Biochemistry

Biochemistry is a science that deals with chemical components of living matter and the chemical changes that occur to the matter during the various life processes. Biochemistry can be defined more broadly as a chemical analysis of biological phenomena.

Biochemistry as an independent science is distinguished by its relatively newness, and in fact, the term biochemistry did not come into existence until 1903 by the German chemist Carl Neuberg. Nevertheless, many biochemical phenomena have been associated since ancient times with organic chemistry, physiology, biology and medicine. Studies that led to the emergence of biochemistry have progressed. Biochemistry as an important science in daily life were advanced by many prominent scientists starting from the seventeenth century to be now side by side with other sciences that are interested in scientific development in the world.

Related references

Meyer ,B.S. ; B. B. Anderson; R. H.Bohning and D. G. Fratianne (1973). Introduction to Plant Physiology. Second edition ,London,UK.

Dalali, B. K. (1986). Fundamentals of Biochemistry. Mosul University, Iraq..

Al-Gilani, Q. A. and I. A. Abdel-Hussein (1986). Biochemistry. University of Basra, Iraq.

Al-Assar, A. M. (2012). Fundamentals of Biochemistry. Academic Library, Arab Republic of Egypt.

Opik , H. and S. Roffe (2005).The physiology of flowering plants . Fourth edition, Cambridge University Press.UK.

Ahern, Rajagopal, and Tan (2018).Biochemistry free for all.Verison 1.3,electronic book.

PLANT CELL

The term cell is derived from the Latin ‘cella’ means storeroom or chamber.The term cell was first used by the English botanist Robert

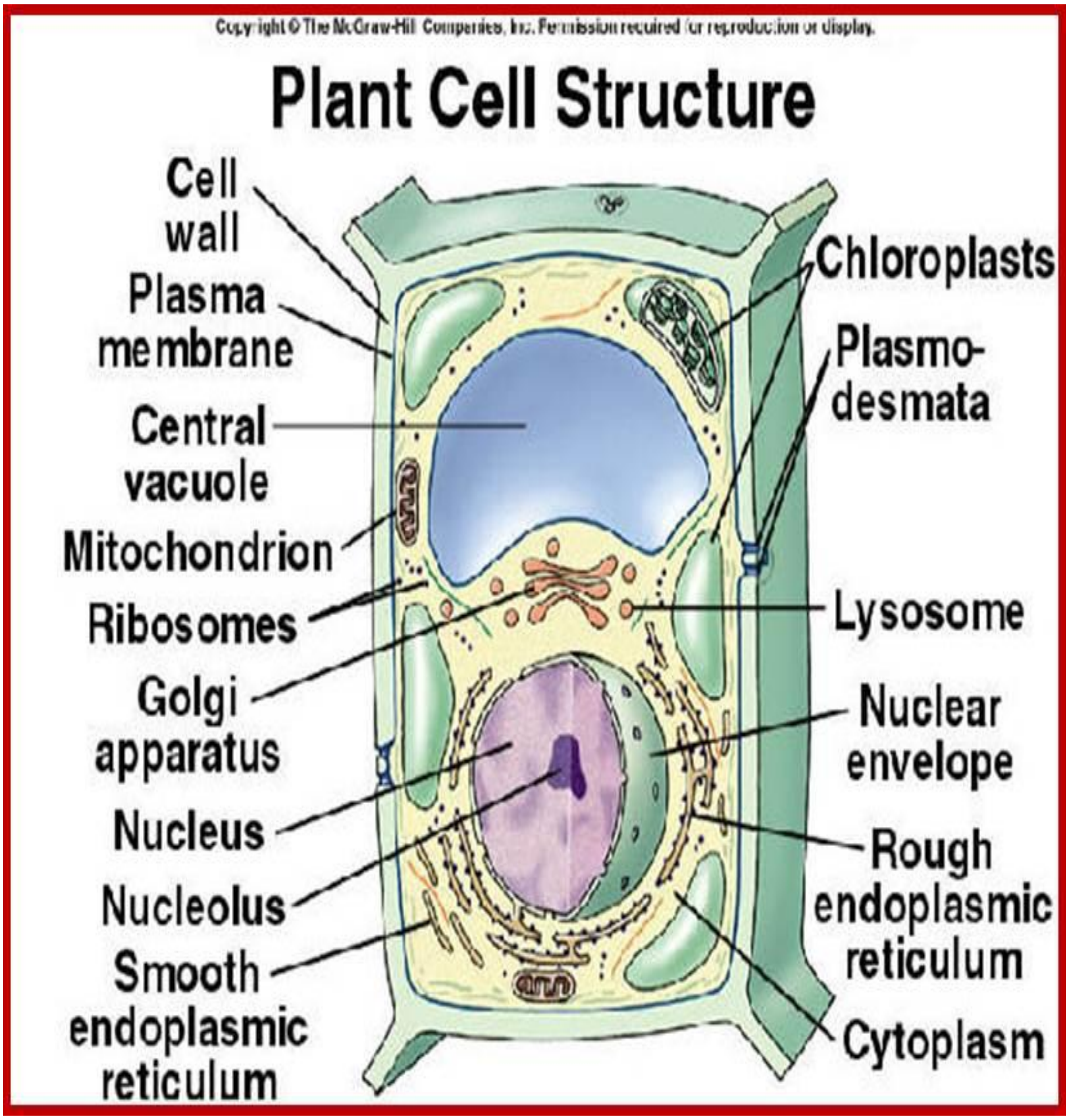
Hooke in 1665, to describe the individual units of the honeycomb-like structure in cork under compound microscope. Plants are multicellular organisms composed of millions of cells with specialized function. All plant cells have the same basic organization of eukaryotes.

The Cell Wall

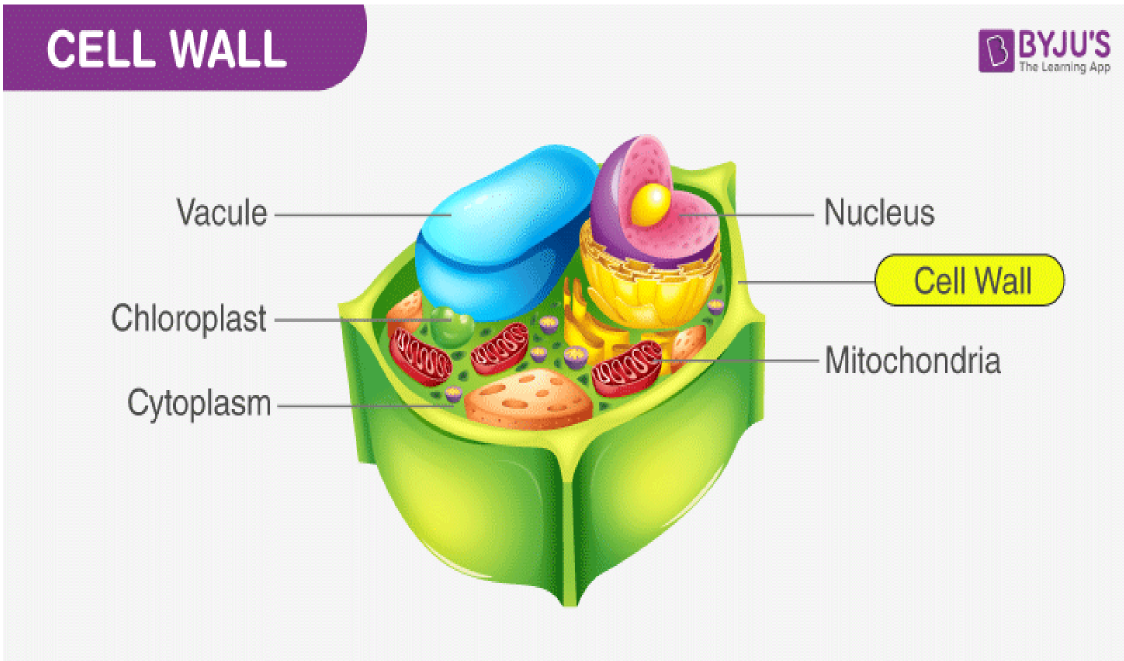
A fundamental difference between plant and animal cells is that the plant cell is surrounded by a rigid cell wall, mostly made of cellulose, hemicellulose, pectin and lignin. Plants have two types of cell walls, primary and secondary. Primary cell walls are thin and characteristic of young, growing cells. Secondary cell walls are thicker and stronger, and they are deposited when most cell enlargement has ended. Secondary cell walls have their strength and rigidity due to lignin; a glue like material. The lignified secondary walls provide the plants the structural reinforcement necessary to grow vertically above the soil. Bryophytes which lack the lignified cell walls are unable to grow more than a few centimeters above the soil. In plants, the neighboring cells are held together by a middle lamella (intercellular layer).

The main functions of the cell wall are:

1. Protecting the cell against physical damage and invading pathogens.
2. Regulates and controls the direction of cell growth.
3. Providing the strength, structural support and maintaining the shape of the cell.
4. Functions as a storage unit by storing carbohydrates for use in plant growth, especially in seeds.
5. It allows entry of smaller molecules through it freely.



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
Plant Cell Structure
Cell wall
Plasma membrane
Central vacuole
Mitochondrion
Ribosomes
Golgi apparatus
Nucleus
Nucleolus
Smooth endoplasmic reticulum
Chloroplasts
Plasmo-desmata
Lysosome
Nuclear envelope
Rough endoplasmic reticulum
Cytoplasm



Plasma Membrane (Plasmalemma)

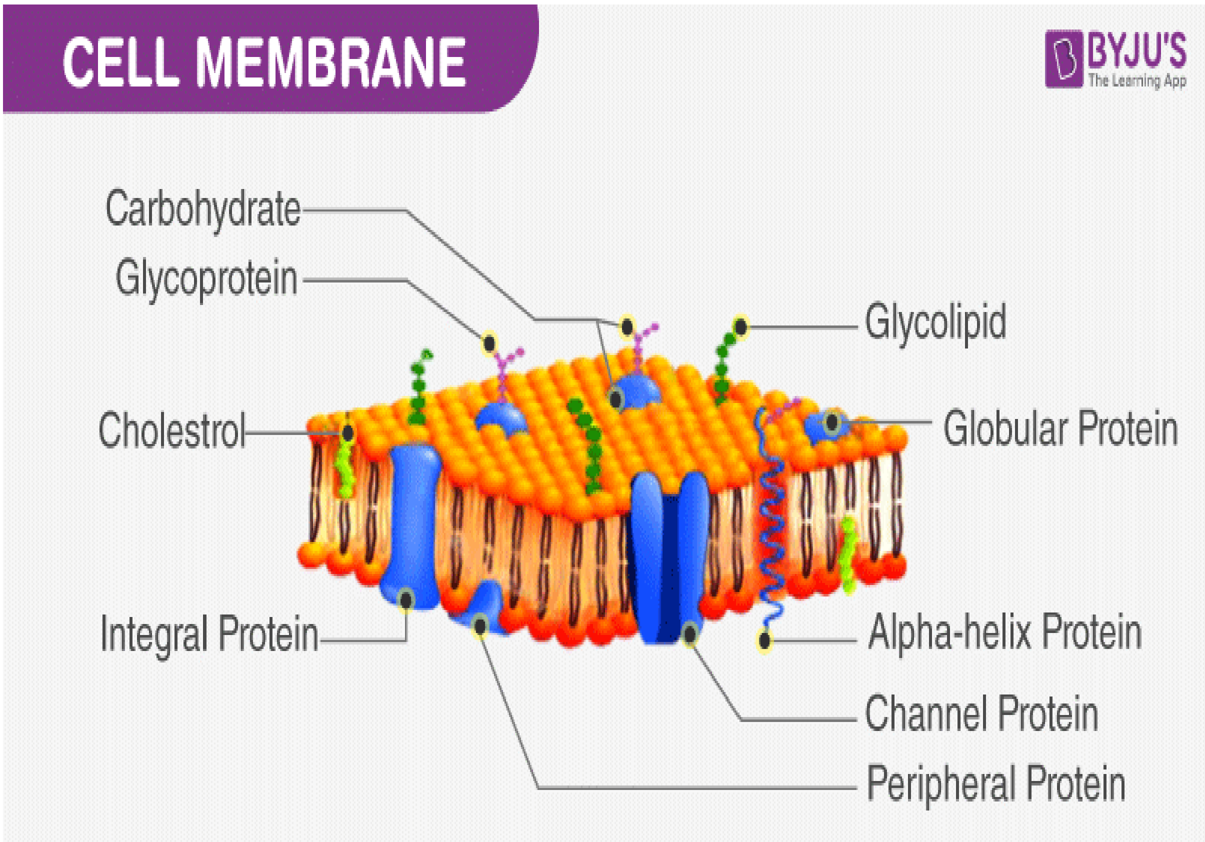
All cells are enclosed in a membrane that works as their outer boundary, separating the cytoplasm from the external environment. This plasma membrane allows the cells to take and retain certain substances while excluding others. Thus, the plasma membrane regulates the selective movement of solutes across the membrane. All biological membranes consist of a double layer (bilayer) of phospholipids in which proteins are embedded. The membrane is not a static structure, but it is a dynamic structure. Both lipid and protein molecules are free to move and are usually in a constant motion. However, these molecules readily move in the plane of membrane, a process known as lateral diffusion.

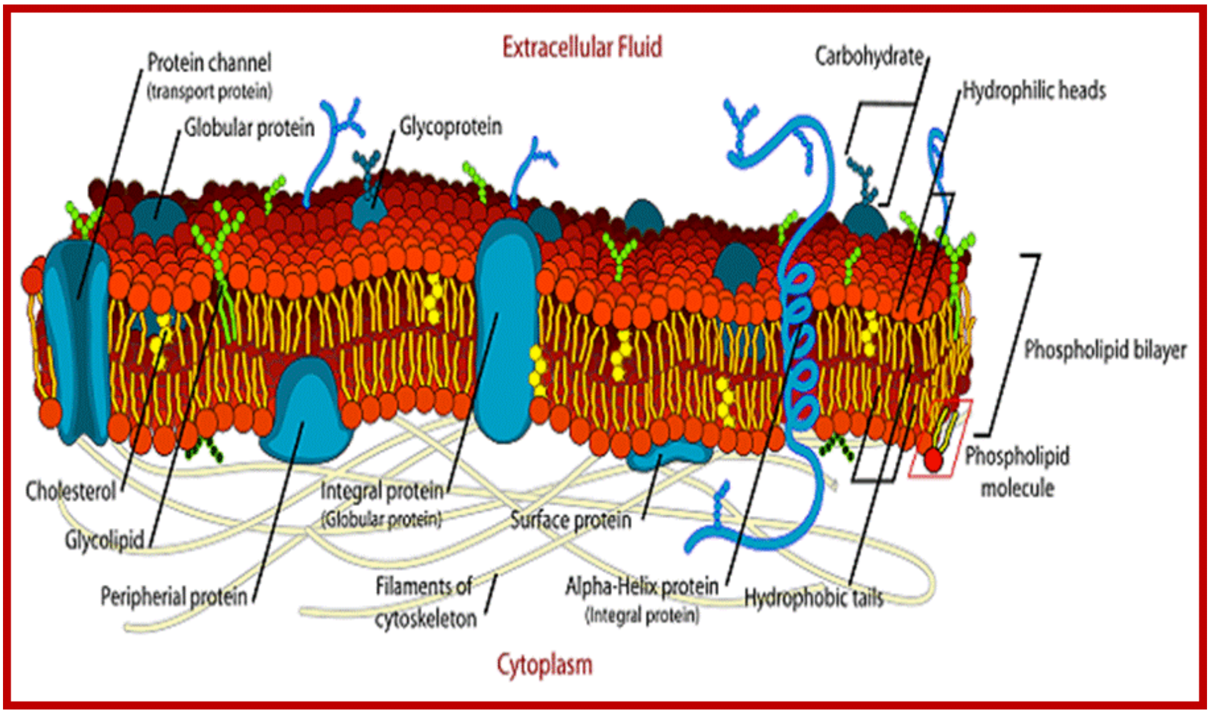
The cell membrane is also known as the plasma membrane. It is a semi-permeable membrane composed of lipids and proteins. The main functions of the cell membrane include:

1. Protecting the integrity of the interior cell.
2. Providing support and maintaining the shape of the cell.
3. Helps in regulating cell growth.
4. The cell membrane also plays an important role in cell signalling and communication.
5. Control of voluntary permeability, that is, it controls the regulation of entry and exit of various substances into cells and

also organelles, meaning that it allows certain compounds to enter and prevents the entry of other substances at a specific time and also allows compounds to leave the cell or enter the vacuole in specific quantities and at different rates according to the degree of their dissolution in Different regions of the membrane according to the needs of the cell. Polar materials such as groups of CHO, NH2, OH, COOH and mineral salts enter the cell slowly, and non-polar compounds such as alcohol and chloroform that dissolve in fat quickly penetrate. The membranes are impermeable to polysaccharides, phospholipids and proteins.

