal Cell | Plant Cell |
| --- | --- |
| | contain cilia. |

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




**Lec:2**

# 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 50 million ton of sugar annually by this process. Photosynthesis needs the following essential requirements:

1-Source of light energy

2-Source of energy capture

3-Means for energy storage

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

$$CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{light}} \text{Sugars} + O_2$$

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

In 1905, 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 $6.02 \times 10^{23}$ (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 645 nm wave lengths.

**c/** chlorophyll c : occurred in brown algae.

**d/** chlorophyll d : occurred in red algae.

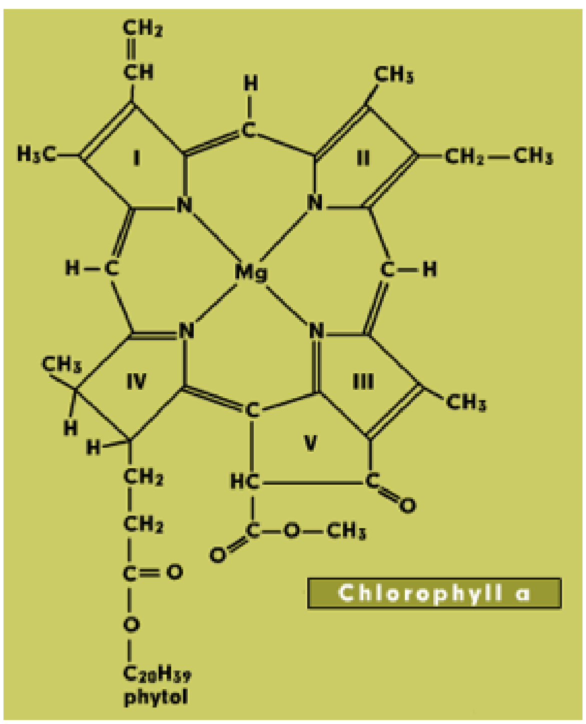
**e/** chlorophyll e : occurred in some plant species.

## **Differences between chlorophyll a and b :

| Chlorophyll a | Chlorophyll b |
|---|---|
| $C_{55}H_{72}O_5N_4Mg$ | $C_{55}H_{70}O_6N_4Mg$ |
| Molecular weight 892.32 gm | Molecular weight 906.32 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 50 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 $C_7$ 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.

*****Electron transfer and photophosphorylation (Z scheme):**

When photosystems I and II exposed to light, both of them are excited, photosystem II starts dissociating $H_2O$ and liberating the electrons. The electron is first captured by P680 in photosystem II which transfer them to primary electron accepter called Q which changes to reduced form. The reduced form transfers the electron to another carrier called B which transfers the electron to plasto quinone. Then the electron reaches the active site of photosystem I (P700) through three carriers namely cytochrome $b_6$, cytochrome f and plastocyanin respectively. Both cytochromes and plastocynin are located in photosystem I . the electron is transferred from photo system I to primary electron accepter called ferredoxin (Fe-S) and change it to reduced form. The reduced form of ferredoxin reduced $NADP^+$ to $NADPH_2$ by the enzyme ferredoxin-$NADP^+$ reductase. The $NADPH_2$ is used to fix $CO_2$ in the dark reactions. Therefor we can conclude that ferredoxin is the terminal electron accepter in the photosynthetic light reaction. The light reaction can be diagramed as Z scheme.

## ***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 680 nm causing P700 excited only. In this case, non-cyclic photophosphorylation is stopped, $NADP^+$ is not available and $CO_2$ 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 accepter.

The ferredoxin is unable to transfer the electrons to form $NADPH_2$ due to the absence of $NADP^+$. However it was found that the ferredoxin is possibly transferred the electron to cytochrome $b_6$ which in turn pass the electron back to P700.

****Function of light reactions:**

1-production of $O_2$ which is necessary for life continues.

2-formation of $NADPH_2$ 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 $CO_2$ in to 5 carbon compound named Ribulose diphosphate according to the following reaction:

$$\textbf{Ribulose diphosphate} + \mathbf{CO_2} \longrightarrow \textbf{2Phosphoglyceric acid(PGA)}$$

