

lectures in
PLANT PHYSIOLOGY
prepared by /
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Solutions

It is a common observation that when a little sugar or salt is dissolved in water, a homogeneous and stable mixture of the two components is obtained which is called as solution. Of these two components, the one (here sugar or the salt) which is present in small quantity is called as solute while the other (here water) present in larger quantity is called as solvent.

The solution is homogeneous because the molecules or the ions of the solute become evenly distributed throughout the solvent. It is a stable system because the molecules or the ions do not settle down. Sometimes more than one solutes may be dissolved in a solvent to form a stable and homogeneous mixture.

Types of solutions

True solution:

A true solution may be defined as a homogeneous and stable mixture of two or more chemical substances. In a true solution the particles are not visible. The size of particles less than $0.001 \mu\text{m}$.

Suspensions and Emulsion:

If some fine sand is mixed with water in a beaker, the sand particles become dispersed in water. They do not break into molecules or ions but after a very short period settle down leaving almost a clear water above. Such an unstable system of a solid and liquid is called as suspension. Due to their large size, the suspended particles are visible under microscope and can be seen even with naked eyes. While emulsions is formed when two immiscible liquids are vigorously shaken together an unstable emulsion is formed.

The size of particles ranges more than $0.1 \mu\text{m}$.

Colloidal solution:

If in place of sand, a little fine clay is mixed with water, the clay particles remain dispersed in it. They neither break into molecules or ions nor they settle down even after long period of time. Such a heterogeneous and stable system is called as colloidal system.

In the above colloidal system the clay particles form a dispersed phase while the water forms dispersion medium.

The sizes of the dispersed particles as well as the properties of the system are midway between the suspension and the true solutions. The size of particles ranges from $0.001 \mu\text{m}$ to $0.1 \mu\text{m}$ in diameter and they remain dispersed throughout water in a stable manner, forming a two-phase system.

The colloidal particles are not visible under microscope but can be observed under an ultra-microscope.

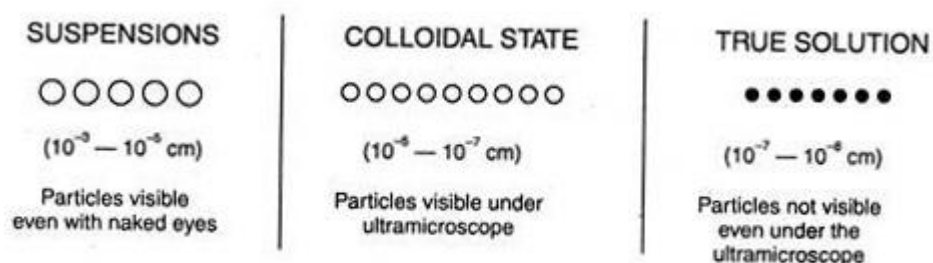


Fig. 2.2. Diameter of solute particles.

Types of colloidal solutions may be of two types:

- (i) Lyophilic Colloidal solutions
- (ii) Lyophobic Colloidal solutions

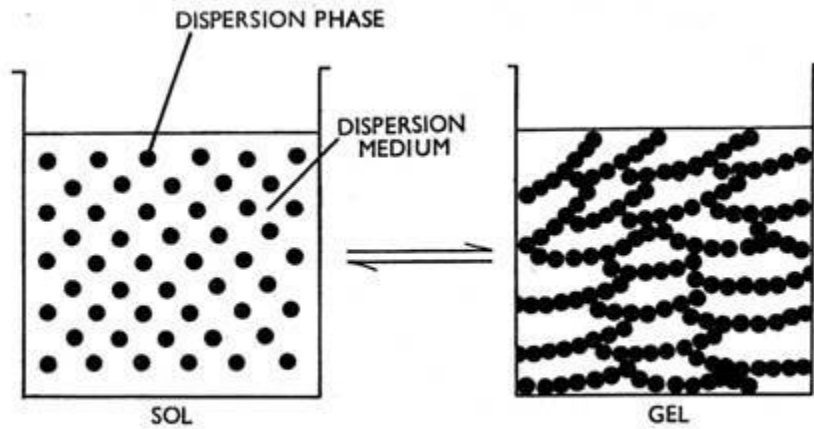


Fig. 2.3. Sol-gel forms of a colloidal solution.

Colloidal Nature of Protoplasm:

Although a large number of chemical substances are found in the protoplasm with water constituting the major portion, the protoplasm is not a true solution. Most of the particulate phase of the protoplasm is colloidal in nature. Again, it is not a simple colloidal system but is considered as complex colloidal system of many phases and shows many properties of the colloidal systems. The colloidal nature of the protoplasm is chiefly due to the presence of protein molecules. In fact, these macromolecules of proteins constitute next major category of chemical substances after water in protoplasm. Moreover, all the enzymes are essentially proteins which provide large surfaces due to their large and often colloidal system to catalyse most of the biochemical reactions in the protoplasm, so important for life to exist.

Properties of Colloidal system:

(1) Tyndall Effect:

If a strong beam of light is passed through a colloidal suspension and observed at right angles through an ultra-microscope, its path is easily observed.

This is due to the scattering of light by minute particles which appear as bright spots. The size and form of the particles cannot be seen. This phenomenon is known as the Tyndall effect.

(2) Brownian Movement:

The colloidal particles show Brownian movement first described by Scottish botanist Robert Brown in 1827.

This is an erratic and continuous movement caused by unequal bombardment of the colloidal particles by molecules of the dispersion medium.

(3) Adsorption:

Molecules or ions tend to adhere to the interface of colloidal systems, and the process is called adsorption.

It is a surface phenomenon and the capacity for adsorption, therefore, is determined by the amount of surface exposed and also the chemical nature of the constituents in question. The process of sub-division of substances increases its surface area.

Therefore, the adsorptive capacity of a colloidal system is very high for a given weight of colloidal particles.

Most of the important functions of colloidal system found in the living cell are dependent upon their immense adsorptive capacity.

This enables the protoplasm to carry on a large number of complex chemical reactions at ordinary temperature which otherwise would need high temperatures in the laboratory.