6. Mineral salts are transported across membranes via passive transport, and active transport that requires energy via carriers and protein pumps, while inactive (passive) transport, which is a natural transfer that is subject to physical phenomena, and ions are accumulated opposite the concentration slope without the need for metabolic energy from the cell . passive transport is carried out in the form of ion exchange - Donan equilibrium and others.





CELL WALL	CELL MEMBRANE
Present only in plants and in some fungi, bacteria, algae.	Present in all types of cells, in humans, animals, plants, bacteria, etc.
It is the outermost part of the plant cell	It is the outermost covering the animal cells
It is made up of pectin, chitin, lignin, glycoproteins, glycolipids, sugar, and cellulose.	It is a lipid bilayer. And is composed of lipoproteins and carbohydrates.
The cell wall is 0.1 µm to several µm in thickness	The cell membrane is 7.5–10 nm in thickness
It is the thick and rigid structure with a fixed shape.	It is a thin and delicate structure. It is flexible to change the shape as needed.
It protects the cell from the external environment.	It protects and maintains the internal environment of the cell.
The cell wall is metabolically inactive	The cell membrane is metabolically active.
The cell wall grows in thickness over time.	It is of the same thickness for the lifetime of the organism.
The cell wall is fully permeable to smaller molecules with the size of 30-60 kDa.	The membrane is selectively permeable and controls the movement of the substance into and outside the cell.
The functions it performs include surrounding, protecting, and determining cell shape and breadth	Functions include permeability, signal reception, motility conduction, cell division, etc.

Nucleus

A living cell contains a spherical or lenticular body known as a nucleus and is immersed in the cytoplasm and is composed of the nuclear membrane, the nucleoplasm and the chromosomes. It also contains one or more nucleolus, and the chromosomes are the main component of the nucleus and the nucleus is a repository in which chromosomes are kept and take the form of a network of fine strings and are composed chemically from nucleoproteins, which consist of DNA, which is also found little other nucleic acid known as RNA and chromosomes carry the genes that control all the cell's vital processes. The chromosomes appear clearly during cell division and the number of chromosomes is constant and distinct for each type of plant .

As for the nucleolus, it is usually spherical in shape and consists largely of nuclear proteins that contain RNA. Its importance is due to the fact that it plays an important role in controlling the representation of protein materials in the cell, and some types of cells contain different numbers of nucleolus.

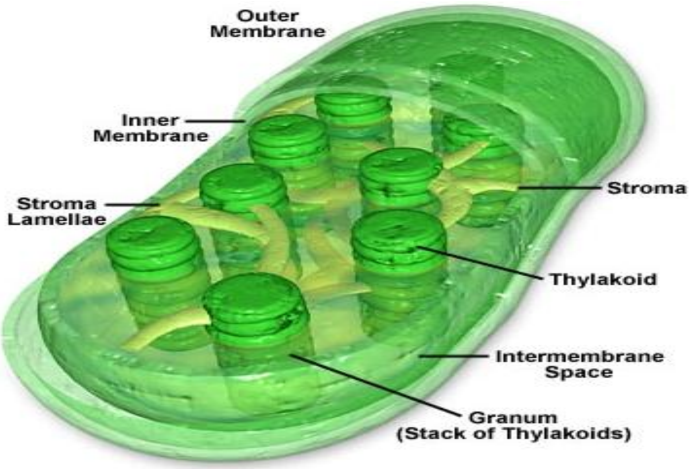
The nucleus is separated from the surrounding cytoplasm by a nuclear membrane composed of proteins and fatty materials, and this membrane controls the passage of materials between the cytoplasm and the nucleus. The nucleus is considered due to the presence of the genes that are the center from which the vital processes that are carried out in the cytoplasm are directed, and there is a close connection between the nucleus and the cytoplasm as neither of them can live without the other, the nucleus is the most important part of the cell because it controls the vital functions of the cell, so it is always present in the growing apex cells with continuous activity.

Plastids

They are protoplasmic bodies found immersed in the cytoplasm. They are in higher plants, small in size, of regular shape, and perform important functions. There are three types of plastids.

A- Chloroplast

It is usually found in living cells exposed to light in leaves and stems and is the repository of the green pigment known as chlorophyll on which plants depend for their photosynthetic function. Green plastids are usually larger and more complex in shape in primary plants such as algae than in higher plants. In chlamydomonas, which is a single-celled green algae, there is one large plastid that occupies most of the cell space and takes the form of a hollow cup in which the nucleus settles.



chloroplast

As for higher plants, the plastids are small in size, many in number, simple in shape, resembling convex lenses. The pigments contained in the green plastids are chlorophyll pigments, which are of the most important types (chlorophyll a and chlorophyll b), as well as xanthophylls and carotene. Using the electron microscope, it was possible to detect the micro-structures of the chloroplasts, and it was found that each plastid in vascular plants is composed of a double membrane containing fine grains known as the stroma. It is closed on both sides.

2- Chromoplast

They are bodies of different shapes and their colors vary between yellow, red and orange. The color is mainly attributed to the two pigments of xanthophyll and carotene. Colored plastids are found in the roots of some plants, such as carrots and petals of some flowers.

3- Leucoplasts

They are found in plant parts far from light, such as the ground organs, for example they are found in tubers as they convert the dissolved sugars into insoluble starch grains suitable for storage, and the storage starch grains begin to form inside the colorless plastids and then these grains gradually enlarge until the plastids are completely filled with them. The wall of the plastid expands to accommodate the increase in particles. Leucoplasts are small in size from which starchy and oily plastids are found.

Endoplasmic reticulum

The endoplasmic reticulum is composed of double membranes, between which there is a vacuum, which makes it transparent under an electron microscope. These membranes are highly branched and this reticulum connects between the nuclear membrane and other membranes surrounding the cytoplasm, and it plays an important role in building protein materials. The cavity that permeates its membranes also helps in the transfer of prepared proteins between parts of the cell, especially from the cytoplasm to the nucleus and plasma membranes. The endoplasmic reticulum may have a smooth surface. or may contain fine granules known as ribosomes.

Ribosomes

Ribosomes are very fine granules that can only be seen with an electron microscope and are found connected to the endoplasmic reticulum and dispersed in the cytoplasm and inside some of the cell's organs, especially plastids and mitochondria, but they are not found in the nucleus. Ribosomes are the main centers for building proteins in a cell.

Mitochondria

They are found in all plant and animal cells in general and are in the form of a short stick or fine filaments ranging in length between 0.5 - 2 microns. In which the respiration process takes place.

Golgi apparatus (bodies)

It was named after its discoverer and it was previously believed to be present in the animal cell only, but using an electron microscope was able to see it in the plant cell and it is believed that its function is related to cell secretions as it is linked to the formation of hormones and enzymes in the animal cell and it forms molecules of complex substances in some plant cells such as the formation of calcium pectate secreted by the cells of the root cap.

Central Vacuole

Mature plant cells contain large, water-filled central vacuole (usually one or two). Central vacuole can occupy 80-90 % of the total volume of cell. Each vacuole is surrounded by a vacuolar membrane or tonoplast. The vacuole contains water, inorganic ions, organic acids, sugars and enzymes. Like animal lysosomes, plant vacuoles contain hydrolytic enzymes including proteases, ribonuleases and glycosidases. Vacuole has storage function as well as to provide rigidity to plant cell.

Microbodies

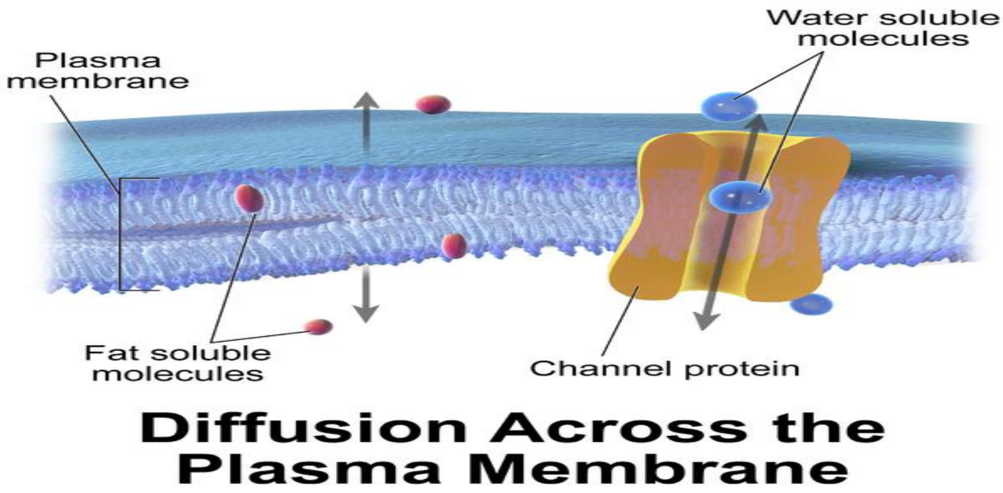
Plant cells also contain microbodies, which are spherical organelles surrounded by a single membrane. The two main microbodies are peroxisomes and glyoxysomes. Peroxisomes are present in photosynthetic cells of plant leaf. Their function is the removal of potentially toxic hydrogen peroxide (H_2O_2) using the enzyme catalase.

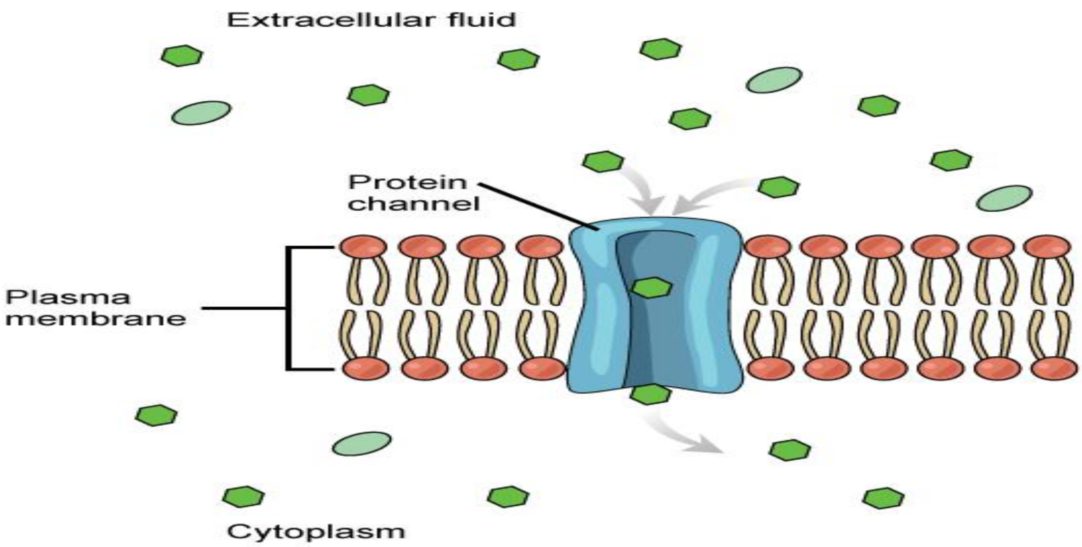
$$H_2O_2 \xrightarrow{\text{Catalase}} H_2O + \frac{1}{2} O_2$$

Glyoxysomes are present in oil-storing seeds. They can convert stored fatty acids into sugars that can be translocated in the plant to provide energy for growth.

Transport process in plasma membranes

The primary function of the cell membrane is to allow the movement of essential compounds needed by the cell and their passage into the cell. There are four ways to do this.





1.Free or simple diffusion

Low molecular weight nutrients are able to penetrate into the cell and this process depends on the concentration of the substance (concentration gradient) on both sides of the membrane as the material is directed from the upper concentration of environment to the lower concentration and this type of diffusion does not show any specialization of stereospecificity, for example amino acids of type D and L penetrate across the membrane at the same speed, and it is not believed that this type has an important role in transporting the materials that the cell needs for its various activities across the membrane, because of the slowness of this type of diffusion and the absence of any kind of selection that regulates the passage of different materials through the membrane.

2. Facilitated diffusion

This diffusion is somewhat similar to simple or free penetration (diffusion) in that the concentrations of the substances that pass the membrane must differ on both sides and this penetration process does not need to expend any energy. As for the points of difference of the facilitated diffusion from the free or simple one, it is

1. The presence of a special protein called a carrier or permease that helps and speeds up in process
2. The presence of specialization of stereospecificity in this type of diffusion, that is, it differentiates between D and L amino acids.

The mechanism of facilitated diffusion is that the above-mentioned special protein present in the membrane forms a complex compound with the substance that will penetrate into the cell. After that, this substance is separated from the complex compound and penetrated into the cell. The carrier is specialized in transporting certain substances, and many of these specialized proteins have been separated, such as lactose, glucose, arginine, tyrosine, and others.

3.Active transport

This process is similar to facilitated diffusion, except that the substance that passes through the cell membrane passes from a low concentration environment to a high concentration environment. Accordingly, this process requires energy consumption and it was found that some cells spend more than 50% of the ATP present in them to carry out the accumulation process of the amino acid called *glycine* inside it.

4.Group translocation

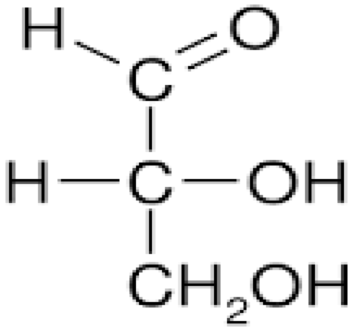
This method has been suggested to penetrate glucose through the cell membrane by converting glucose into glucose-6-phosphate, so that this phosphorylated glucose cannot reverse penetration out of the cell, and this process requires a special protein that contains histidine.