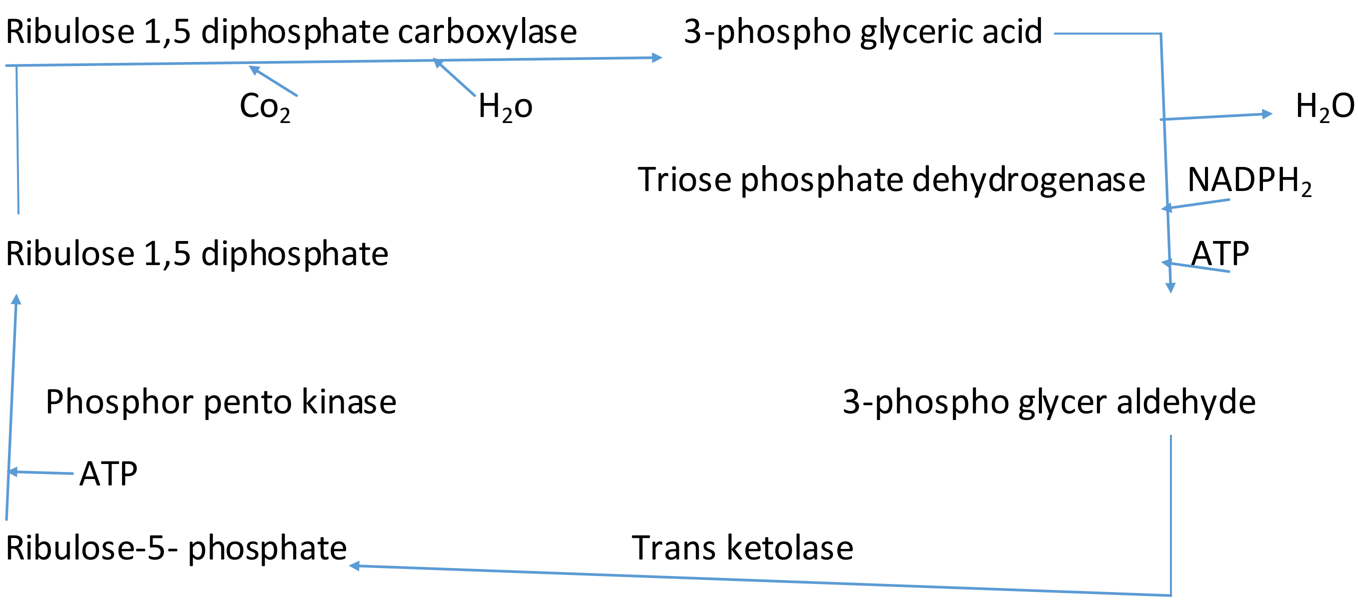
The enzyme catalyzed this reaction is **Ribulose diphosphate carboxylase** which is proved to be biosynthesized in chloroplast. It has been shown that one mole of $CO_2$

requires 3 moles of ATP and 2 moles of $NADPH_2$. The dark reactions which known to be a cyclic have collectively named **Calvin cycle**.

****Methods of $CO_2$ fixation:** studies revealed the presence of 3 kinds of $CO_2$ fixation in plants. Accordingly, the plants were divided into 3 groups:

### 1* $C_3$ plants:

The plants with 3C compound as a primary initial $CO_2$ fixation product such as wheat, tomato and date palm. The compound is **PGA**.




**Calvin- Benson cycle (C3 Plants)**

### 2*$C_4$ Plants:

The plants with 4C compound as a primary initial $CO_2$ fixation product such as corn and sugar cane. The compound is **oxaloacetate**.

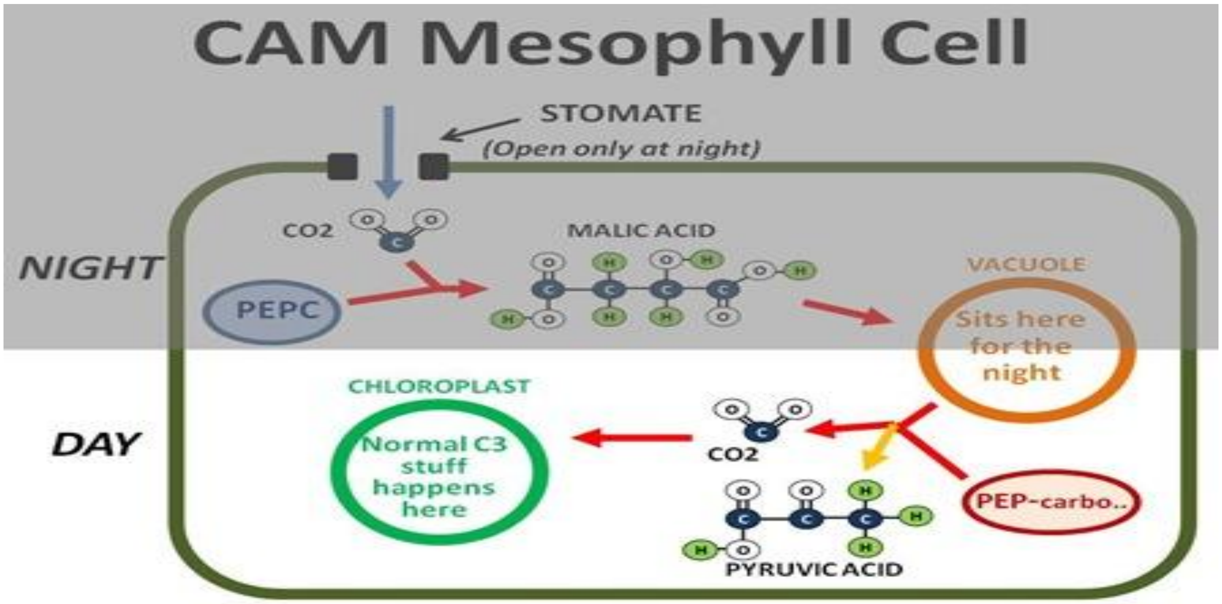
$CO_2$ gas is fixed first in the phosphor phenol pyruvate (PEP) which is present in the chloroplasts of the mesophyll cells forming a 4C compound named oxaloacetate. The oxaloacetate converts into malate which moves to enter the chloroplast of the sheath cells, then converts to pyruvate and $CO_2$. The $CO_2$ is re-fixed again in Calvin cycle while the pyruvate enters the chloroplast of the mesophyll cells to convert into PEP.