(4) Electrical Properties:

Colloidal particles carry electric charge which may be positive or negative. For any one colloidal system the charge is the same on all the particles.

The charges are due to the adsorption of free ions in the dispersion medium. The preferential adsorption of positive ions by a colloidal particle will give it a positive charge and the reverse is true of negatively charged colloidal particles.

In case the dispersed phase has a positive charge, all the particles of a colloidal system will collect at the cathode and in case of negatively charged, they will collect at the anode. This phenomenon is called electrophoresis.

The similarity in the charge of the particles of a suspension is responsible for the stability of the colloidal suspensions.

The fact that units of like charge repel each other, prevent their aggregation and precipitation out of suspension.

(5) Flocculation:

Destruction of the electric double layer enforces the dispersed particles of a colloidal suspension to collide, aggregate and precipitate out of suspension.

This is caused by the addition of the certain amount of electrolyte. This practice of flocculation by adding electrolytes is called salting out.

Valency of an ion is very significant in determining the extent to which precipitation is caused by it when added to a colloidal system.

For instance, the monovalent sodium ion is far less effective than the divalent barium ion or the trivalent aluminium ion.

(6) Viscosity:

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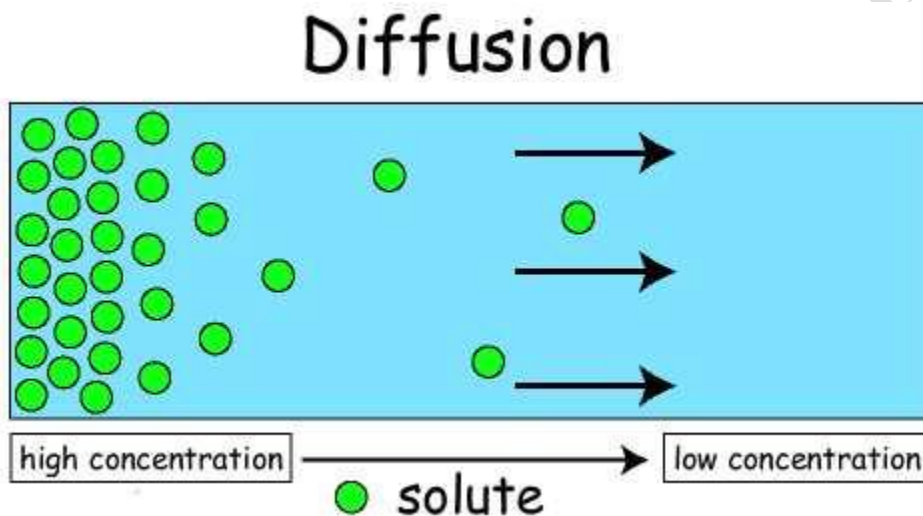
The viscosity of a colloidal solution is more than that of water. The colloidal solution of albumin diffuses at a rate of about $1/7000$ to that of sucrose solution.

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Diffusion

Diffusion is a very important process for photosynthesis where carbon dioxide from the stomata diffuses into the leaves and finally into the cells. Also, during transpiration, the water and oxygen diffuse from the leaves into the environment.

It includes the movement of particles of a medium from the region of its higher concentration to the region of its lower concentration without the expenditure of energy. This process is slow and occurs mostly in gases and liquids. The rate of diffusion is affected by various factors like temperature and pressure, concentration gradient, separating membrane's permeability etc.



Factors affecting Diffusion in Plants

Temperature

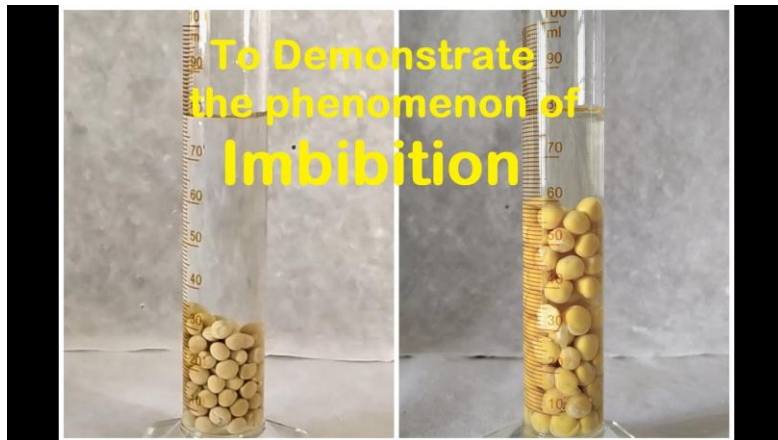
The rate of diffusion is directly proportional to the increase in temperature.

Density

The rate of diffusion is inversely proportional to the density of the diffused particles.

Imbibition

It is a special type of diffusion in which water is absorbed by solid particles (or colloids) of an object resulting in an increase in volume. For example, when dry wood is soaked in water.



Water surface potential movement takes place along a concentration gradient; some dry materials absorb water. A gradient between the absorbent and the liquid is essential for imbibition.

Examples include the absorption of water by seeds and dry wood. If there is no pressure due to imbibition, seedlings would not be able to emerge from soil.

Osmosis

Osmosis is when a substance crosses a semi-permeable membrane in order to balance the concentrations of another substance. In biology, this is usually when water move high concentrated medium to lower concentrated one through semi-permeable membrane. Osmosis happens spontaneously and without any energy on the part of the cell.

Types of Solutions

In biology, there are three different types of solutions that cells can be in: isotonic, hypotonic, and hypertonic. Different types of solutions have different impacts on cells due to osmosis.