Carbohydrates

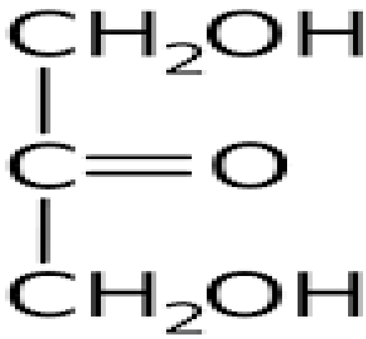
Carbohydrates have four important functions for an organism

1. An energy source .
2. Source of carbon atoms for the synthesis of other cell components
3. A major store for chemical energy
4. Carbohydrates have structural functions for cells and tissues, as sugars enter the structure of the plant cell wall in the form of cellulose. Also, sugars or carbohydrates participate in the formation of a complex compound which is the main component of the bacterial cell wall.

Carbohydrates are known as aldehydes or ketones that contain a number of hydroxyl groups or their derivatives. This definition also includes every compound that produces these substances upon its dissolution. In general, carbohydrates are white solids that are less soluble in organic solvents, but they dissolve in water except for some polysaccharides. The simplest sugars in nature are glyceraldehyde and dihydroxyacetone, each containing three carbons. Carbohydrates are denoted by the symbol (CH2O)n , and the value of n is equal to the number 3 or more



glyceraldehyde



dihydroxyacetone

Classification of carbohydrates

Carbohydrates are classified as follows:

1. Monosaccharides

They are compounds that cannot be analyzed into a simpler form, as they are also called simple sugars such as glucose and fructose

2. Oligosaccharides

They are compounds that contain a number of monosaccharides ranging from 2-10 and can be classified into parts depending on what they contain from monosaccharides molecules. Compounds that contain two molecules of monosaccharides are called disaccharides such as sucrose and are called trisaccharides if they contain three molecules of monosaccharides.

3. Polysaccharides

They are compounds that contain more than 10 molecules of monosaccharides such as starch and cellulose.

Sugars can be classified into two main groups depending on their reductive capacity, as they are either reducing sugars such as glucose, fructose and maltose, or non-reducing sugars such as sucrose, cellulose and glycogen.

Naming of monosaccharides

Monosaccharides are classified according to the number of carbon atoms they contain, as follows

A. Triose, meaning a monosaccharide containing three carbon atoms

B. Tetrose, meaning a monosaccharide containing four carbon atoms

C. Pentose, meaning a monosaccharide containing five carbon atoms

D. Hexose, which means a monosaccharide containing six carbon atoms

E. Heptose, which means a monosaccharide containing seven carbon atoms.

The suffix -ose means that this compound is a carbohydrate, however, there is another way to classify the monosaccharides depending on the carbonyl group that they contain. If it is aldehyde, the compound is called aldose, and if it is a ketone, it is called ketose.

However, the two methods are considered deficient, as the first classification does not include the fact that the compound is an aldehyde or a ketone, and there is no indication in the second classification to the number of carbon atoms in the compound, so the two classifications are combined in another arrangement that includes the nature of the compound and the number of carbon atoms in it. The compound aldopentose, for example, means that it is an aldehyde and contains 5 carbon atoms, while the term ketohexose means that the compound is ketone and contains 6 carbon atoms.

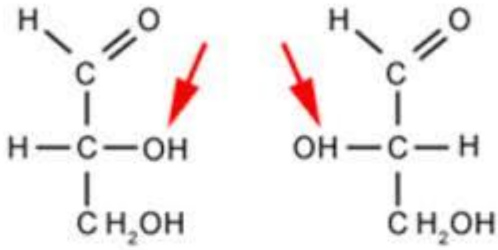
Stereoisomers

Chemically the element carbon is known as tetravalent, which means that each carbon atom is joined to neighboring atoms by four bonds. If all of are these are single bonds then they are arranged around the carbon atom in a three-dimensional tetrahedral shape. But if one particular carbon atom is joined to four atoms or groups which are themselves different: it becomes possible to arrange the surrounding atoms or groups in either of two different ways. On paper they look similar but in biological terms they may be quite different. Take for example the simplest of the aldehyde sugars, glyceraldehyde.

Many monosaccharides contain the same number of carbon, hydrogen and oxygen atoms, and the same groups, whether hydroxyl or carbonyl groups, but they differ in many characteristics. The general formula, C6H12O6, for example, represents 16 different types of simple sugars despite containing the same general formula

CH2OH.CHOH. CHOH. CHOH. CHOH. CH2OH

This could be explained based on the difference that occurred as a result of the arrangement of these groups in a vacuum. The isomers unite depending on the number of asymmetric carbon atoms in the compound. Since the glucose sugar contains four asymmetric atoms, the total number of its isomers equals 16 according to the formula $S= 2^n$ and thus = 16 .The presence of many isomers in carbohydrates necessitates finding a standard compound that can be relied upon in dividing compounds into two types of isomers. Therefore, glyceraldehyde was considered the simplest carbohydrate compound to classify compounds as (D) Dextro or (L) Levo. It was termed according to that is to give the letter D for the compound in which the hydroxyl group OH attached to the carbon atom adjacent to the primary alcohol group CH2OH is to the right, while the letter L is written for the compounds that have the same hydroxyl group OH to the left.



D-Glyceraldehyde L -Glyceraldehyde

In addition to the previous effect of asymmetric carbon atoms, the compound that contains this type of atoms is photoactive, as the phenomenon of optical rotation that is caused by asymmetric carbon atoms can be observed when a beam of polarized light is directed on a solution of carbohydrates by a special device to measure the degree of optical rotation called polarimeter, so the substance that deflects light to the right is called dextrorotatory (right rotation) and gives a positive + sign, while the substance that deflects light to the left is called levorotatory (left rotation) and gives a negative sign - the property of optical rotation does not depend on whether the compound is of the D or L group. Rather, it is a property enjoyed by the compound itself.

Haworth method (projection)

is a common way of writing a structural formula to represent the cyclic structure of monosaccharides with a simple three-dimensional perspective.

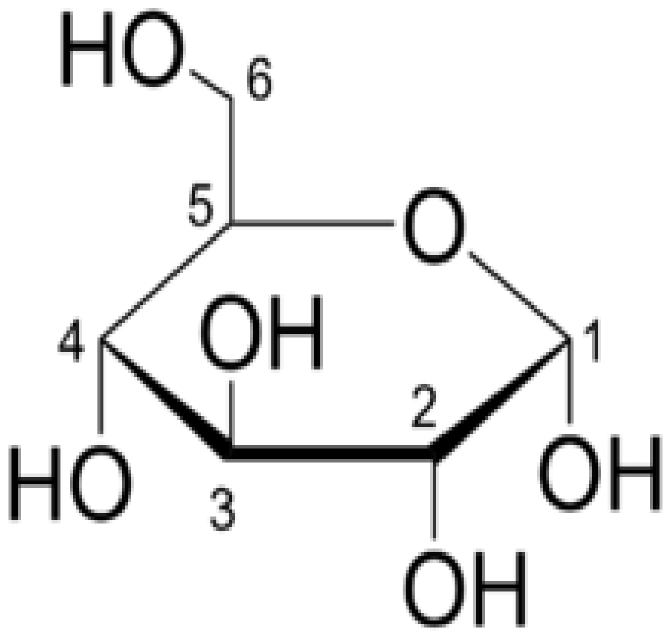
It was renamed the method in the name of the English researcher Haworth

Haworth method has the following characteristics:

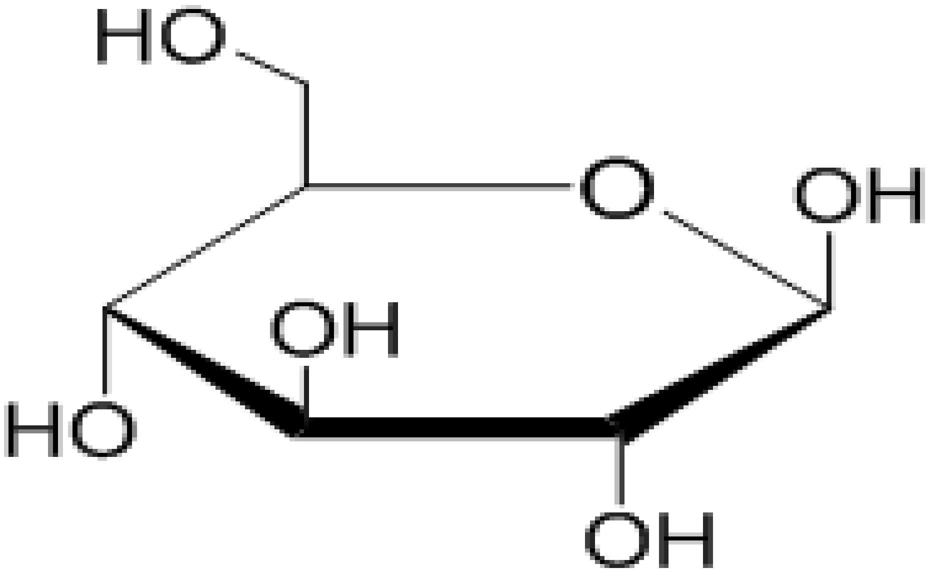
1. The carbon atom is implicit. As in the example, the atoms numbered 1 to 6 are all carbon atoms.

2. Hydrogen atoms are implicit. In the example, atoms 1 to 6 have hydrogen atoms on them.

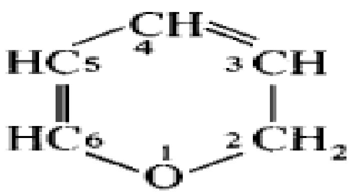
3. The thick line represents the atoms close to the viewer. In the example on the right, atoms 2, 3 and their OH groups are closest to the viewer, while atoms 1 and 4 are farther from the viewer, and finally the remaining atoms are farthest.



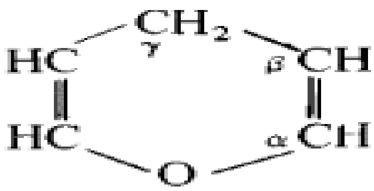
Howarth proposed the name pyranose to sugars in which the oxygen atom is bound to 5 carbon atoms, based on the general structure of the pyran molecule, while the name furanose is given to sugars in which the oxygen atom binds to 4 carbon atoms depending on the furan molecule.



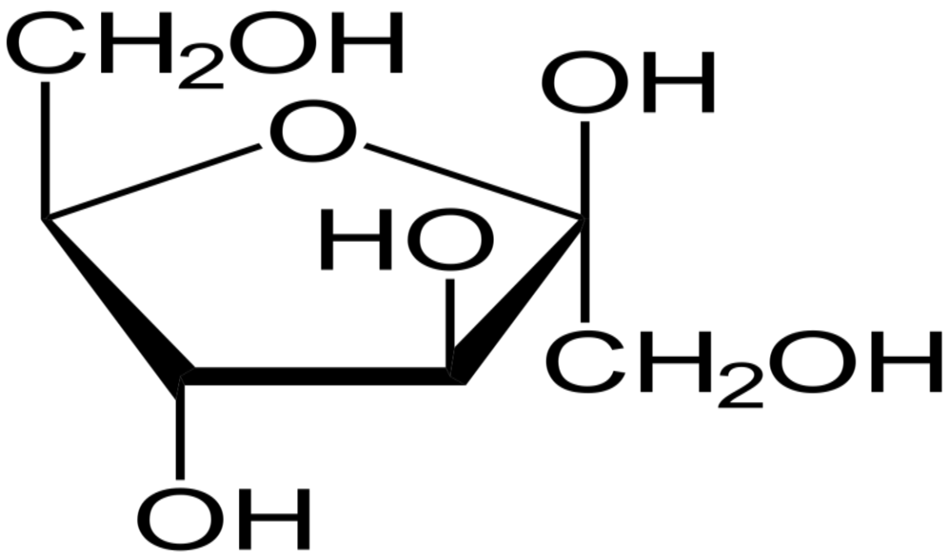
pyranose structure



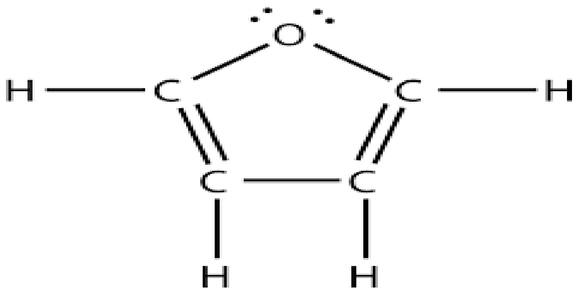
α-Pyran



γ-Pyran



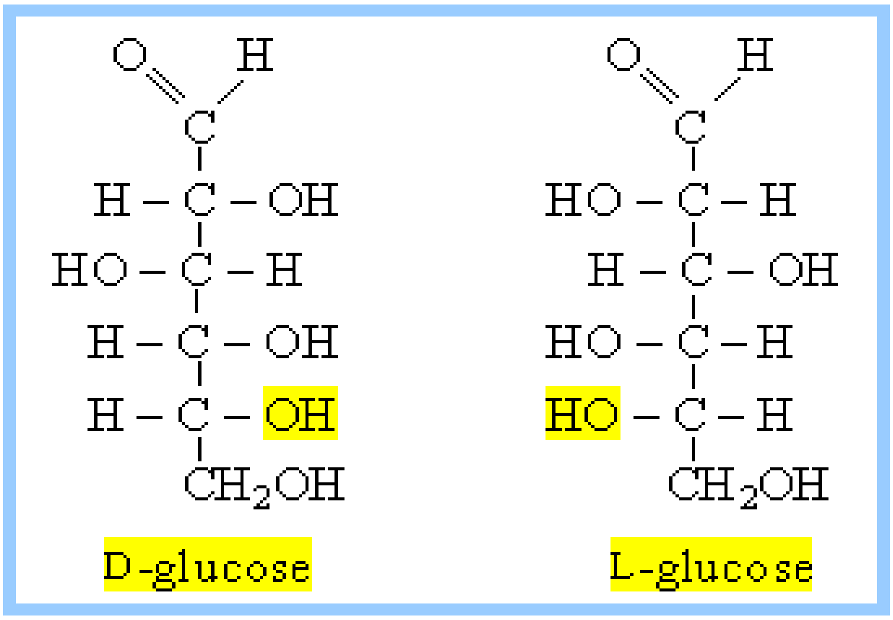
furanose structure

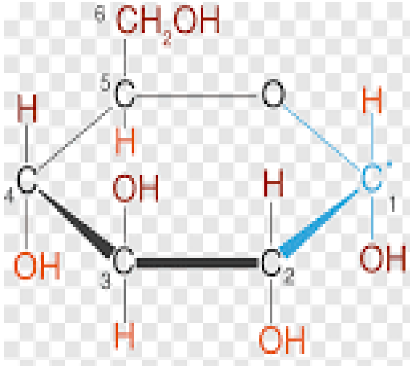


furan

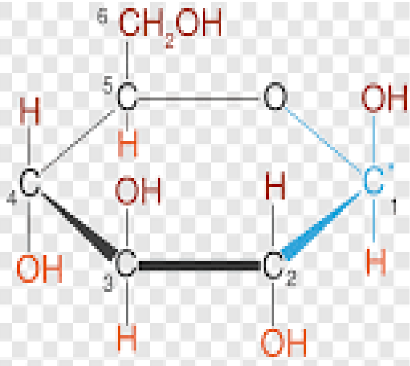
GLUCOSE & FRUCTOSE

Glucose and fructose are monosaccharides and sucrose is a disaccharide of the two combined. Glucose and fructose have the same molecular formula ($C_6H_{12}O_6$) but glucose has a six member ring and fructose has a five member ring structure. Fructose is known as the fruit sugar as its make source in the diet is fruits and vegetables. Honey is also a good source. Glucose is known as grape sugar, blood sugar or corn sugar. Listed in food ingredients as dextrose. Fructose is more soluble than other sugars and hard to crystallize because it is more hygroscopic and holds onto water stronger than the others. The formation of the ring in glucose links together carbons 1 and 5 of glucose through the atom of oxygen and in doing so makes carbon 1 asymmetric. The two different compounds are denoted as α - and β-glucose. In the straight-chain form of glucose, carbon 1 is not asymmetric because it has two of its bonds attached by a double bond to an atom of oxygen. In ring-shaped glucose, this carbon is effectively joined to four different groups. The important difference to notice is that for α -glucose we draw the hydroxyl group on carbon 1 as pointing downwards, whereas in the β form it points up. These two versions of glucose are actually quite different compounds which do not even have the same melting point.