## 3*CAM plants:

Means plants with crassulacean acid metabolism. They called CAM since it was first investigated in plants of Crassulacean family which are commonly produced crassulacean acid. Plants of this group open their stomata at night to fix $CO_2$.

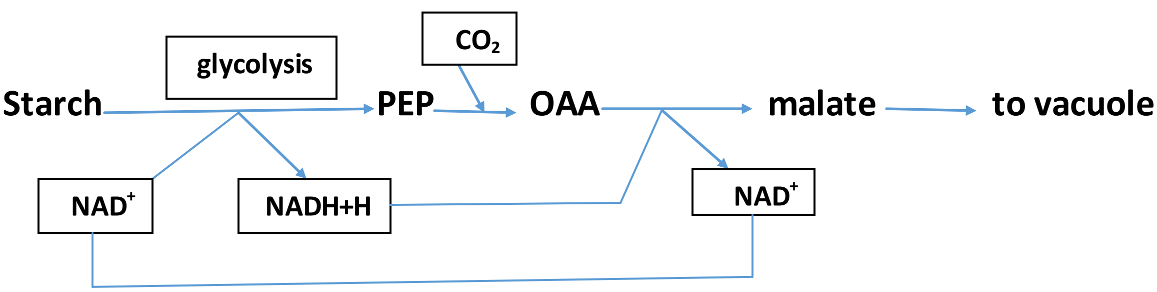
**During night**, starch breaks down by reaction of glycolysis to form phosphor phenol pyruvate (PEP) . $CO_2$ is fixed into oxaloacetate by the enzyme PEP carboxylase, then this acid is converted to malate by dehydrogenase enzyme. Malate is stored in the vacuole.

**During day-light,** malate come out of the vacuole and dehydrogenated to form oxaloacetate again. Oxaloacetate is decarboxylated to form $CO_2$ and PEP . the $CO_2$ is re-fixed into Calvin cycle while PEP convert to starch by reverse glycolysis. Some of starch produced by reverse glycolysis and Calvin cycle can be utilized again during night to fix $CO_2$ again.