Isotonic

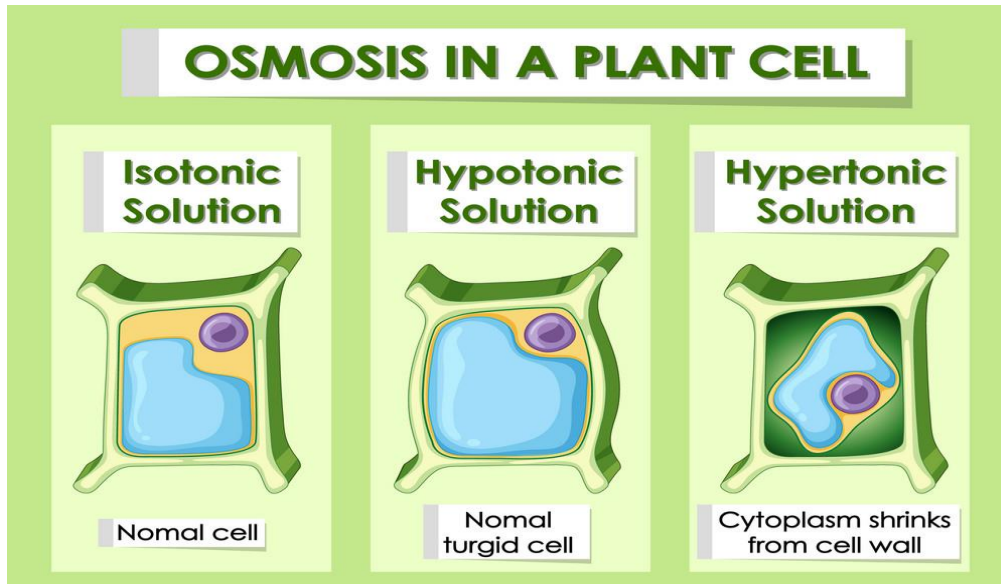
An isotonic solution has the same concentration of solutes both inside and outside the cell. Under these conditions, there is no net movement of solvent; in this case, the amount of water entering and exiting the cell's membrane is equal.

Hypotonic

In a hypotonic solution, there is a higher concentration of solutes inside the cell than outside the cell. When this occurs, more solvent will enter the cell than leave it to balance out the concentration of solute.

Hypertonic

A hypertonic solution is the opposite of a hypotonic solution; there is more solute outside the cell than inside it. In this type of solution, more solvent will exit the cell than enter it in order to lower the concentration of solute outside the cell.



The role of osmosis in plants

1. It helps the root system of the plants to absorb water and minerals from the soil
2. Helps maintain the turgidity (shape) of the plant cell
3. It play a key role in the movement of water and other substances from one cell to another
4. Enables the plants to overcome severe conditions such as drought and frost.
5. It helps maintain turgor pressure which control the opening and closing of stomata

A plant cell has a cell membrane and cell wall as its boundary. The cell wall is freely permeable to water, hence it is not barrier to movement.

(ii) In plant cells, the cells usually contains a large central vacuole, whose contents, the vacuolar sap, contribute to the solute potential of the cell.

(iii) The cell membrane (Ectoplast) and the membrane of the vacuole, the (Tonoplast), together are important determinants of movement of molecules into the cell

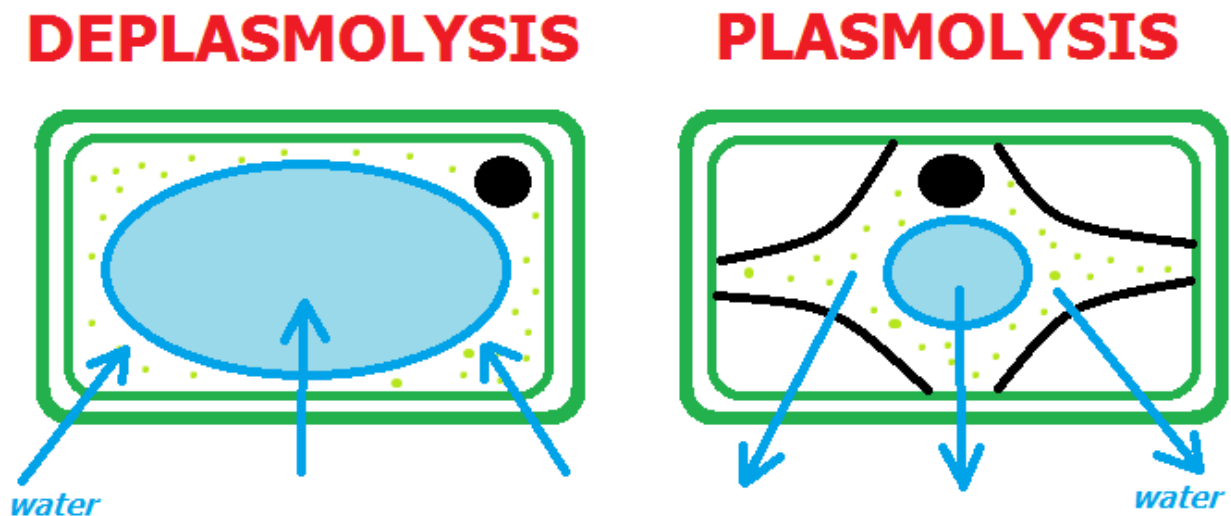
- A cell is an osmotic system. The net movement of the cell sap depends on the type of solution present in the surrounding.

If the osmotic concentration of the solution is less than that of the cell sap, the solution is called a hypotonic solution. This causes swelling of the cell takes place.

If the osmotic concentration of the solution is more than that of the cell sap, the solution is called hypertonic solution, this causes the cell shrinks.

If the osmotic concentration of both the solution as well as the cell sap is same, no net movement takes place. No net change occurs in the cell.

Plasmolysis is the process in which cells lose water in a hypertonic solution. The reverse process, **deplasmolysis**, can occur if the cell is in a hypotonic solution resulting in a lower external osmotic pressure and a net flow of water into the cell.



Loosing of water from the plant

TRANSPIRATION

Although large quantities of water are absorbed by plant from the soil but only a small amount of it is utilized. The excess of water is lost from the aerial parts of plants in the form of water vapours. This is called as transpiration.

Transpiration is of three types:

1. Stomatal transpiration: Most of the transpiration takes place through stomata.
2. Cuticular transpiration: Cuticle is impervious to water, even though, some water may be lost through it.
3. Lenticular transpiration: some water may be lost by woody stems through lenticells which is called as lenticular transpiration.