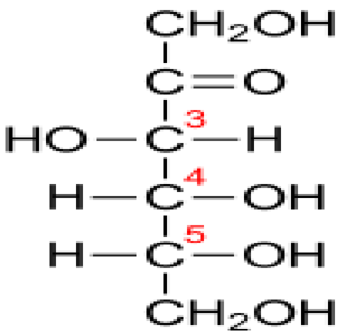




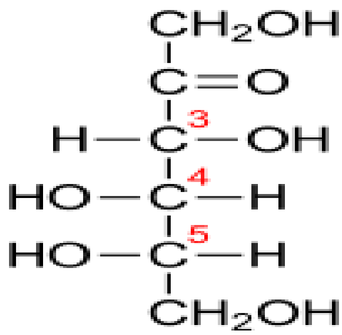
α-D-Glucose



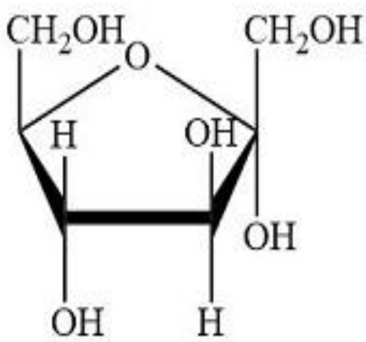
β-D-Glucose



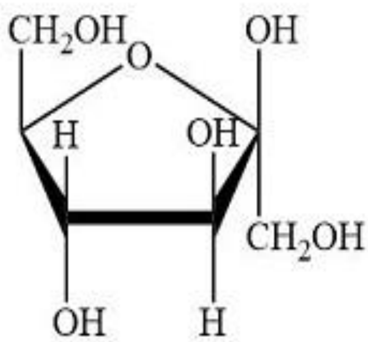
D-Fructose



L-Fructose



α-D-Fructose

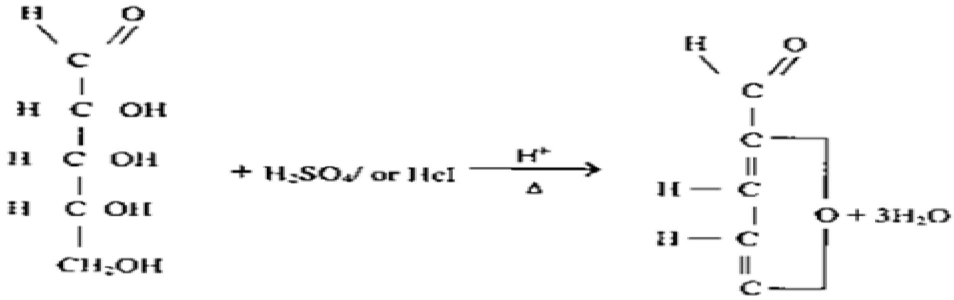


β-D-Fructose

Reactions of monosaccharides:

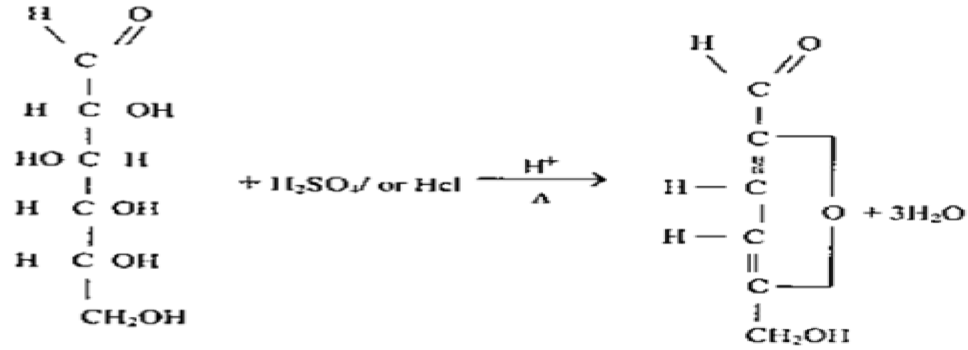
1 - Reaction with hydrochloric or sulfuric acid:

Pentose and hexose react when heated with the concentrated acids and lose three molecules of water to give the compound furfural in the case of pentose, and 5-hydroxymethylforfural compound in the case of hexose, which is converted by further heating to levulinic acid and formic acid.



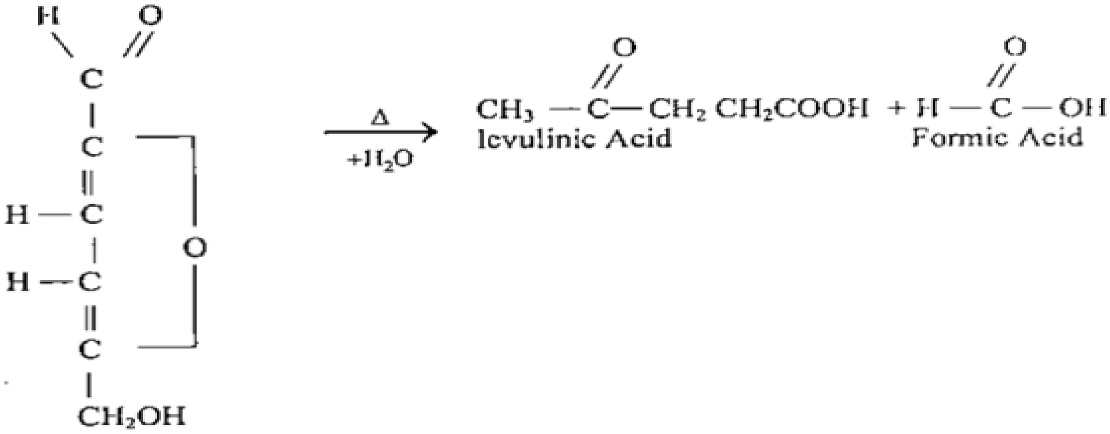
D - Ribose

FurFural



D - Glucose

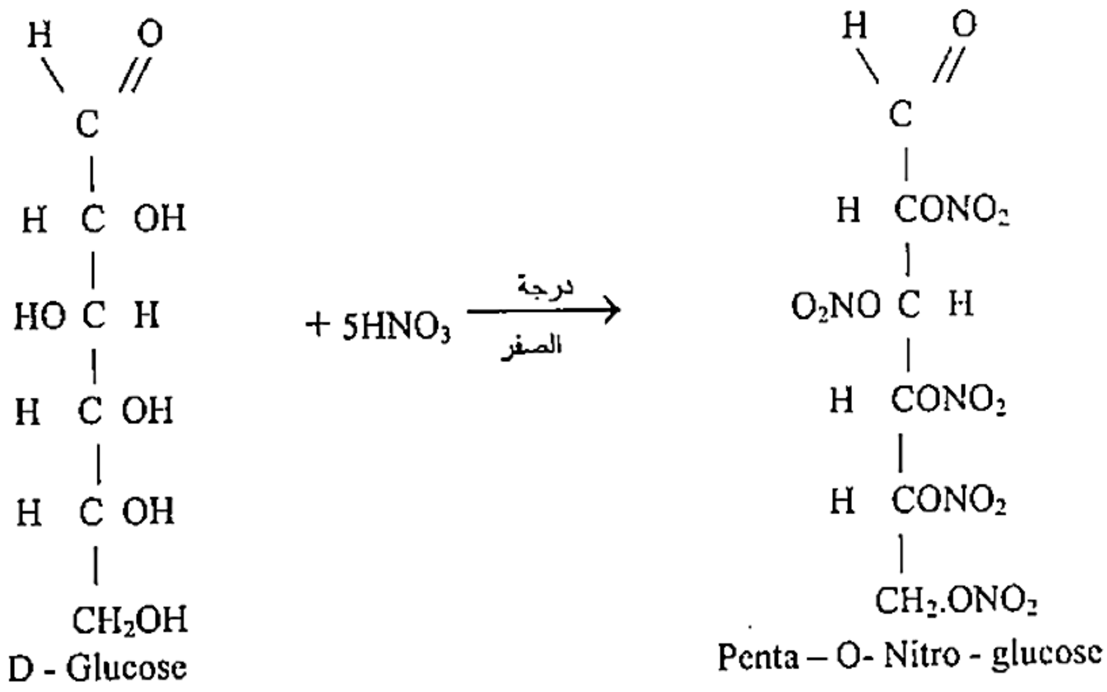
5 – Hydroxy



5 – Hydroxy methyl furfural

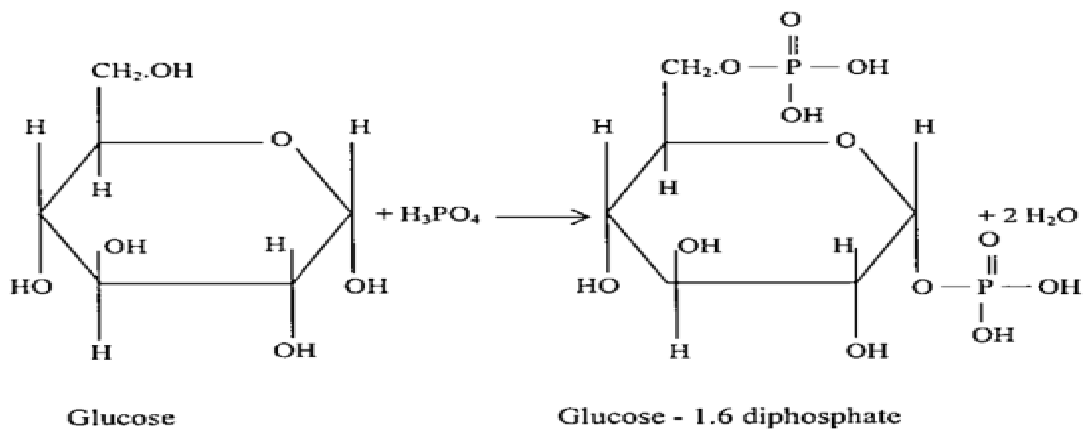
2 - Reaction with nitric acid:

Monosaccharides react with nitric acid at 0 ° C to give glucose pentanitrate with molecular formula $C_6H_7N_5O_{16}$



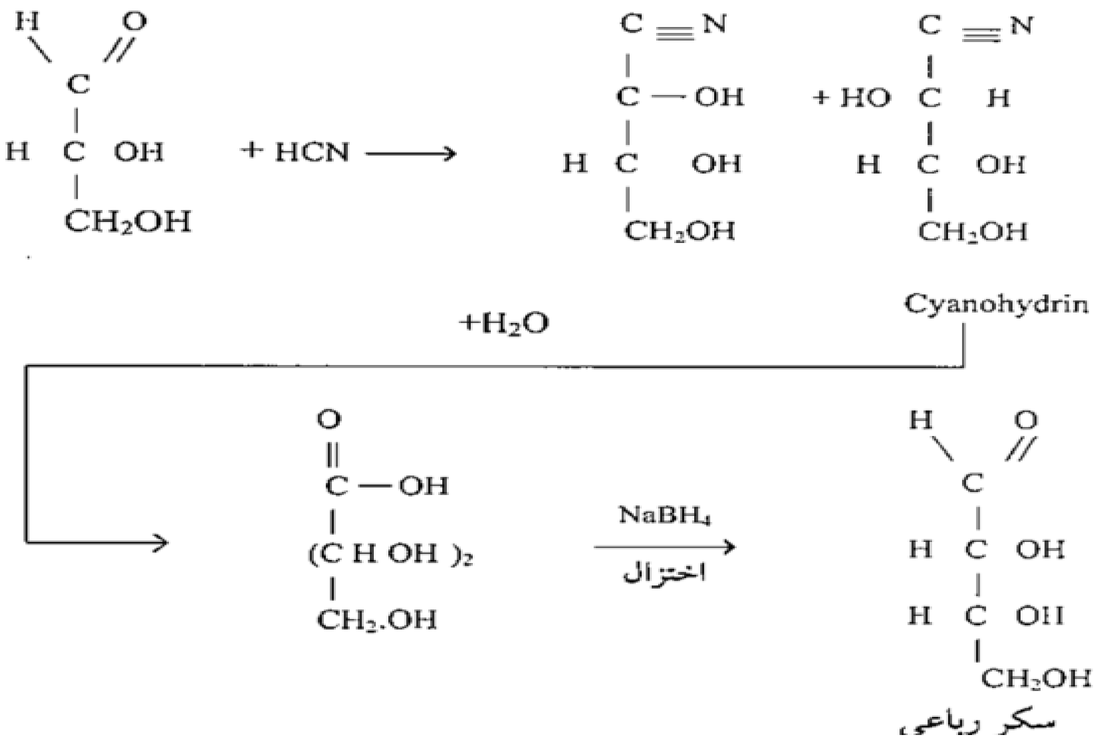
3 - Reaction with phosphoric acid:

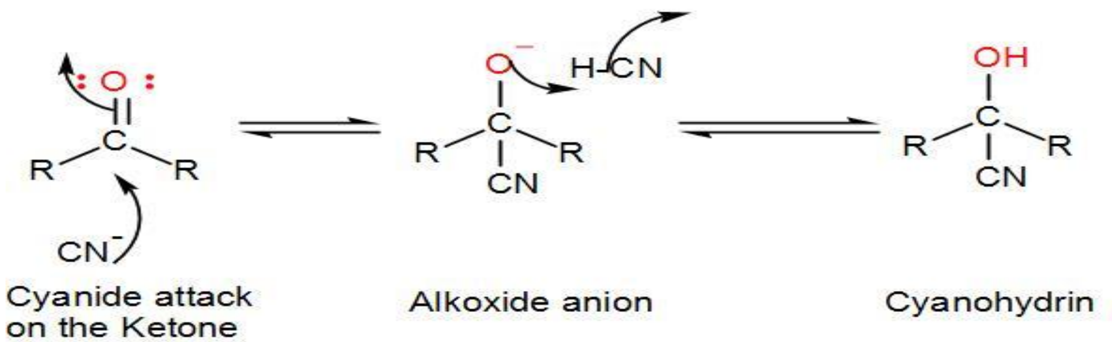
Pentose and hexose react with one, two or three molecules of phosphoric acid to produce phosphoric acid esters, which are vitally important compounds because they are liberated upon the dissolution of nucleic acids by the influence of some enzymes, and they are also necessary compounds to start the metabolism of sugary compounds.