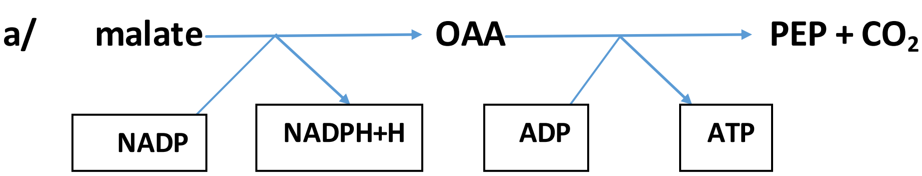


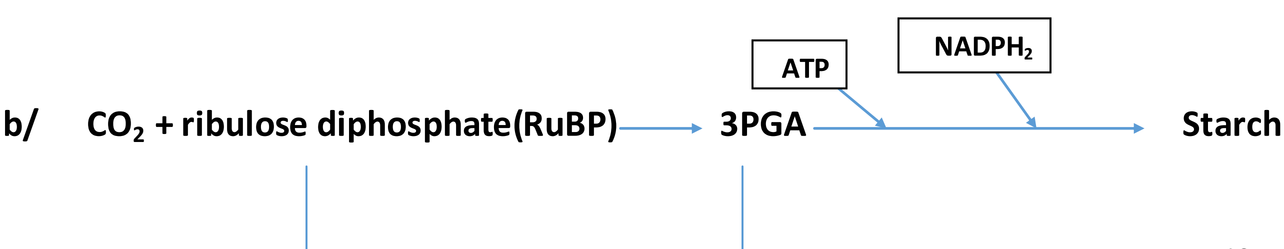

## $CO_2$ fixation in CAM plants:

### 1-Darkness (stomata opened):



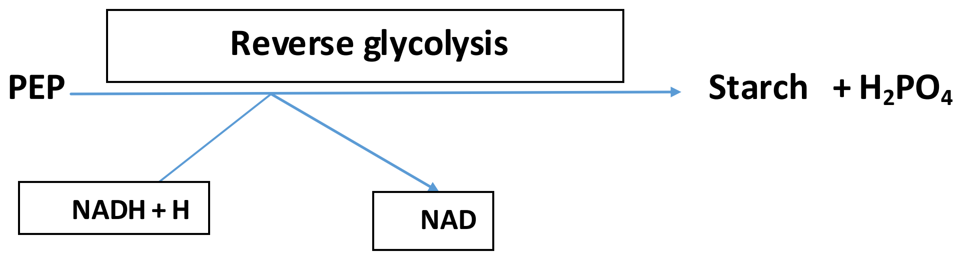

### 2-Day-light (stomata closed):



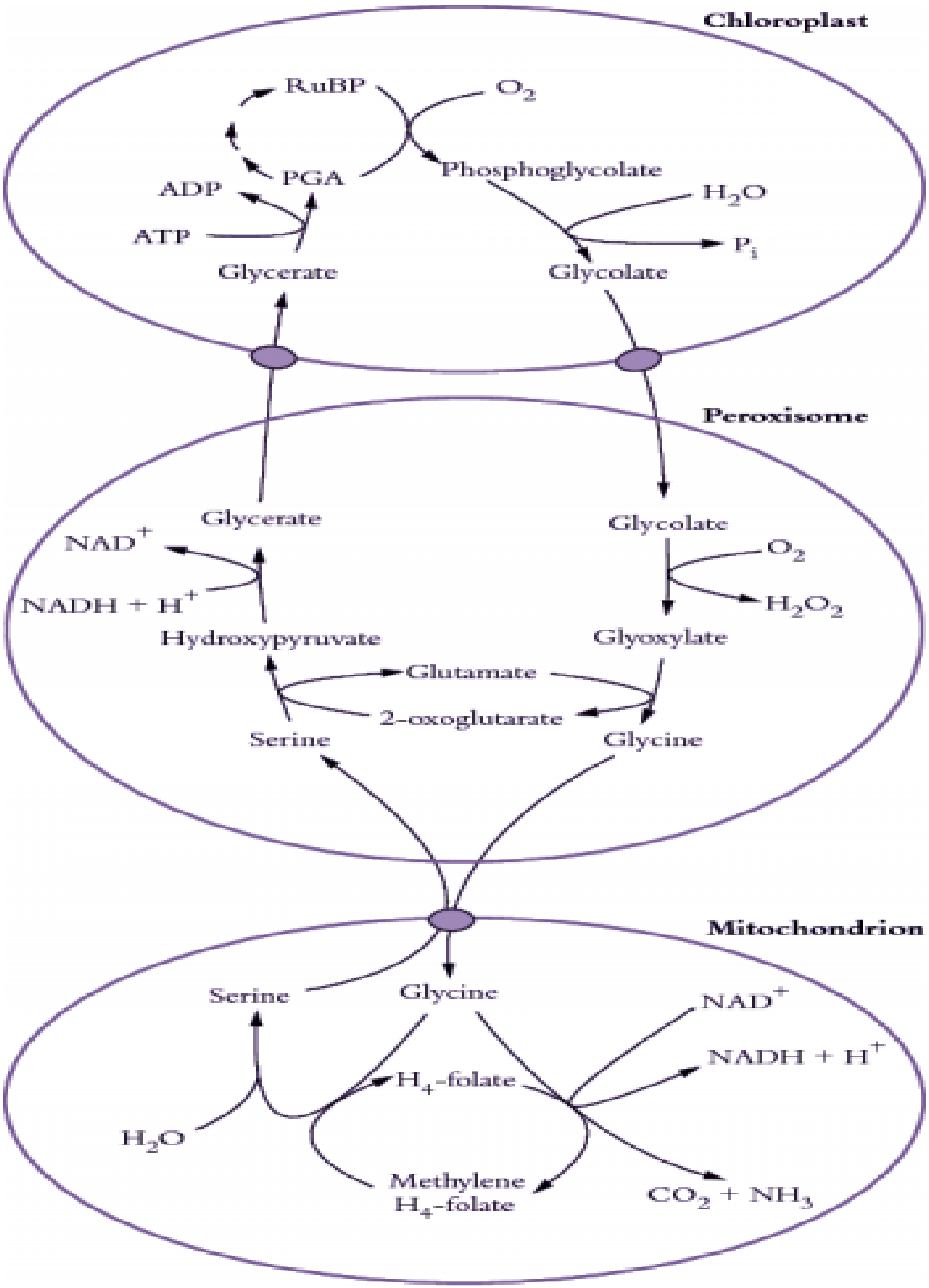
**Calvin-Benson cycle**

c/




## ***Photorespiration:

Photorespiration presents in all plants and takes place in the presence of light. The reactions of photorespiration are completed in 3 cellular structures namely **chloroplast**, **perexisome** and **mitochondria**. The first reaction starts with the combination of $O_2$ with the Ribulose diphosphate carboxylase to form glycolate and 3-phosphoglyceric acid (3-PGA). Both compounds moved from the chloroplast to the peroxisome. The glycolate converts to glyoxylate which converts to glycine. 3-phosphoglyceric acid convert to glyceric acid which converts to hydroxyl pyruvate then to serine. Serine moves to mitochondria to convert to glycine by decarboxylation process. The process is important for biosynthesis of the amino acids (glycine and serine) which are essential for protein biosynthesis.