Guttation

The phenomenon of guttation is associated with the presence of special types of stomata at the margins of the leaves which are called as water stomata or hydathodes. Each hydathode consists of a water pore which remains permanently open.



Bleeding

Bleeding is the exudation of sap from the injured parts of a plant. The root pressure generated by a plant forces the cell sap to rise through the stem. This causes bleeding of the cell sap from the cut surface of the plant.

ENZYMES

An enzyme is a protein that functions as a catalyst to speed up a biochemical reactions.

CHARACTERISTICS of Enzymes

1. Enzymes do not make anything happen that couldn't happen on its own, just makes it happen faster.
2. Enzymes are not used up in reactions. They can be used over and over again!
3. Enzymes are only needed in small amounts.
4. Each enzyme is highly selective about its substrate.
5. Enzymes chemically recognize, bind and modify substrates.

Enzyme Nomenclature

There are many methods for naming enzymes:

- 1- according to the name of substrate by adding the suffix –ase to the end of the substrate for example sucrose sucrase
- 2- according to the type of the reaction which the enzyme catalyse and adding also, the suffix – ase to the end of the reaction for example carboxylation
carboxylase
- 3- According to Enzyme Commission

Enzyme Code (EC): Each enzyme has a numerical code which is formed of four digits separated by dots:

- The first digit denotes the class (reaction type) of the enzyme.
- The second digit denotes the functional group upon which the enzyme acts.

- The third digit denotes the coenzyme.
- The fourth digit denotes the substrate.

For example :

1.1.1.1 enzyme, 1 means oxidoreductase,

1.1 means that the functional group is hydroxyl group (-OH),

1.1.1 means NAD is the coenzyme and

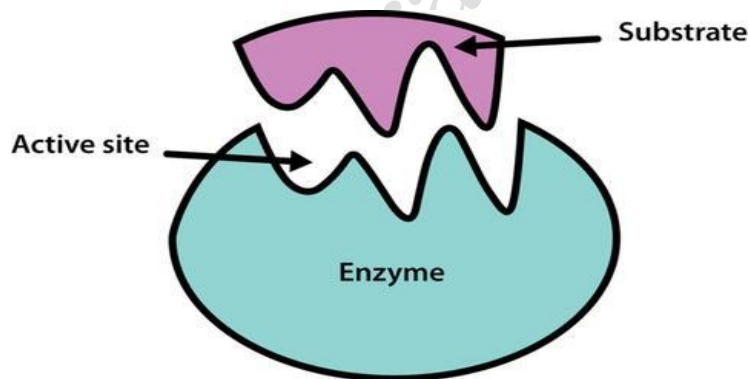
1.1.1.1 means alcohol.

So, 1.1.1.1 means alcohol dehydrogenase enzyme

Chemical Nature of Enzymes

Protein enzymes are classified into 2 types:

- 1- Simple Protein enzymes: They are formed of protein only.
- 2- Complex (conjugated) Protein : They are formed of protein part and non protein part.



Complex (conjugated) Protein :

enzymes formed of two parts:

- 1) Protein part: called apoenzyme
 - 2) Non- protein: called cofactor or co-enzyme
- The whole enzyme is called holoenzyme

Prosthetic group

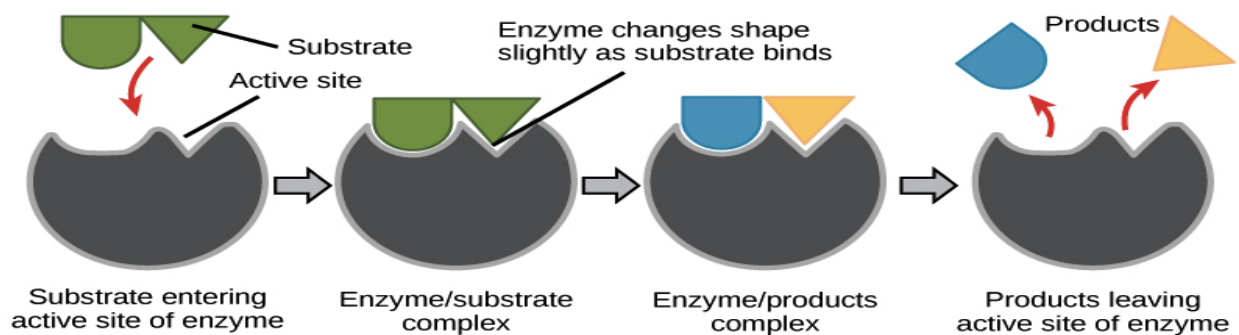
- **Coenzyme:** Is organic, loosely attached to enzyme.
- They are mainly vitamin B derivatives e.g. FAD, NAD.

Activators: Is inorganic, firmly attached to enzyme.

- They are usually metal ions e.g. Ca^{++} , Zn^{++} .

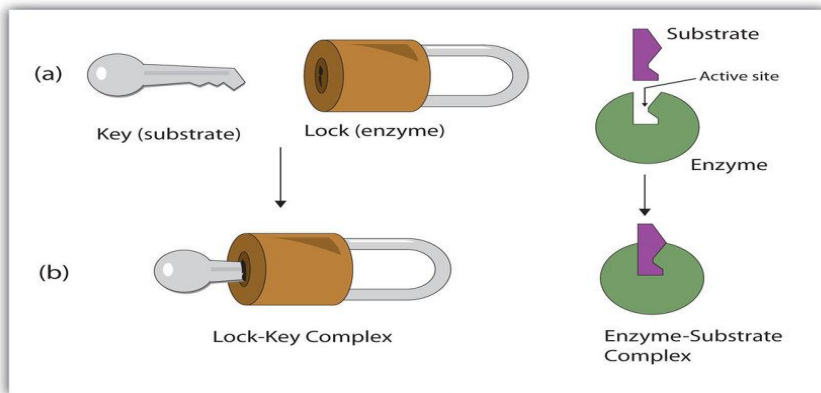
ENZYME ACTION

- 1- The substrate (S) binds to the enzyme (E) at its active catalytic site to form activated intermediate enzyme substrate complex (ES).
- 2- The activated complex (ES) cleaved to the products (P) and the original enzyme (E)



Lock and Key model –

the substrate molecule has a specific 3-dimensional shape that allows it to fit into the specific 3-dimensional shape of an enzyme's active site. Both enzyme and substrate already exist in these specific 3-dimensional shapes.