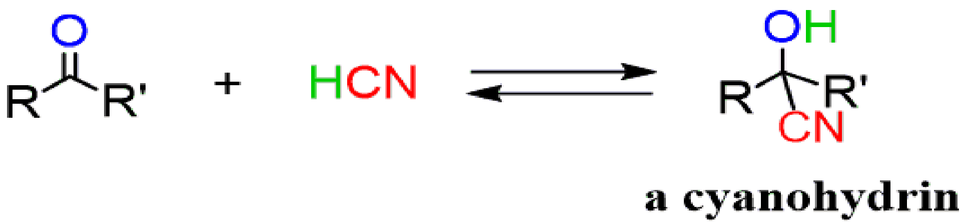


4 - reaction with hydrocyanic acid:

Aldose react with hydrocyanic acid (HCN) through the aldehyde group. As a result, an additional asymmetric carbon atom is created, giving the potential to produce two different sugary compounds. This method has been used to produce many sugars, as it is possible to produce tetrose from triose and pentose from tetrose, and so on, as shown in the following reactions:





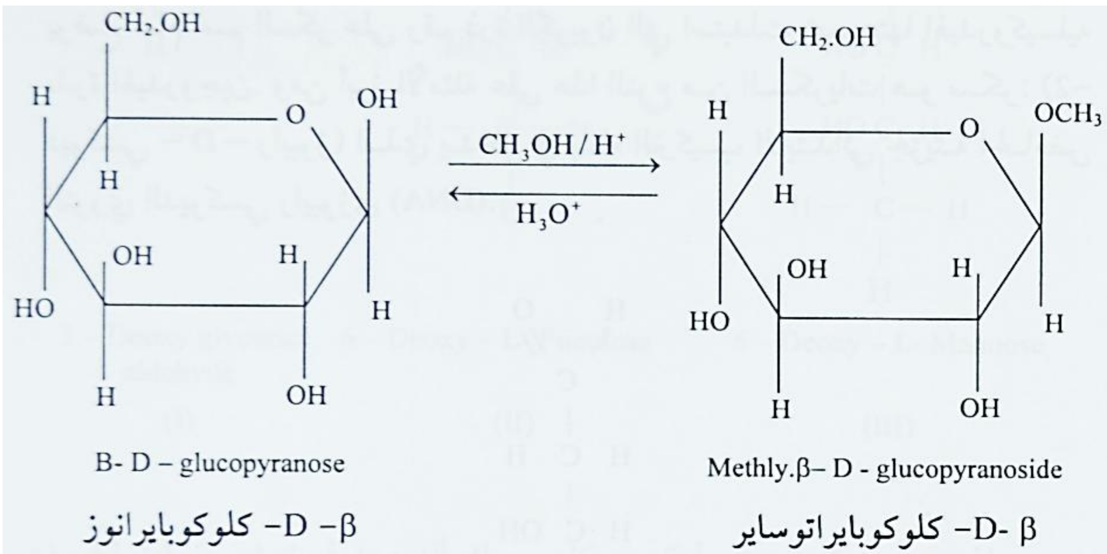


The cyanohydrin from aldose reaction are non-toxic. Therefore, these reactions have major medical benefits in the treatment of cyanide poisoning.

5- Reaction of monosaccharides with alcohols:

When treating monosaccharides with alcoholic compounds in the presence of hydrochloric acid as an auxiliary agent, we obtain compounds called glycosides, which are distinguished by their constant cyclic shape in water, which may be formed in the form of furanose or pyranose, where they can exist in an alpha or beta . The stability of the ring shape of these compounds in the water leads to the disappearance of the phenomenon of the optical rotation in it. In addition, they are considered non-reducing sugar derivatives.

The glycosides are widely distributed in nature, and many of them have various medicinal benefits for treating many diseases and other biological effects.

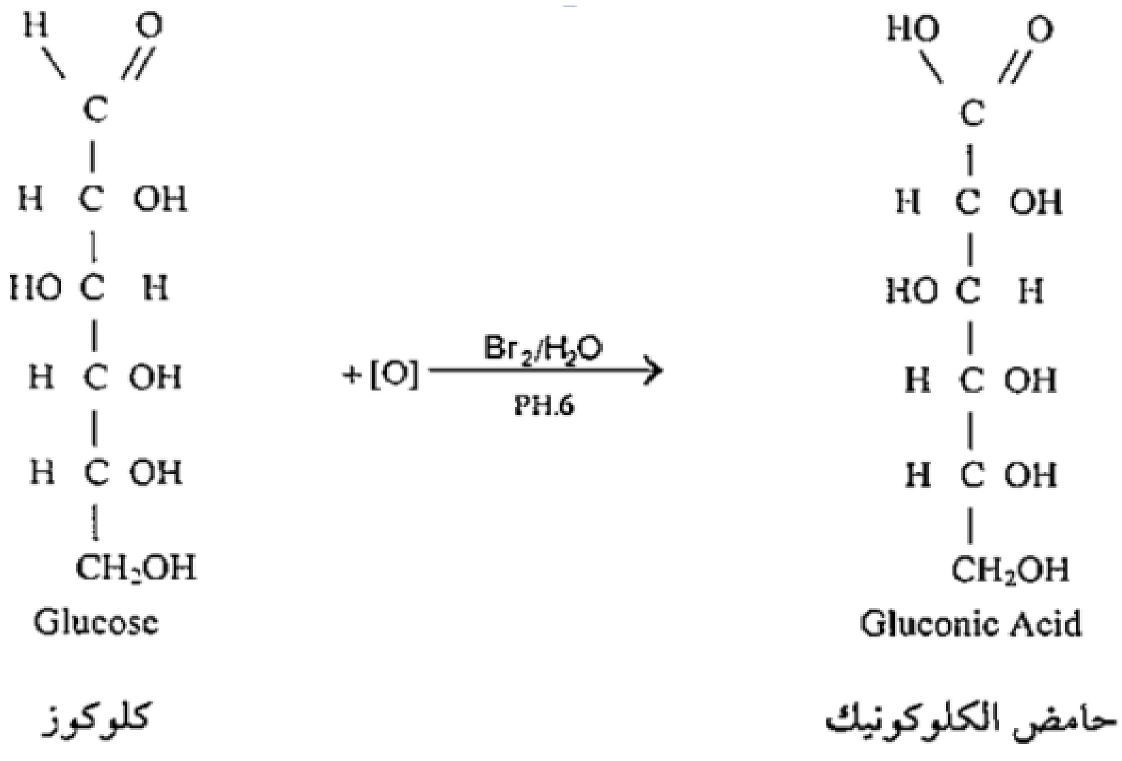


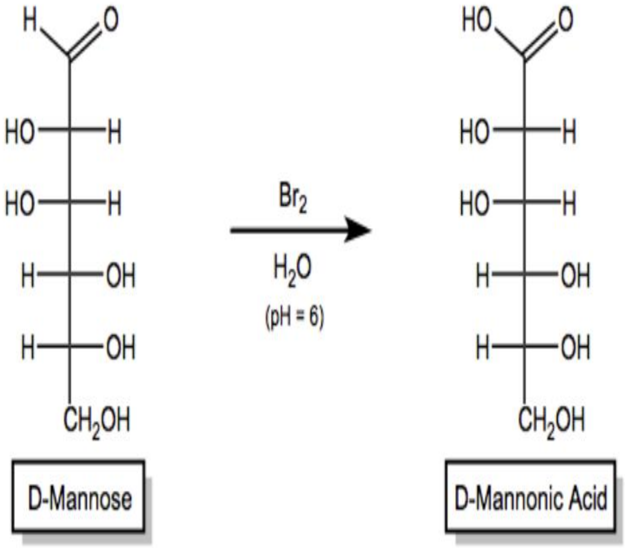
6. Monosaccharides oxidation

Monosaccharides, especially aldose sugars, are oxidized under special conditions to produce acids with one or two carboxyl groups, or we may obtain a sugary acid that, in addition to the carboxyl group, contains an aldehyde group that is through the following different oxidation methods:

A - oxidation by bromine water:

The aldose can be oxidized by using bromine water when the pH is adjusted with an appropriate buffer solution at (6.0) into monocarboxylic aldonic acids, where the aldehyde group is converted by the action of bromine water to a carboxyl group. The effect of bromine water is limited to aldose sugars as it has no effect on ketose sugars such as fructose, so this reaction can be used to distinguish between aldose and ketose sugars

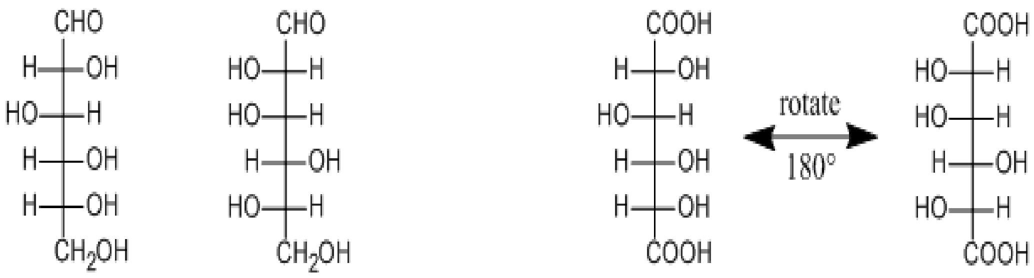




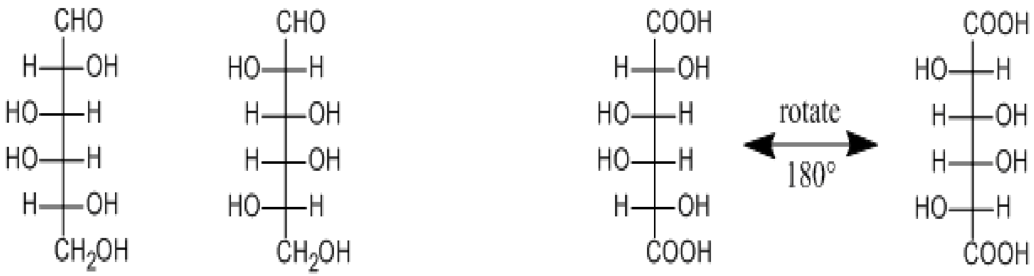
B - oxidation by concentrated nitric acid:

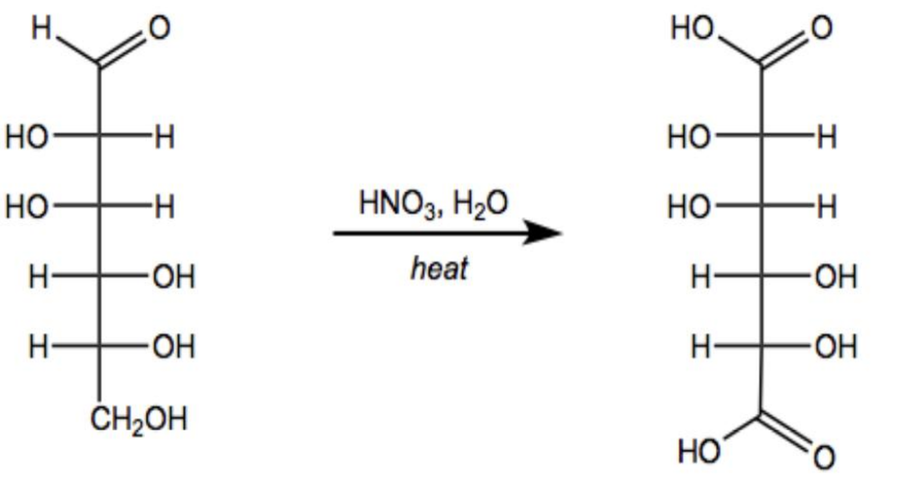
The other method of oxidation of aldose sugars is by using concentrated nitric acid under suitable conditions to convert the sugary aldehyde group and the primary hydroxyl group (on the carbon 6 atom) into carboxyl groups to produce dibasic sugar acids known under the name Aldaric or Saccharic acid, depending on sugar used by oxidation, by replacing the suffix (ose) of the sugar name with the suffix (aric), and this nomenclature is preferred over the one using the term (Saccharic). Here are some types of dibasic sugar acids:

D-glucose L-gulose D-glucaric acid is the same as "L-gularic acid"



D-galactose L-galactose D-galactaric acid is the same as "L-galactaric acid"