**Metabolic path ways of photorespiration**

**Factors affecting rate of photosynthesis:

**1-$CO_2$ concentration:** both concentration and diffusion affect photosynthesis rate. It has been shown that the diffusion of $CO_2$ inside the internal leave tissues is controlled by diameter aperture. The diffusion of $CO_2$ increased with the increasing diameter of the aperture. Photosynthesis is increased with the increased $CO_2$ concentration up to a define limit after the concentration becomes toxic to plants. the upper limit varied with plant species.

**2-$O_2$ concentration:** the increased in $O_2$ con. significantly decreased the rate of photosynthesis. It has been suggested that the high concentration of $O_2$ competes with $CO_2$ on the hydrogen ions of $NADPH_2$ and combines with them to form $H_2O$. In this case $CO_2$ fixation is inhibited (means photosynthesis is inhibited).

**3-Water:** water is very important factor that affects the rate of photosynthesis under drought conditions, stomata close and diffusion of $CO_2$ and $O_2$ inside the leave inhibited and these lead to inhibit the rate of photosynthesis. Excess water also inhibit the rate of photosynthesis. Flooding of plants prevents $CO_2$ and $O_2$ and thereby reducing photosynthesis rate.

**4-Temperature:** extreme temperature is significantly inhibited photosynthesis rate. The low temperature freezes the water inside and outside the cells and thus preventing the movement of $CO_2$ and $O_2$ into the cells. It also causes protein denaturation. The high temperature inhibits or destroys enzymes including enzymes of Calvin cycle. Generally the increase temperature increases the activity of the plant to a limit then the increase in temperature harms the plant.

**5-Light intensity:** It has been shown that rate of photosynthesis increases with increasing light intensity to a limit after which, the increase in light intensity slightly increases the rate of photosynthesis. however at very light intensity, the rate of photosynthesis inhibited due to photooxidation of chlorophylls.

Lec:3

# Plant Hormones

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

**Characters of plant hormones:**

**1-**integrate many different plant parts.

**2-**natyrally occurring organic substances.

**3-**affects plant growth and development.

**4-**opreats in a very low concentration.

**5-**actions may involve sites far removed from hormones origin.

**6-**hormones elicit a wide range of responses from growth to dormancy.

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

**A/Promote hormones:**

**1-Auxins 2-Gibbrelline 3-Cytokinins**

**B/Inhibit hormones:**

**1-Ethylen 2-Abscisic acid**

*****Note:** that hormones are a specific chemicals which produced in specific organism in small quantities and travel to other areas (the target area), at the target area they regulate physiological responses (like: growth, movement, reproduction).

*****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 or phytohormones:** 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-flowring regulators:** are regulators that affect flowering.

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

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

**1-**Firist 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.

**2-**cell and organ differentiation.

**3-**flower initiation and development, fruit set, fruit growth, and embryo growth.

**4-**abscission of leaves, flowers and fruits.

**5-**direction of growth (tropism of stems or roots).

**6-**apical dominance.

**7-**parthenocarpy in some plants.

**8-**enlargment 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 enlargment 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 acetonitrl 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**.

****Artificial auxins:** are synthetic chemical compounds acts as plant hormones and are divided into two groups:

**1-**compound containing indol derivative such as indol butyric acid and indol propionic acid.

**2-**compound don't contain indol derivative such as α and β naphthalene acetic acid, 2,4 dichloro phenoxy acetic acid and 2,4,5 trichloro phenoxy acetic acid.

The low concentration of these compounds acts as auxin.

****Biosynthesis of Indol acetic acid (IAA):**

The amino acid tryptophan is considered a primary precursor of IAA of plants. The production of auxin is an enzymatic process.

IAA could be formed from tryptophan via two different pathways:

1- By the deamination of tryptophan to form indol pyruvic acid, followed by decarboxylation to form indol acetaldehyde.

2- By the carboxylation of tryptophan to form tryptamine followed by deamination to form indol acetaldehyde.
By either pathway indol acetaldehyde is formed thus must be considered the immediate precursor of IAA in plants.

*****Destruction of Auxin:**

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

1- Enzymatic oxidation.
2- 2- Photo oxidation.

The enzymatic system is called IAA oxidase, the IAA oxidase content of the various plant parts. The enzyme increases in activity from tip to down. IAA oxidase activity seams to be low in regions of high auxin content (high growth) and high in regions with low IAA content (low growth).

*****photooxidation:** it has long been known that IAA can be inactivated by ionizing radiation x and gamma radiation. Ultra violet light also in activate IAA, and visible light between 300-700 millemicron.