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Enzymes Classification

Oxidoreductases

These catalyze oxidation and reduction reactions, e.g. pyruvate dehydrogenase, catalysing the oxidation of pyruvate to acetyl coenzyme A.

Transferases

These catalyze transferring of the chemical group from one to another compound. An example is a transaminase, which transfers an amino group from one molecule to another.

Hydrolases

They catalyze the hydrolysis of a bond. For example, the enzyme pepsin hydrolyzes peptide bonds in proteins.

Lyases

These catalyze the breakage of bonds without addition of water, e.g. aldolase (an enzyme in glycolysis) catalyzes the splitting of fructose-1, 6-bisphosphate to glyceraldehyde-3-phosphate and dihydroxyacetone phosphate.

Isomerases

They catalyze the formation of an isomer of a compound. Example: phosphoglucomutase catalyzes the conversion of glucose-1-phosphate to glucose-6-phosphate (phosphate group is transferred from one to another position in the same compound) in glycogenolysis (glycogen is converted to glucose for energy to be released quickly).

Ligases

Ligases catalyze the association of two molecules. For example, DNA ligase catalyzes the joining of two fragments of DNA by forming a phosphodiester bond.

Factors affecting on the rate of enzyme activity

- 1- Substrate concentration
- 2- Enzyme concentration
- 3- Temperature
- 4- PH
- 5- Inhibitors

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Inhibitors

An enzyme inhibitor is a molecule that binds to an enzyme and decreases its activity.

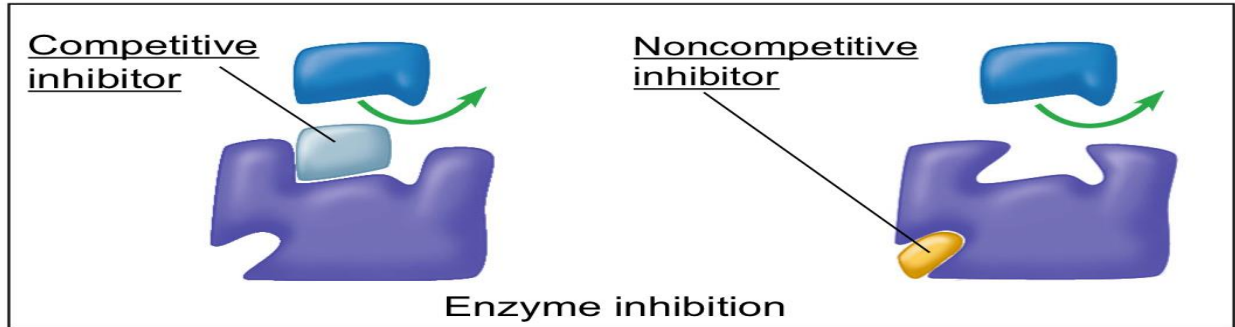
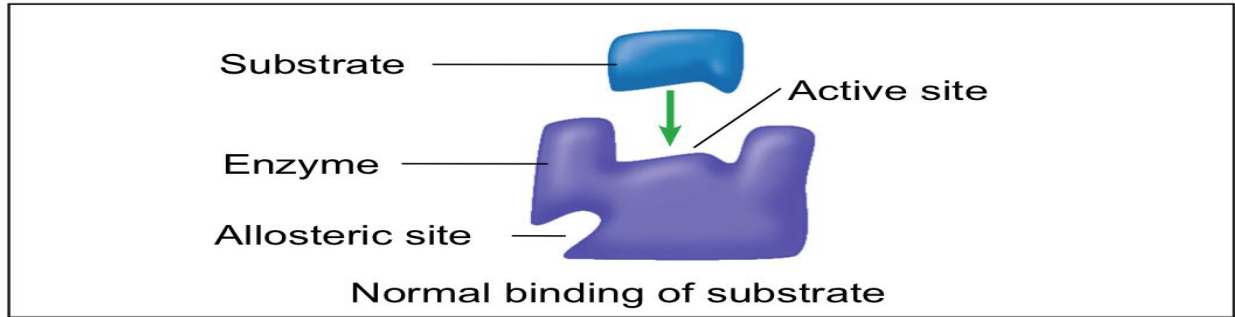
There are two types of inhibitors:

Competitive inhibitor:

the inhibitor and substrate compete for the enzyme (i.e., they can not bind at the same time). It can be overcome by increasing the concentration of substrate in the medium.

Non-competitive inhibitors

in contrast to competitive inhibitors, noncompetitive inhibitors do not compete with the substrate for the active sites. The inhibitor reacts with other parts of enzyme not involved in catalytic activity or with enzyme-substrate complex. It can not be overcome by addition of more substrate.



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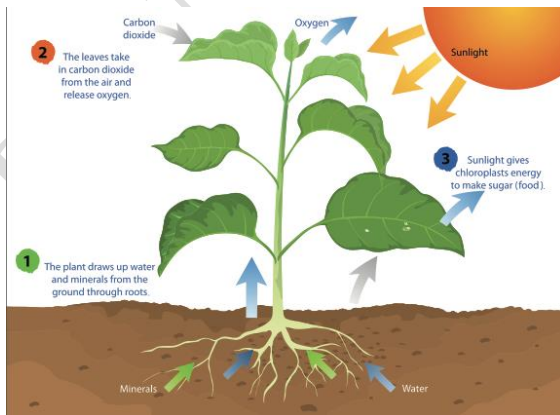
Metabolism

Plant metabolism is divided into Anabolism and Catabolism.

- Anabolism is the total series of biochemical reactions involved in synthesis of organic compounds
- Catabolism is the series of biochemical reactions that breakdown larger molecules. Energy is released this way, some of it can be utilized for anabolism

Photosynthesis

Plants are called autotrophs because they can use energy from light to synthesize, or make, their own food source. Many people believe they are “feeding” a plant when they put it in soil, water it, or place it outside in the Sun, but none of these things are considered food. Rather, plants use sunlight, water, and the gases in the air to make glucose, which is a form of sugar that plants need to survive. This process is called photosynthesis and is performed by all plants, algae, and even some microorganisms. To perform photosynthesis, plants need three things: carbon dioxide, water, and sunlight.