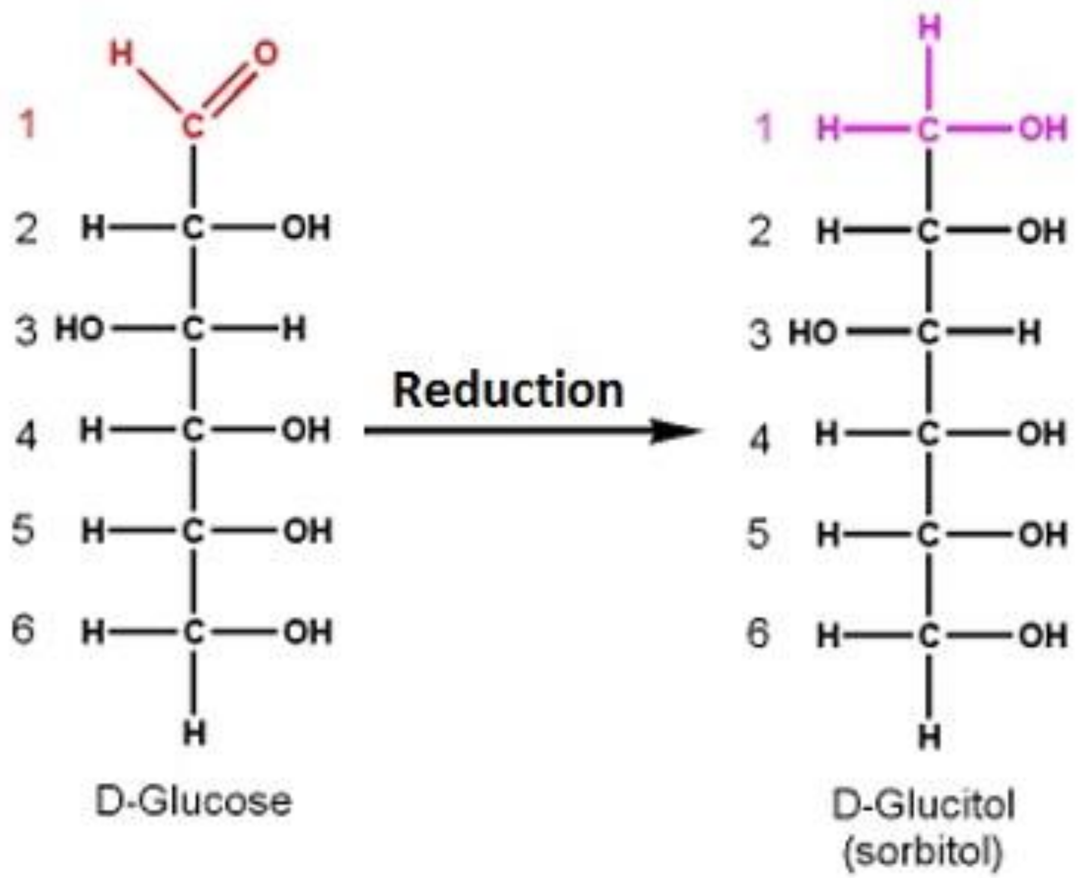


D-Mannose D-Mannaric Acid

7. Reduction of monosaccharides

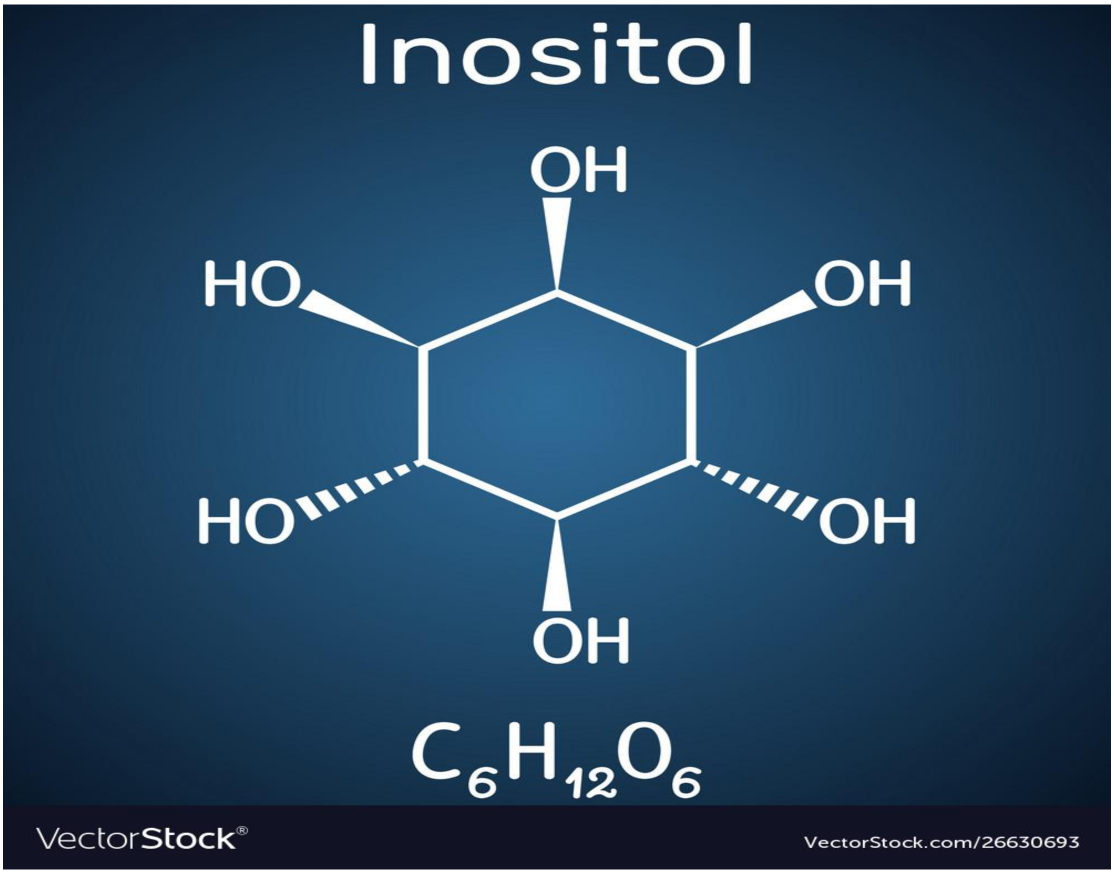
When treating monosaccharides, whether containing an aldehyde group or a ketone group with hydrogen gas, with the presence of cofactors such as sodium borohydride, or with the influence of some enzymes, we obtain polyhydric alcohol. When reducing the glucose sugar, for example, we get the polyhydric alcohol known Sorbitol that

less commonly known as glucitol is a sugar alcohol with a sweet taste which the human body metabolizes slowly. It can be obtained by reduction of glucose, which changes the converted aldehyde group (−CHO) to a primary alcohol group (−CH2OH). Most sorbitol is made from potato starch, but it is also found in nature, for example in apples, pears, peaches, cranberry and is used as a substitute for sugar in many types of processed and pre-packaged foods. It is converted to fructose by sorbitol-6-phosphate 2-dehydrogenase. Sorbitol is an isomer of mannitol, another sugar alcohol; the two differ in the orientation of the hydroxyl group on carbon 2 and the two sugar alcohols have very different sources in nature, melting points, and uses.

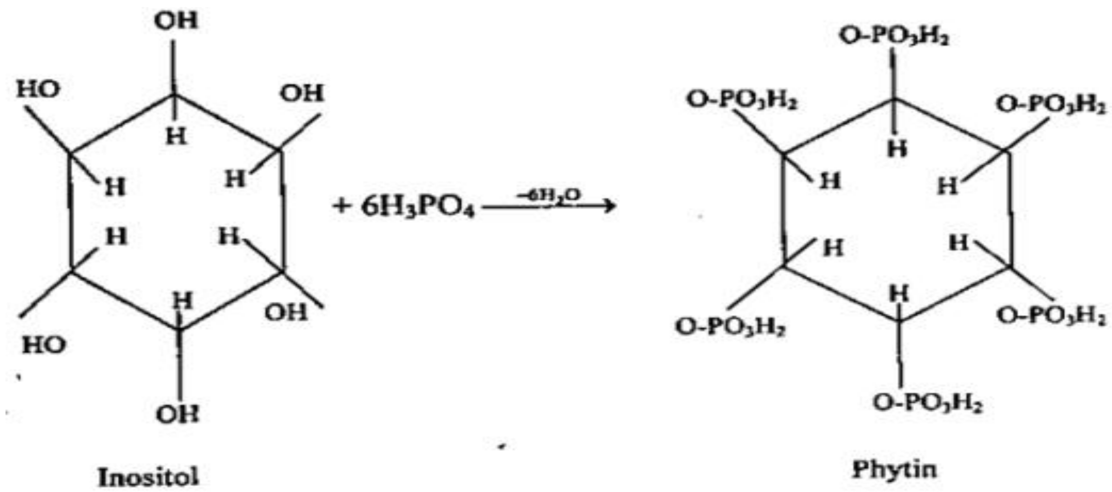


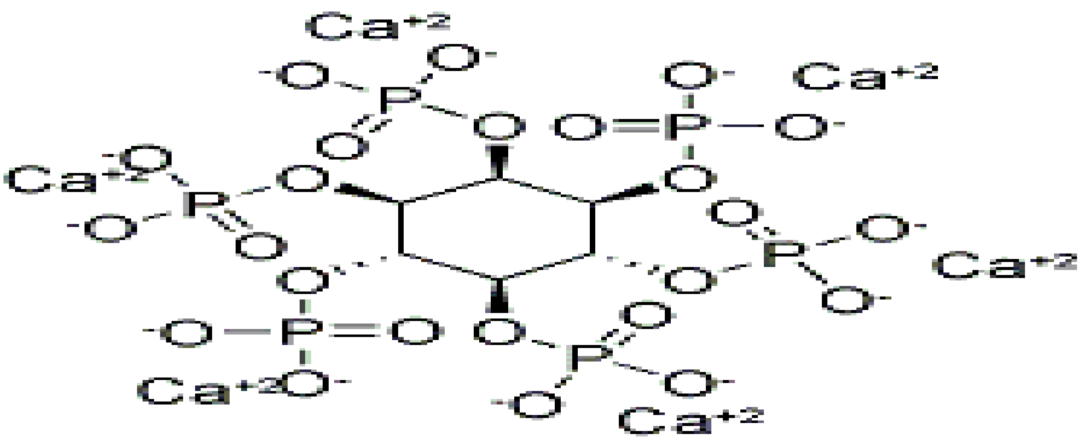
$$\underset{\text{glucose}}{C_6H_{12}O_6} + NADH + H^+ \xrightarrow{[\text{aldehyde reductase}]} \underset{\text{sorbitol}}{C_6H_{14}O_6} + NAD^+$$

It is also possible to obtain alcohol inositol ,a cyclic compound derived from glucose, after the conversion of the aldehyde group in it to a secondary alcohol and bonding of carbon atom No. (1) with carbon atom No. (6).



Inositol is found in the muscles and is called muscle sugar, as it is a component of the vitamin B-complex. Inositol reacts with six molecules of phosphoric acid to form a phosphate ester called phytic acid . Among the properties of this acid is its high ability to form insoluble salts with calcium and magnesium elements in the intestine called Phytin, and thus it limits the absorption of these elements in the intestine.

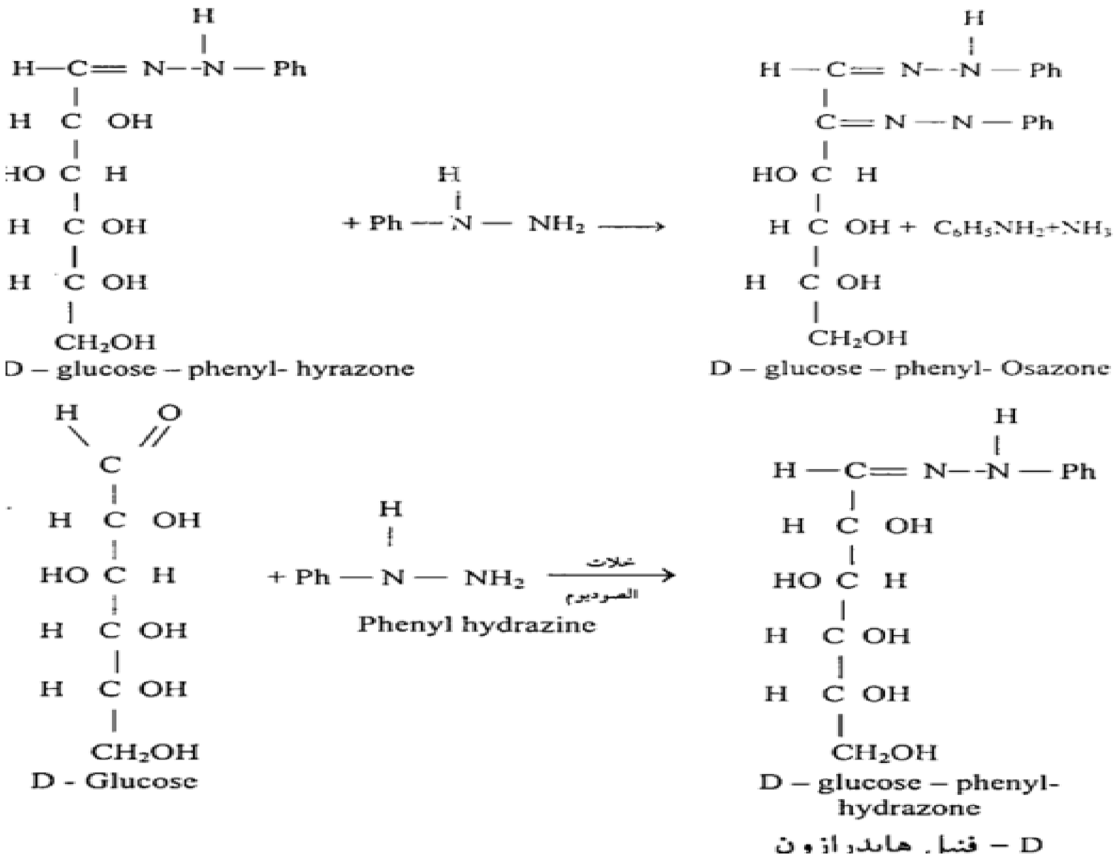


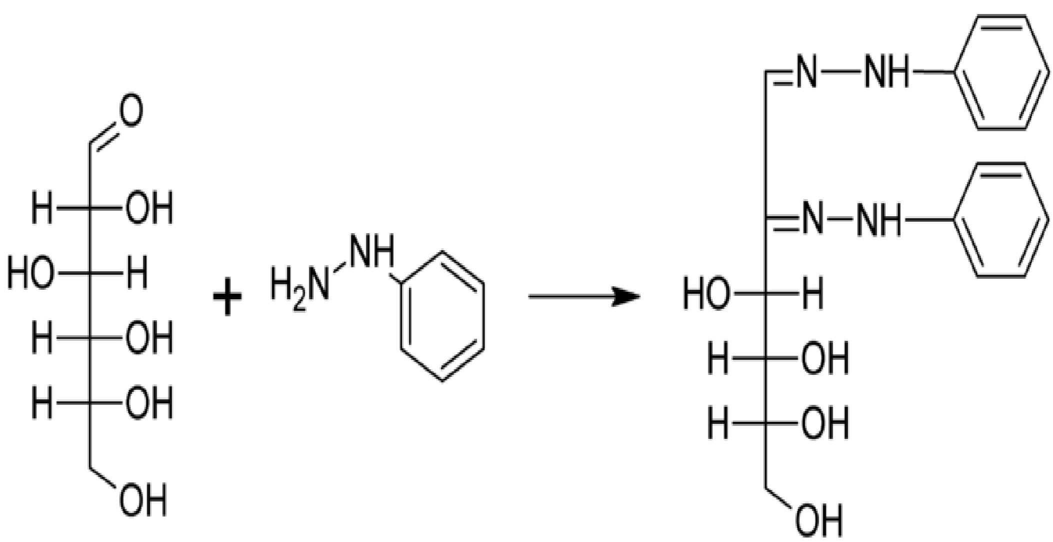


8. Reactions of monosaccharides with phenylhydrazine

Aldose and ketose monosaccharides react with the compound - Phenyl hydrazine to give the compound Phenyl hydrazone, by increasing the concentration of Phenyl hydrazine in the reaction medium we get **Osazone** , which are crystalline compounds of different shapes that appear under the microscope, and this method can be used to distinguish between the different sugars, especially if we know that these compounds have different melting points, which makes it a good method to distinguish the sugary compounds, and it is also possible to distinguish between monosaccharides that differ in the distribution of hydroxyl groups on the third, fourth and fifth carbon atoms.

These complexes are prepared by adding a mixture of phenylhydrazine in the form of hydrogen chloride and sodium acetate to the sugar solution, and heating the reaction mixture in a boiling water bath for a certain period of time. The reaction can be followed through the following equations:





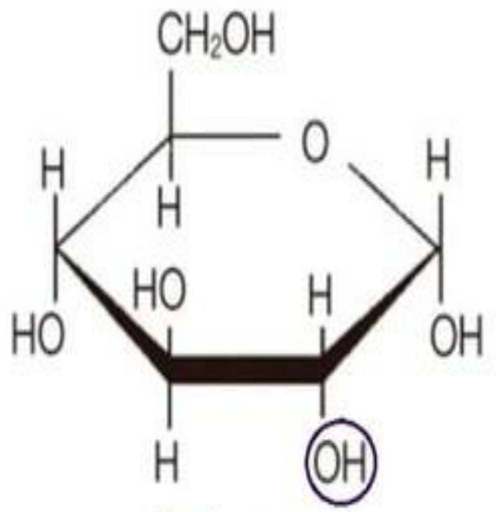
The reactions of (ketoses) take place in the same way. By looking into the structures of osazon for glucose, fructose, and mannose, we see that they give the same type of osazone despite their difference in chemical composition due to the similar distribution of the hydroxyl groups on the last four carbon atoms. As for galactose, it produces a different type of osazon due to the difference in the distribution of the hydroxyl groups on the last three carbon atoms than in the sugars glucose, fructose and mannose.

Bio-derivatives of monosaccharides

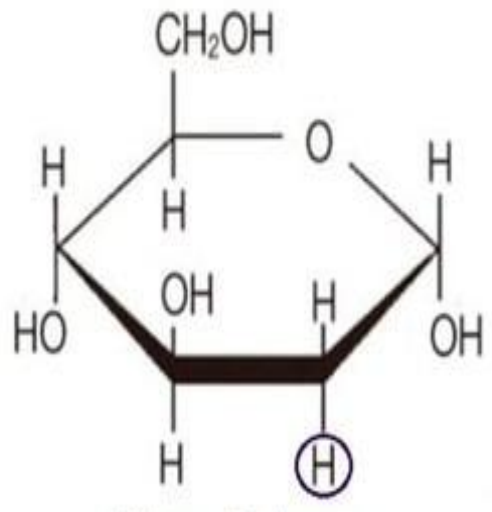
1- (Deoxy Sugars)

Deoxy sugars is a group of monosaccharides from which one or more hydroxyl groups are replaced by hydrogen atoms, where the number placed in front of the sugar name indicates the number of the carbon atom whose hydroxyl group has replaced by the hydrogen atom. Among the most prominent examples of this type of sugars is: (2- Deoxy-D-ribose), which is included in the construction of the primary structure of the deoxyribonucleic acid (DNA).