## ***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.

Lec:4

## ***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 on 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:

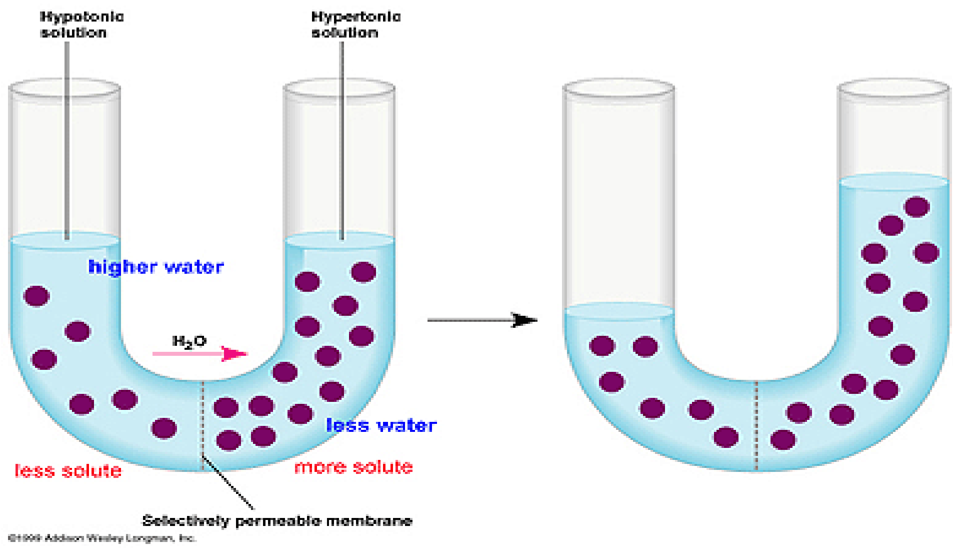
Diffusion is the net movement of molecules from an area of greater concentration to an area of lesser concentration. Diffusion by random movement continues until the distribution of molecules becomes even throughout the solution. The rate of diffusion depends on:

1- The size of the molecules (larger molecules move slower).
2- The temperature of the solution (higher temperature cause faster movement).
3- 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.

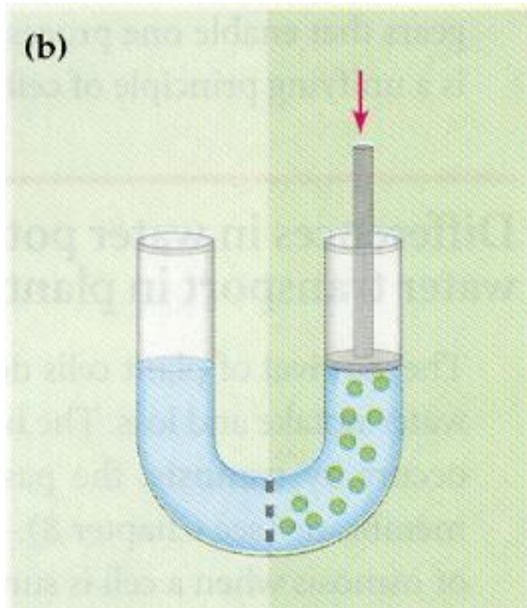
## **Osmosis is the diffusion of water across a selectively permeable membrane:

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.

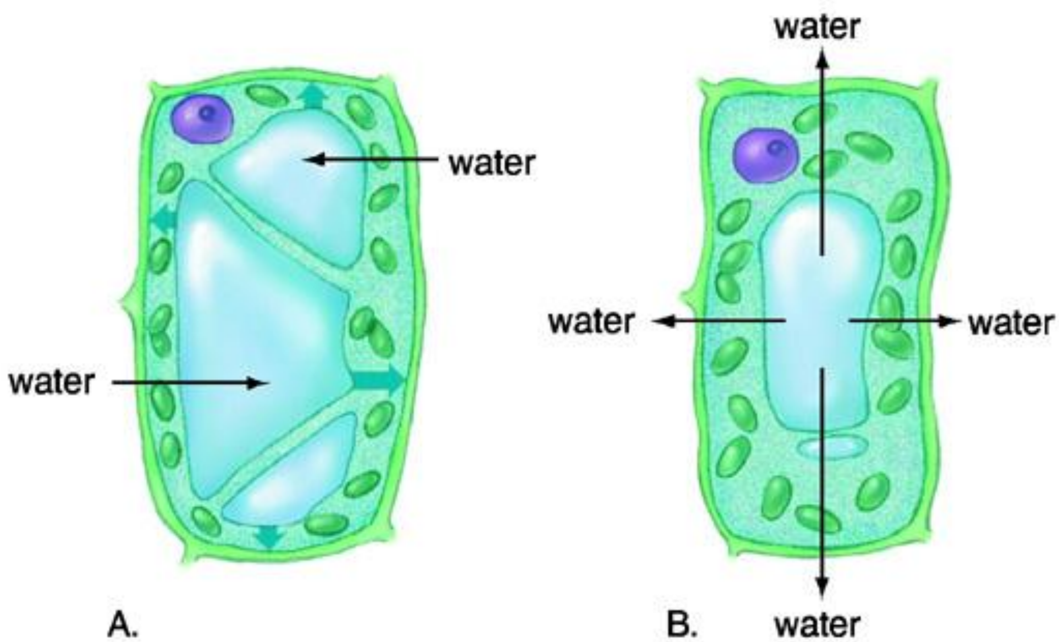



Higher water potential in the left-hand solution causes water to move into the right-hand solution. the amount of pressure that is necessary to maintain constant volume on the right equals the force of water movement across the membrane.