Photosynthesis may be summarised by the word equation



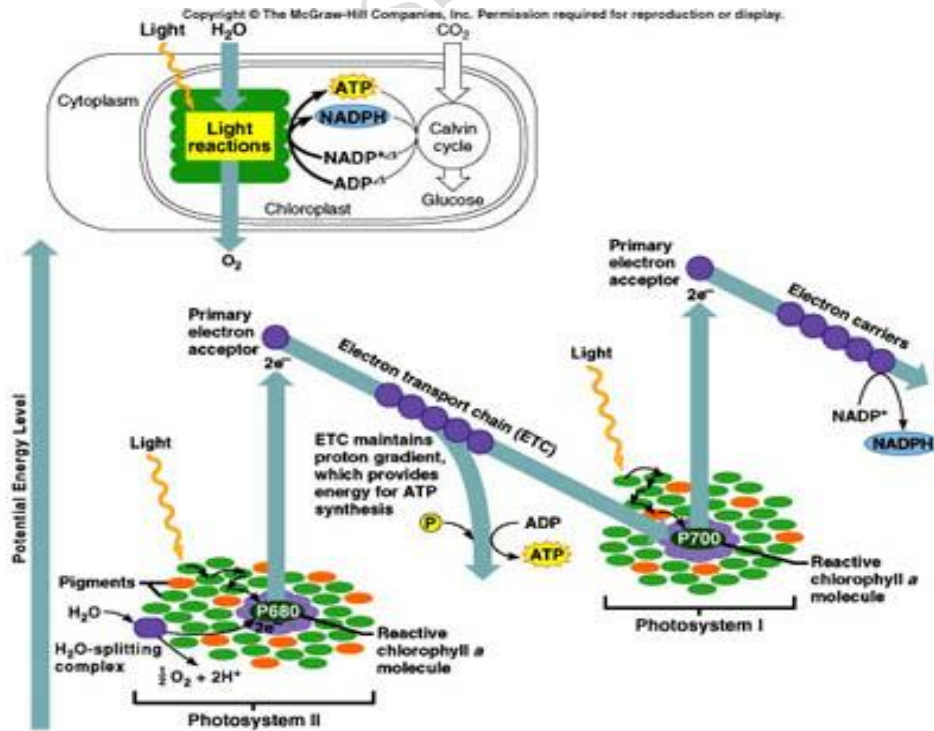
It divided in to two reactions:

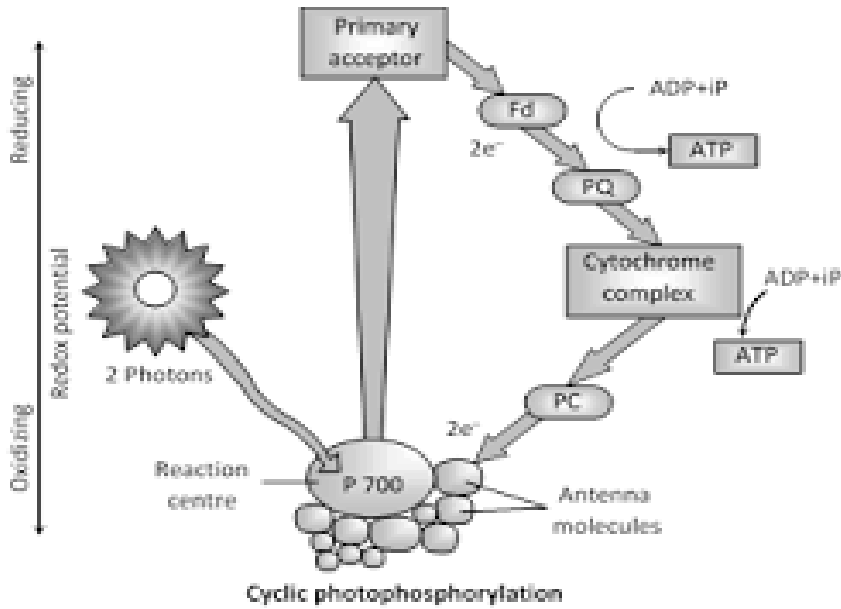
- Light reactions (Hill reactions)
- Dark reactions
- **Light reactions (Hill reactions)**

The light-dependent or “Light” Reactions: convert sunlight energy into chemical energy (stored in ATP & NADPH).

Light reactions (Hill reactions):