These sugars are characterized by giving most of the reactions to the monosaccharides, but they fail to give a positive detection with phenylhydrazine and the formation of the osazone complex, due to the absence of a hydroxyl group on carbon atom No. (2), and these sugars enter the composition of the cell wall in bacteria, in addition to the sugar 2-Deoxy-D-ribose, there are many of these sugars naturally present. Among them, for example, are the following sugars, as there is sugar 3-deoxy glyceric aldehyde in the wood of the walnut plant, and 6- deoxy-L-mannose in many glycosidic compounds.



D- glucose

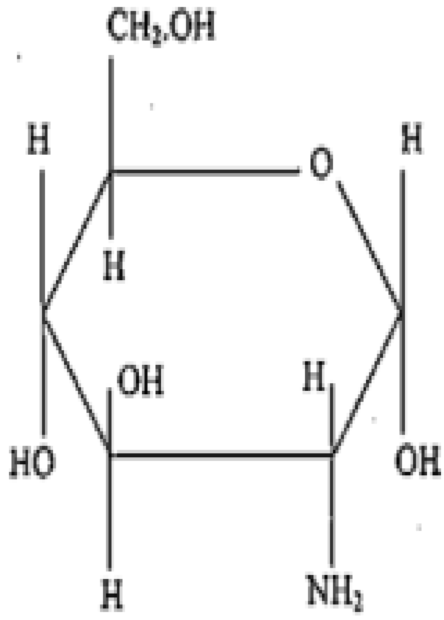


2-Deoxy-D-glucose

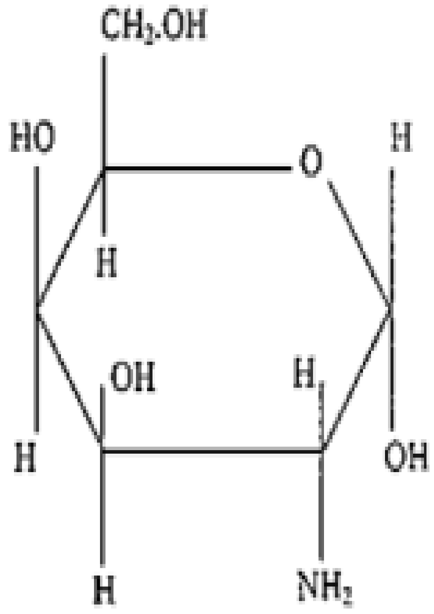
2 - (Amino Sugars)

When one of the hydroxyl groups in monosaccharides is replaced by an amino group (-NH2), a new type of sugars appears called amino sugars. Although many of these compounds can be manufactured experimentally, there are only very limited numbers of them in nature, such as D-glucosamine and D - galactosamine .

D -. glucosamine is found in a number of polysaccharides such as (Chitin), which has a structural function, as it enters into the structure of the solid outer layer in many insects as well as in marine crabs , as for the amino sugar galactosamine, it is included in the formation of cartilage as a basic component . There are many antibiotic compounds that contain in their synthetic formula some amino sugars, which is believed to be the vital activity of these antibiotics due to the amino sugars. Below are some examples of amino sugars:



2- Amino 2- Deoxy- D-glucose
Glucosamine or Chitosamine



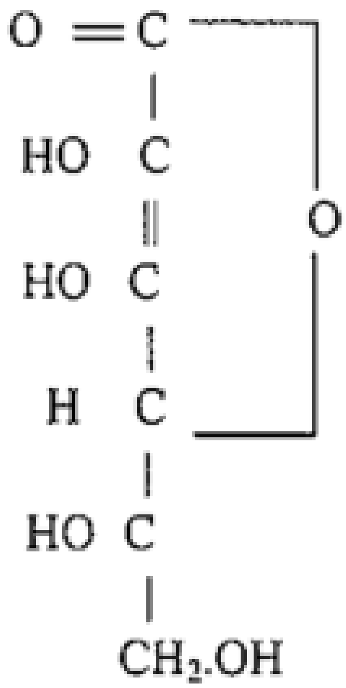
2- Amino 2- Deoxy- D-galactose
Galactosamine or Chondrosamine

3- Sugar acids

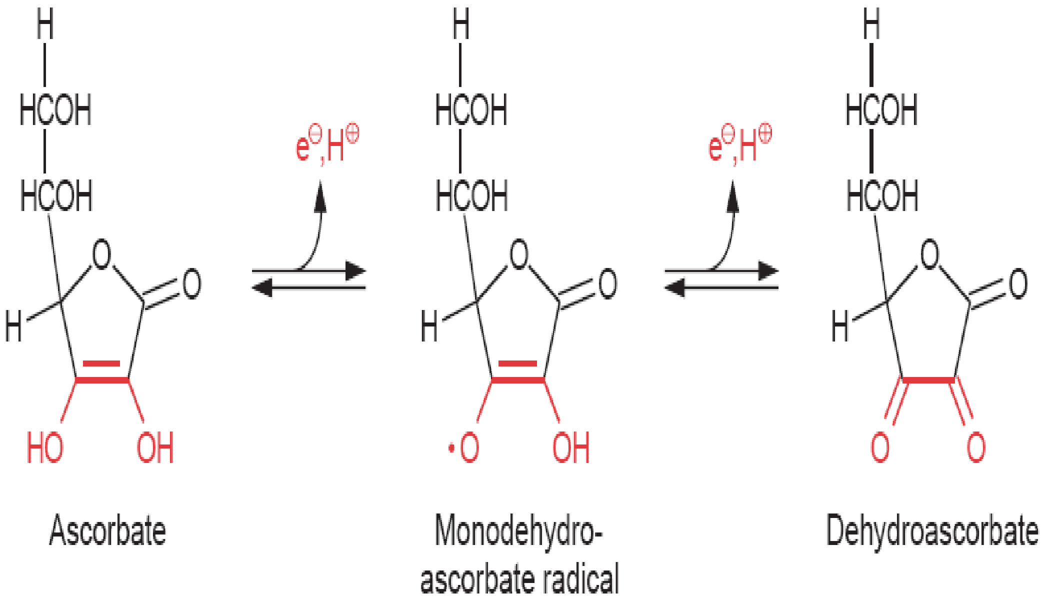
Monosaccharides, such as D-glucose, produce three types of sugar acids when oxidized, including one carboxyl group created due to oxidation of the aldehyde group called the resulting acid (D-gluconic acid), which is one of the intermediate compounds in glucose metabolism in some organisms , including those that contain two carboxyl groups, due to the oxidation of the aldehyde group and the hydroxyl group on the last carbon atom (the primary alcohol group), so the resulting compound is called D-glucaric acid.

In addition to the possibility of obtaining a third type of sugar acid that results from oxidation of the primary alcohol group.

One of the most important sugar acids is ascorbic acid (vitamin C), the deficiency of which in humans leads to scurvy. Below is the structural formula of this acid:



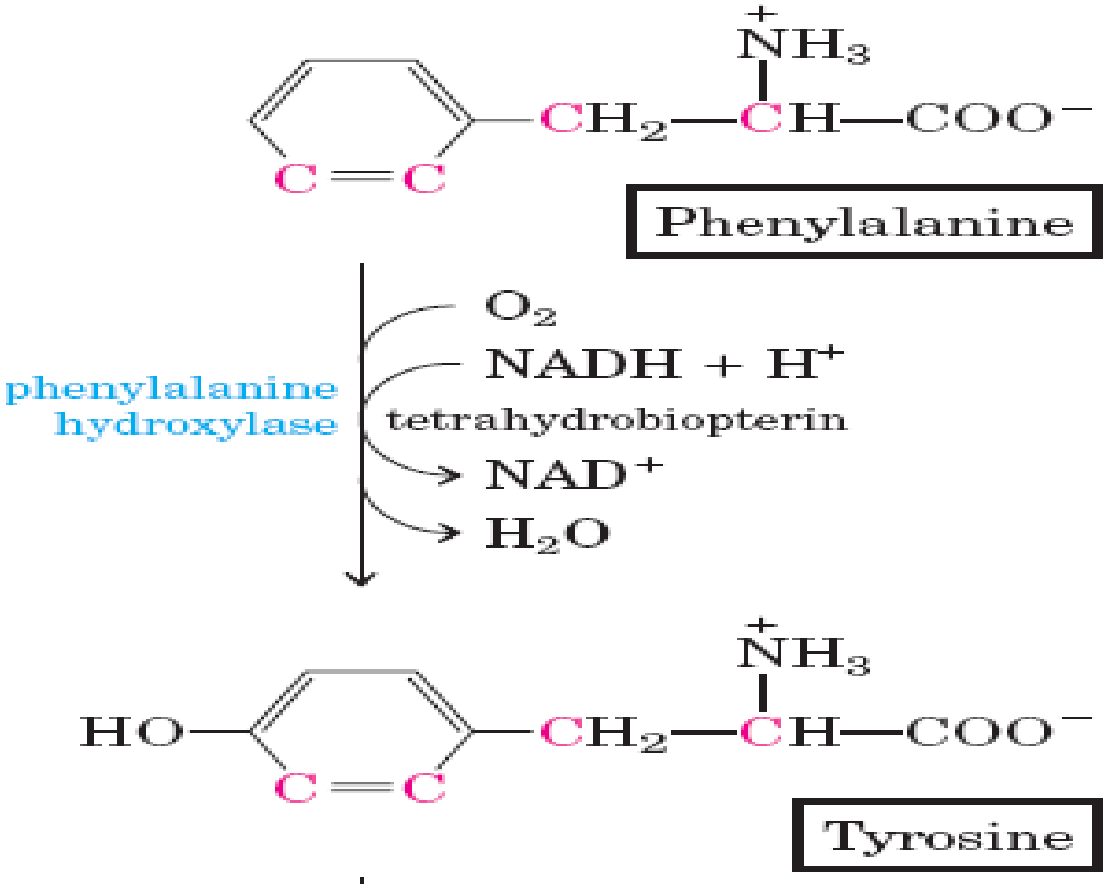
حامض الاسكوربيك (فيتامين C)



Vitamin C has several functions

a. It is a coenzyme that helps in the process of introducing the hydroxyl group for a number of vital compounds, including proline and lysine, in the process of formation glycogen, which is one of the important proteins for the formation of tissues such as skin, cartilage, bones and teeth and therefore has a role in healing wounds

B. It helps in introducing the hydroxyl group to the amino acid phenylalanine and converting it to tyrosine and then participating in the conversion of tyrosine to dihydroxyphenylalanine



c. The role of vitamin C as an anti-oxidant, as it is a water-soluble antioxidant and works to remove reactive oxygen species (ROS) for example, it reacts with Super oxide anion O2 ⁻ ,hydroxyl radical OH and hydrogen peroxide H2O2, as well as converting the oxidized vitamin E radical to It's an effective reductive form and thus works to reduce oxidative stress in the body and reduce tissue damage.

H. It has a role in reducing folic acid to tetrahydrofolic acid, which is stored in the body in this way.

F. As a result of its antioxidant activity, it inhibits the process of decomposition of cooked or stored food when added in limited quantities.

j. It is involved in many different metabolic processes such as cholesterol metabolism, drug metabolism and carnitine metabolism

G. It interacts during the formation of Nitrosamine by direct interaction with nitrites and thus can reduce the risk of cancer, as Nitrosamine is one of the compounds that work on the occurrence of various cancers.

It is known that plants absorb nitrates from the soil, and if they are not represented in the formation of proteins, they are stored in the cells as they are. The danger of nitrates comes from its conversion inside the body to nitrites, which combine with protein derivatives (amines and amides) that make up nitrosamines that cause cancerous diseases.

R .Relieves cold symptoms and reduces the risk of osteoporosis

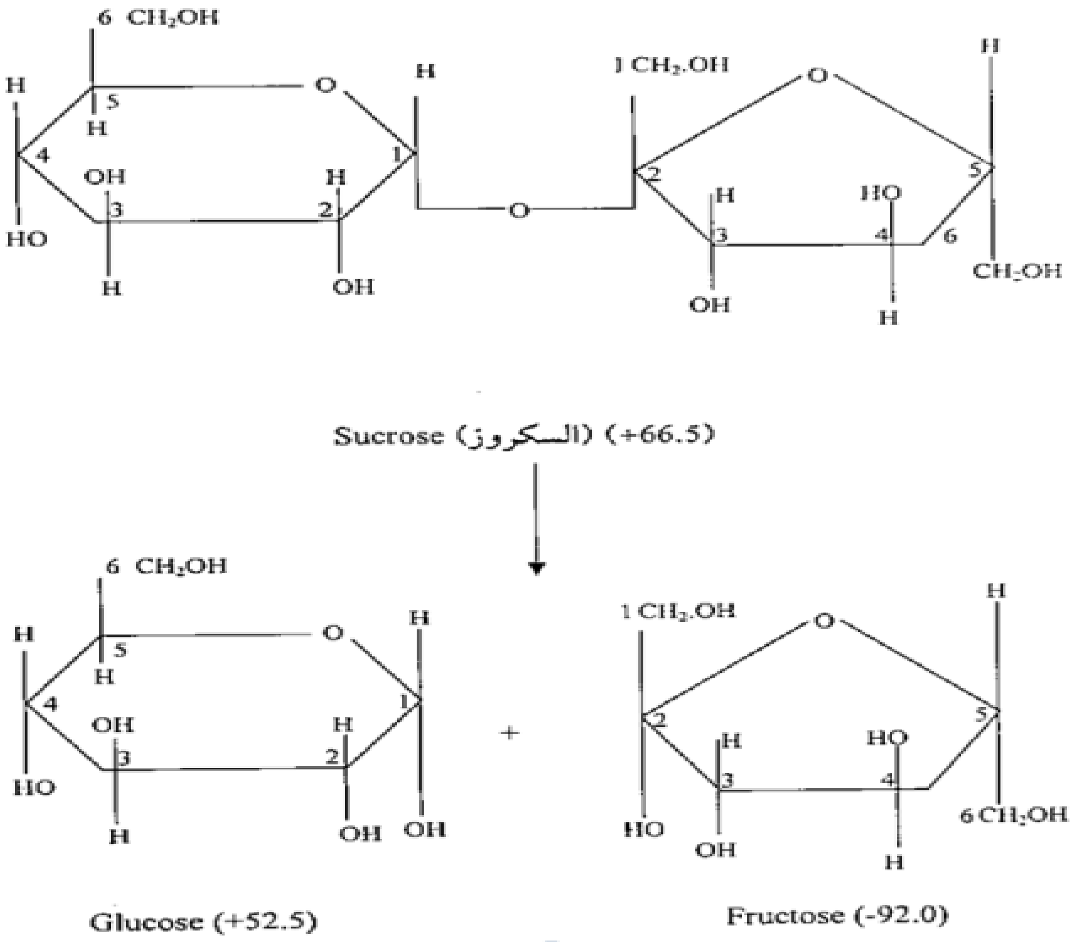
Disaccharides:

Disaccharides are formed from two similar or different monosaccharide units linked to each other by an oxygen bond through sites (1 and 4) reducing disaccharides are formed as in the sugars lactose and maltose, or through sites (1 and 2) to form non-reducing sugars as in the case in sucrose..