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 $\Psi_P$ represents the **pressure potential**. It is identical to P and represents the hydrostatic pressure in excess of ambient atmospheric pressure. The term $\Psi_S$ 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.

Lec:5

# **Absorption of water**

## <u>Mechanism of absorption of water:</u>

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:**

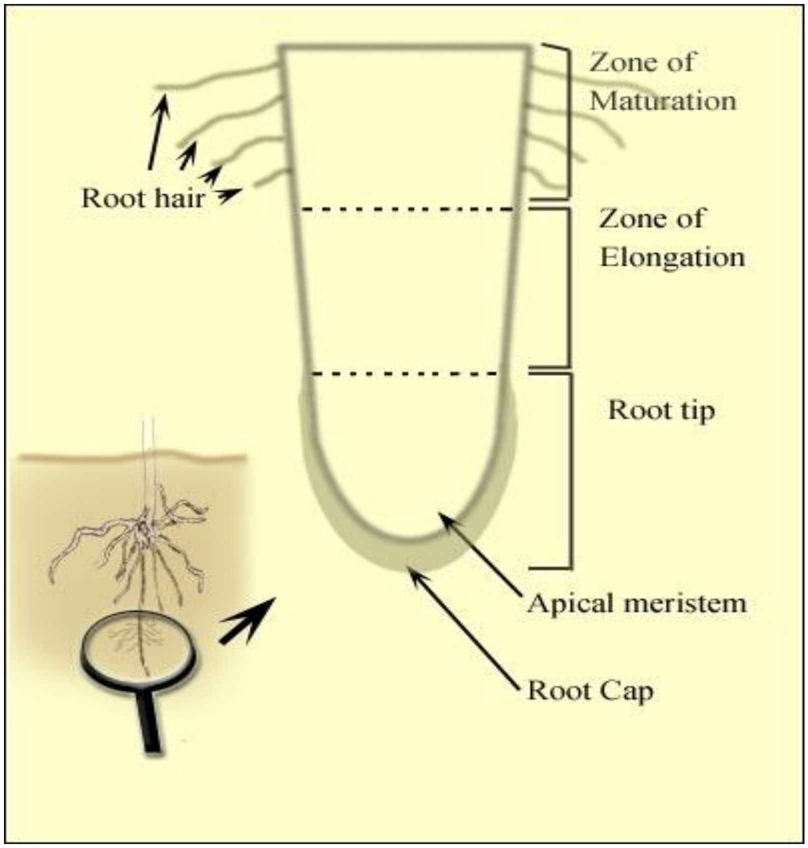
1- **Active absorption** of water. In this process the root cells play active role in the absorption of water and metabolic energy released through respiration is consumed.

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.

2- **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:

1-the factors which inhibit respiration also decrease water absorption.
2-poisons which retard metabolic activities of the root cells also retard water absorption.
3-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:

### 1-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.

**2-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**.

**3-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.

**4-soil temperature:**

Increase in soil temperature up to about 30C favors water absorption. At higher temperature water absorption is decreased .At low temp., also water absorption decrease so much so that at about 0C 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.

**A/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 cm 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 Add 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.