- Non-cyclic photophosphorylation
- Cyclic phosphorylation

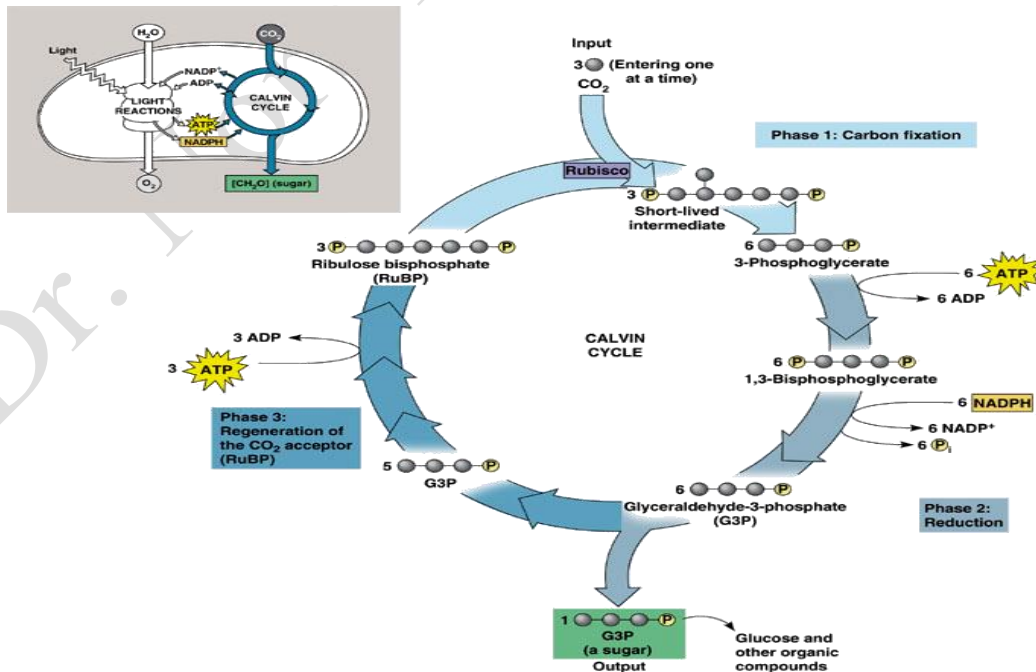




- **The “Dark” Reactions**

The “Dark” Reactions A series of reactions called the Calvin cycle that synthesize glucose from CO₂ and H₂O.

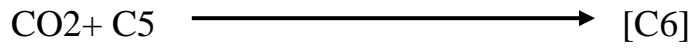
Endergonic reactions of this pathway are fueled by ATP & NADPH from the “light” reactions.



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RUBP= Ribulose-1,5diphosphate = C5

Carboxydismutase



PGA=Phosphoglyceric acid

PGAL= Phosphoglyceraldehyde.

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Respiration:

Is the biochemical process by which organic compounds release energy.

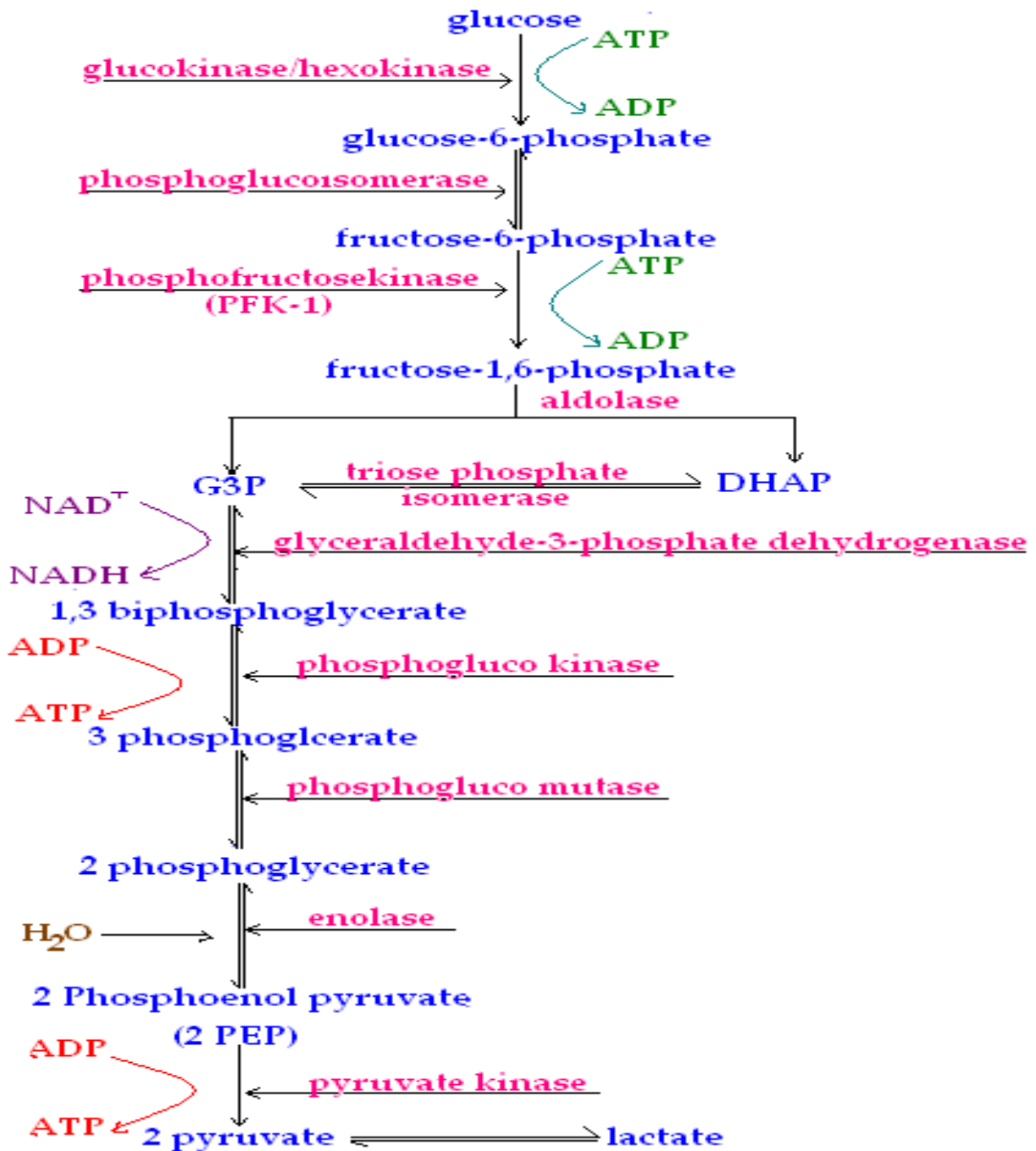


There are two types of respiration:

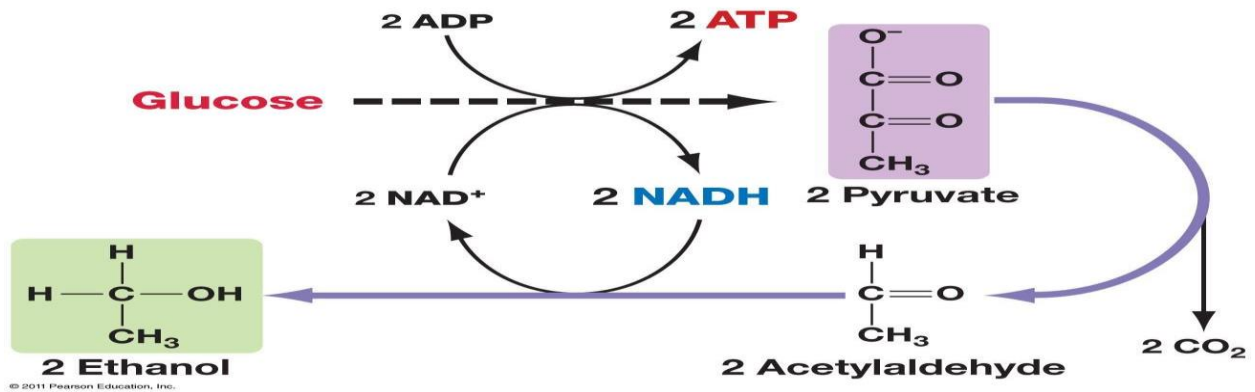
- Aerobic, which requires oxygen and releases lots of energy
- Anaerobic, which does not require oxygen but releases much less energy.

Aerobic respiration takes place in three steps:

1. Glycolysis/Embden-Meyerhof-parnas pathway (EMP pathway)
2. Kreb's cycle/Citric acid cycle/Tricarboxylic acid cycle
3. Electron transport system (ETS).



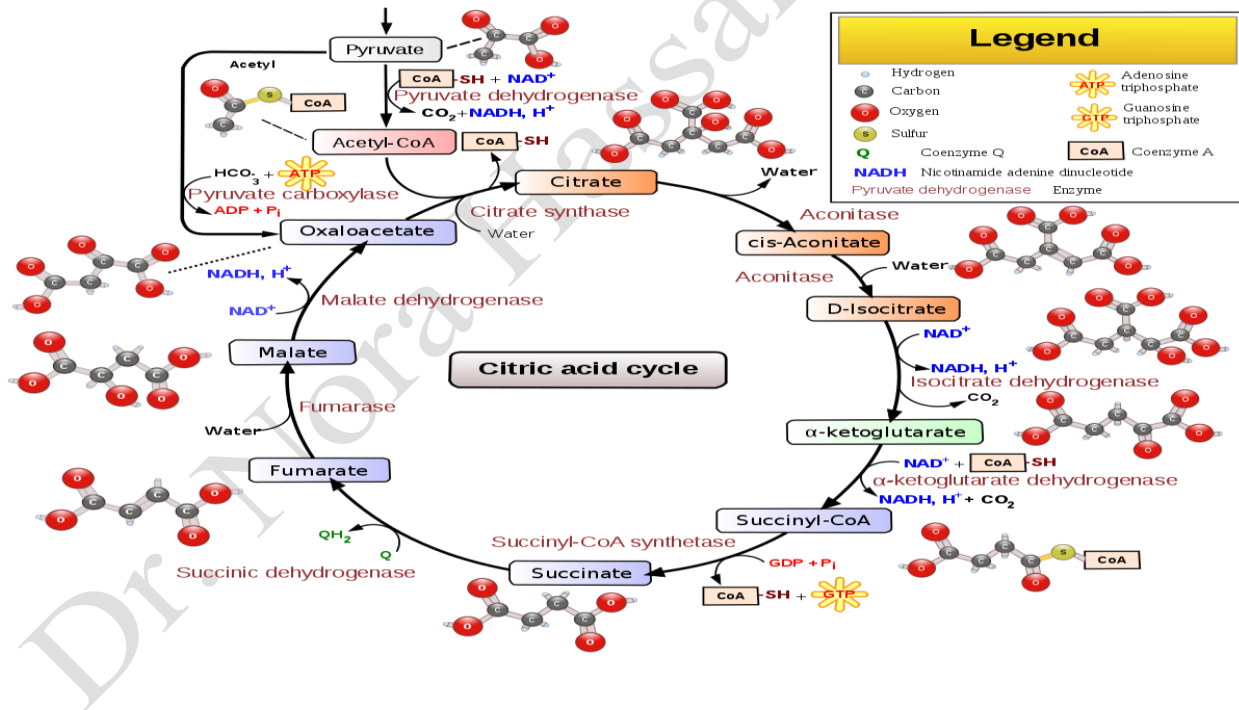
Fermentation



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2- Krebs cycle

The krebs cycle is the second of three stages of cellular respiration, in which glucose is oxidized. The oxidation of these molecules is primarily used to transform the energy contained in these molecules into ATP. The TCA cycle starts with the condensation of acetyl group with oxaloacetic acid (OAA) and water to yield citric acid .



Electron Transport System (ETS)

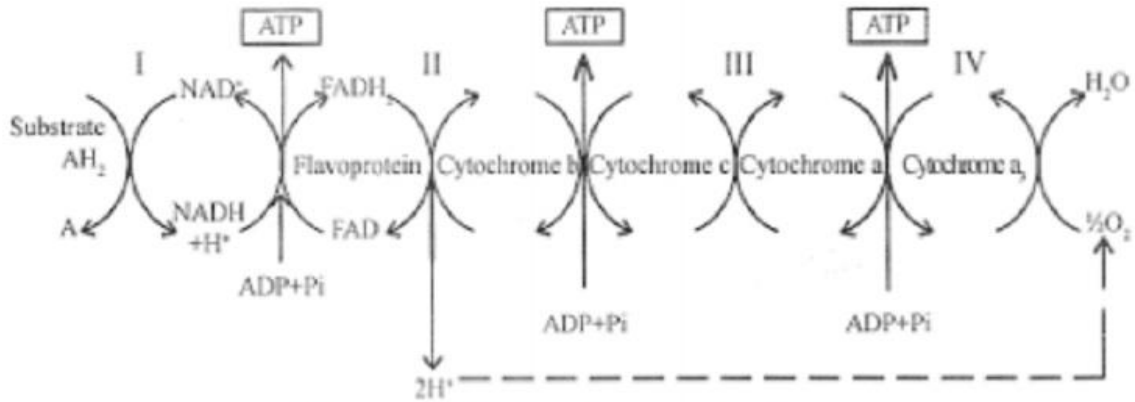


Fig. Electron transport system

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