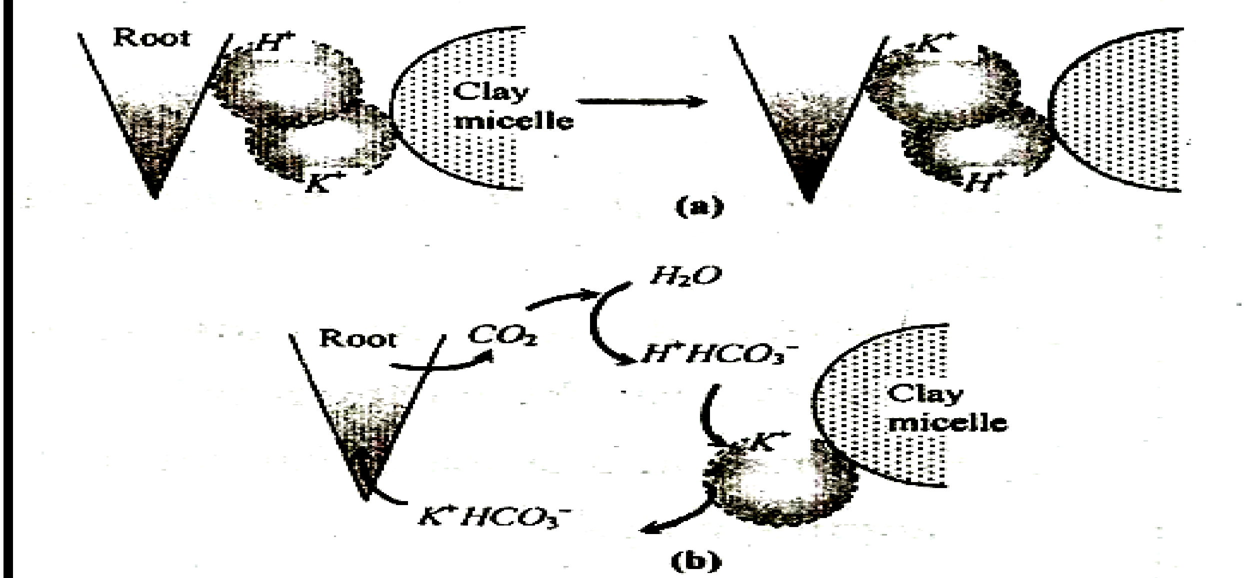



**Fig : Diagrammatic representation of (a) The contact-exchange theory and (b) The carbonic acid exchange theory**

## **Donnan's Equiliberium:

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**).

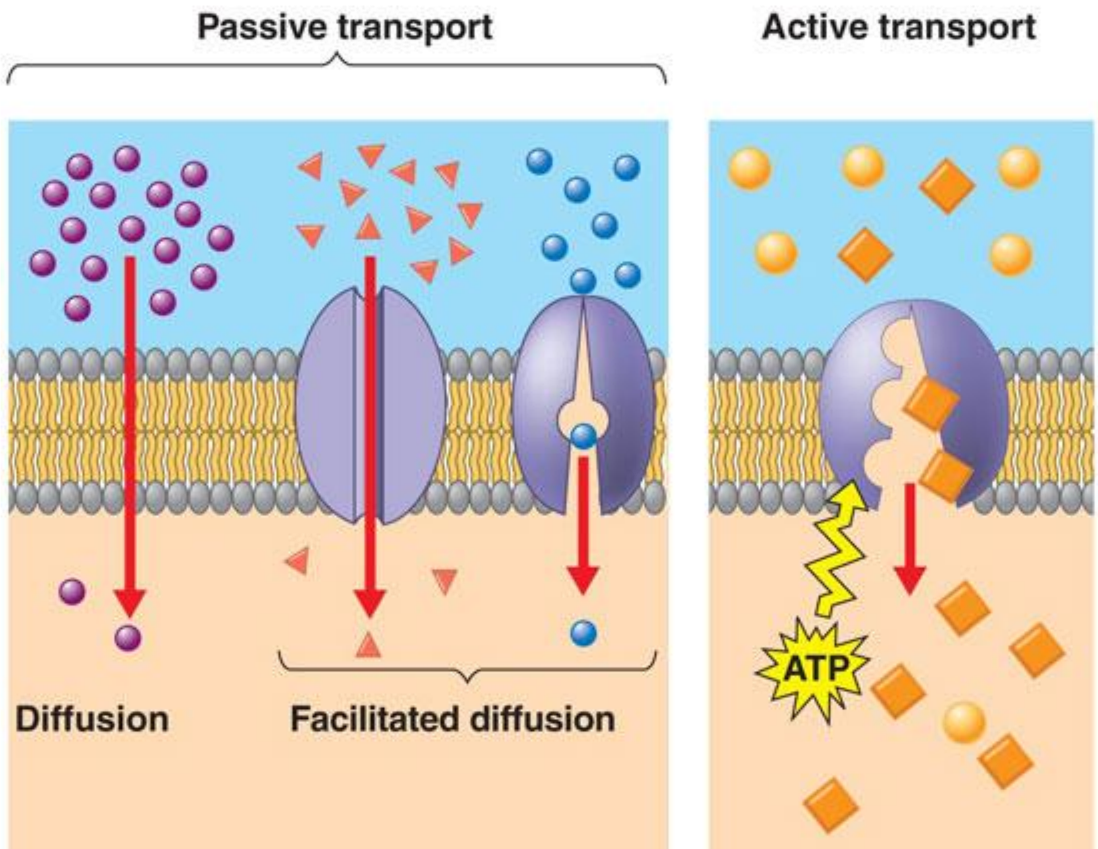
According to this theory, there are certain pre-existing ions inside the cell which cannot diffuse outside through membrane. Such ions are called as in diffusible or fixed ions which may be in the form of charged carboxyl($-COO^-$) and amino ($-NH_4^+$) groups of proteins or charged groups of other macromolecules 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 ledpeople 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 *Nitetta* 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
ATP
Diffusion
Facilitated diffusion