The general properties of reducing sugars are similar to the properties of monosaccharides, as disaccharides reduce solutions of basic copper salts (such as Fehling's solution) and can form glycosides, and enjoy the phenomenon of changing the optical rotation, in addition to their reaction with phenylhydrazine to form osazon compounds. These two types of disaccharides are represented by the fact that the reducing disaccharides are unable to reduce copper acetate in neutral or slightly acidic conditions (Barfoed's test) in a short time as is the case with monosaccharides.

This reaction can be used to distinguish between reducing monosaccharides and disaccharides.

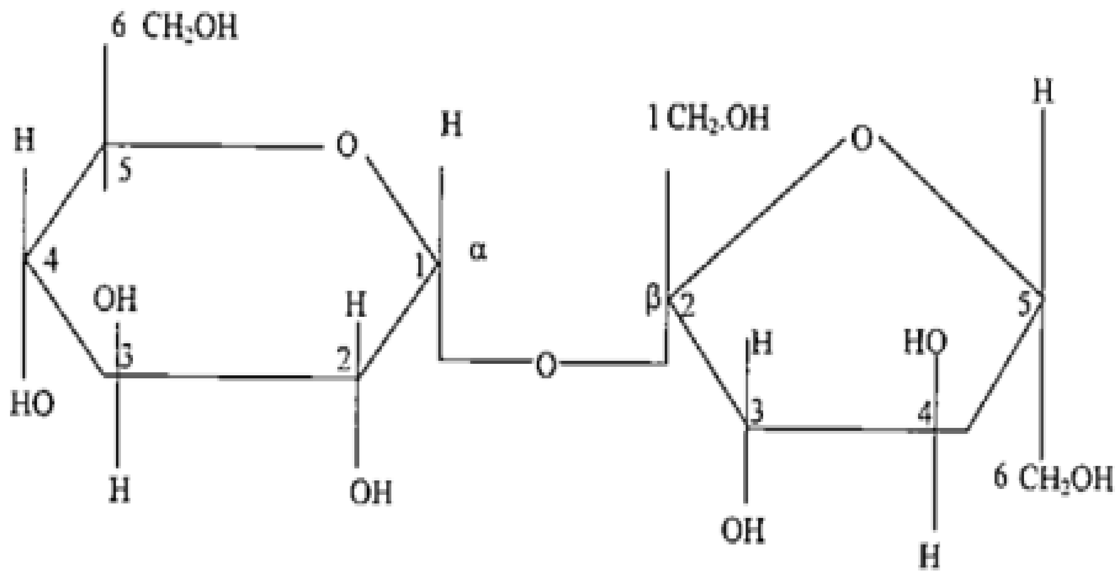
Disaccharides are broken down into monosaccharides with the help of enzymes or by acids. This decomposition process can be followed up by measuring the increase in the reductive strength of the resulting compounds. The best example to study this case is the process of decomposition of sucrose, which is a non-reducing sugar, which is characterized by a positive rotation degree of (66.0+) to its main components fructose and glucose, which are two reducing sugars in a product characterized by negative value of the optical rotation result, as this phenomenon is called the phenomenon of rotation inversion. Explained in the following equations



1. Sucrose

It is the usual sugar used for household purposes. It can be obtained from the sap of sugary plants such as beets and sugar cane. It is easily crystallized from its aqueous solutions and has an important role in human food. It is fermentable and non-reducing sugars and does not form osazon.

Sucrose consists of one molecule of alpha D-glucose linked to a molecule of beta-D fructose, wherein the glycosidic bond is formed between the reducing groups of both glucose and fructose by an oxygen bond, as shown in the figure by Haworth method.



SUCROSE

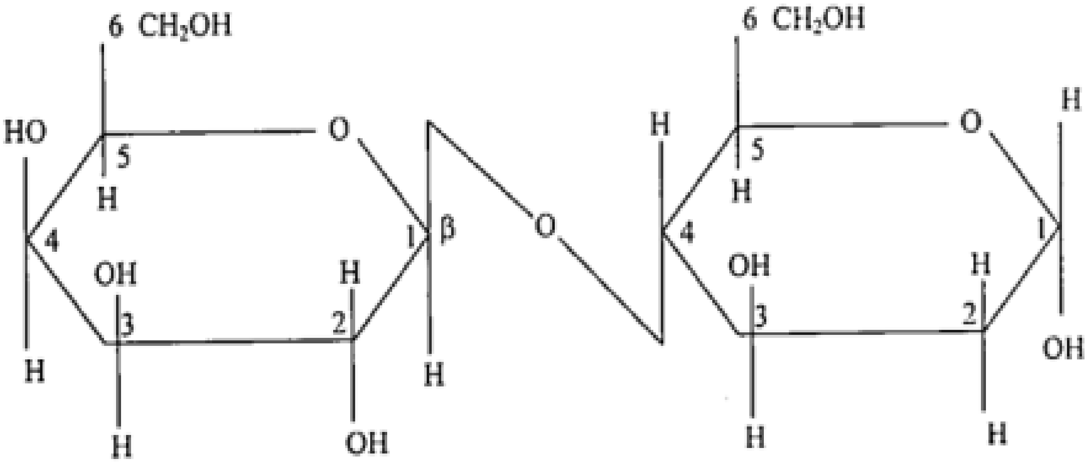
(α - D – glucopyranosyl -β - D - fructofuranoside

2. Lactose

Lactose is found in milk, it is obtained from the process of milk coagulation. Lactose is a white solid sugar that melts at 203 C. Its molecular formula is C12H22O11 and molecular weight is 342.30 g/mol.It is less soluble than the other disaccharides.

The lactose sugar molecule consists of one alpha-D-glucose, one beta-D-galactose. Lactose is considered a reducing sugar, because the sugar retains the reducing end in the glucose, and unlike sucrose, the structure of lactose can be written in the form of alpha or beta depending on the site of the hydroxyl group in the reducing end, and the following figure represents the chemical composition of lactose according to Haworth's method.

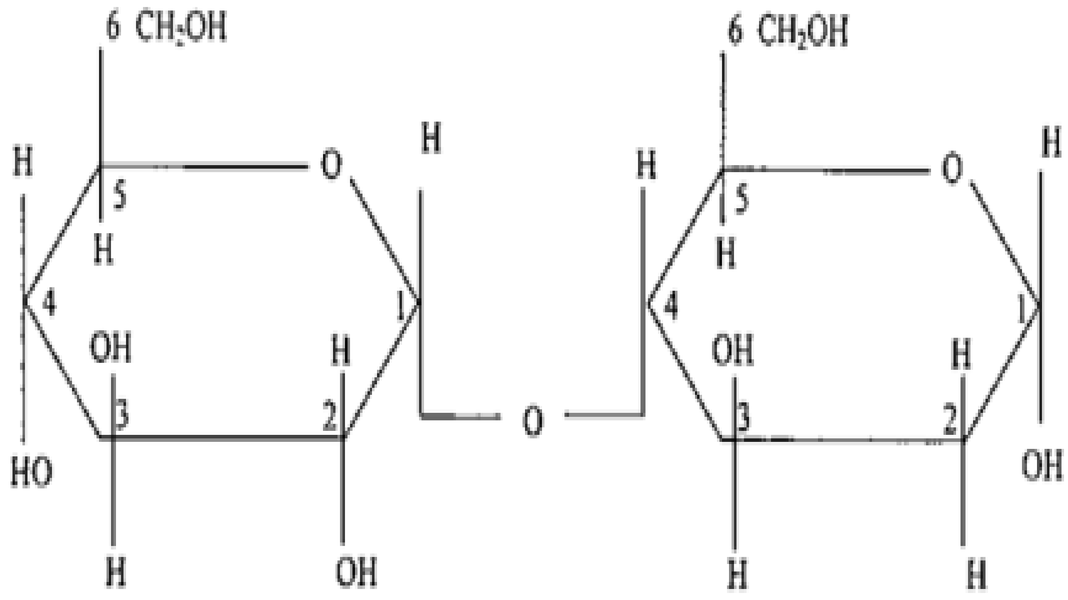
It is possible to write the beta form for lactose after placing the hydroxyl group on the carbon (1) atom in the glucose above .



LACTOSE (α - form)

3. Maltose:

This sugar is found in grains, it dissolves well in water, and crystallizes in aqueous solutions. It is produced as an intermediate compound during the hydrolysis of starch by the amylase enzyme. The structure of the maltose consists of two molecules of glucose, carbon atom No. (4) in one of them is linked with the reducing group in carbon atom No. (1) of the second molecule to form a reducing sugar, and as in lactose sugar, maltose exists in two forms, alpha and beta, depending on the site reducing hydroxyl group. Maltose is easily digested and subjected to fermentation because it contains an alpha-glycosidic bond. The following figure shows the chemical composition of maltose, drawn according to the Haworth method:



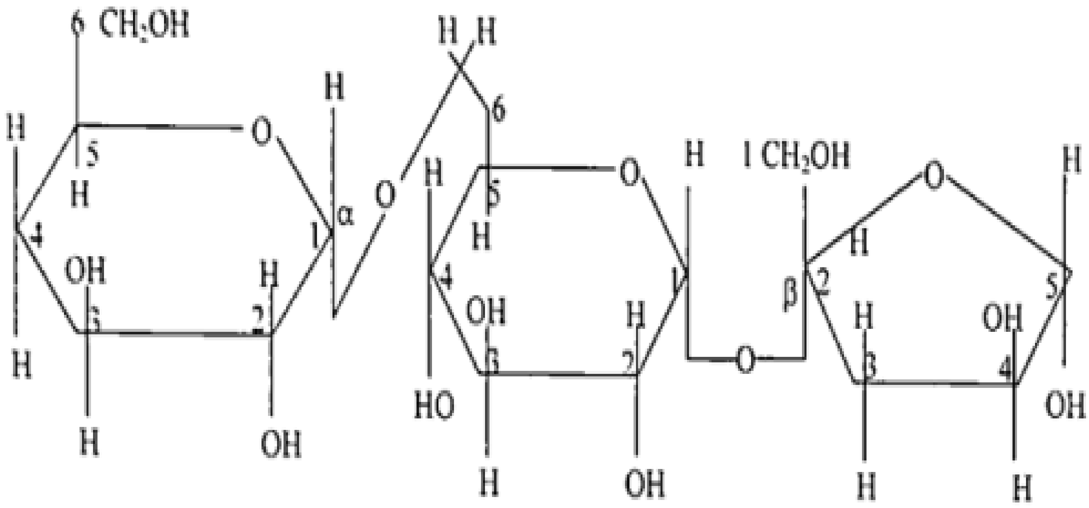
MALTOSE (α - form)

Trisaccharides

Trisaccharides consist of three molecules of monosaccharides linked together by glycosidic bonds (oxygen bonds). The most important trisaccharides are raffinose sugar, whose composition consists of alpha - D - glucose, alpha - D - galactose, and beta - D - fructose. The following figure shows the primary structure of raffinose

Raffinose is the second sugar after sucrose in terms of its abundance in the plant kingdom. However, it is only found in its free form (0.05%) in the beet plant.

Raffinose is a non-reducing trisaccharides because all of its reducing groups are occupied by glycosidic bonds (oxygen bonds). In addition to raffinose as a non-reducing trisaccharides,



RAFFINOSE

O- α- D – glactopyranosyl (1-6), O- α - D- glucopyranosyl (1-2)- β - D-Fructofuranoside

Polysaccharides: -

Polysaccharides are carbohydrates consisting of no less than ten units of monosaccharides, and thus they are polymeric compounds of monosaccharides with high molecular weights and are distinguished as a good source of energy because of their ease of converting into digested sugars when needed.

Polysaccharides include two distinct types, one of which contains repeating units that are linked together by oxygen bridges of a specific monosaccharide and are called **homopolysaccharide**, while the second type contains two or more different types of monosaccharides, so they are called **heteropolysaccharide**. In general, polysaccharides can be found in the form of an unbranched chain, as in the case of cellulose, or in the form of branched, as in the case of glycogen.

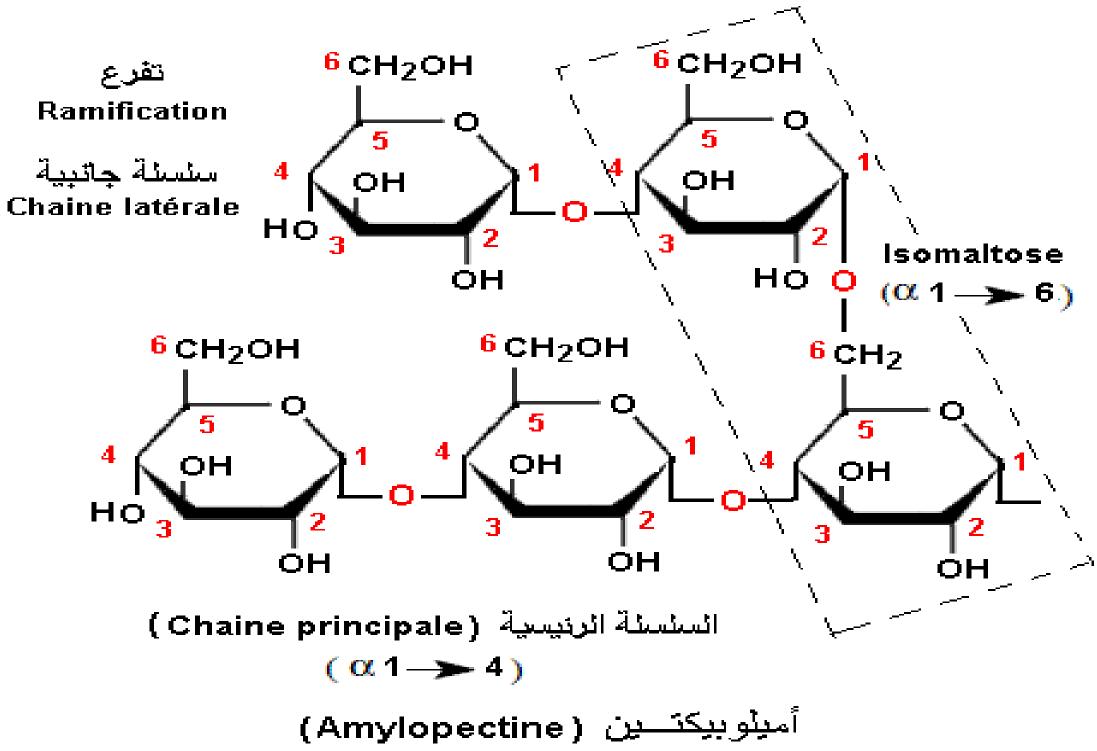
Polysaccharides are called depending on the monosaccharide that composes them by replacing the suffix ose with the suffix an, for example, the sugar derived from mannose is called mannan ,but if the polysaccharide is of a heteropolysaccharide, it is called, depending on the monosaccharides included in its composition, such as D-galacto-Dmannoglycan means that polysaccharide consists of galactose and mannose, however, special names such as starch and cellulose are often used instead of the regular names.

Starch

Plants by photosynthesis make glucose in the form of starch as a storage of energy that plants may need or as a food source for people who feed on these plants, starch is found in particular in some plant parts such as potato tubers.

Starch is divided into two types: amylose, which consists of units of glucose sugar linked to alpha- glycosidic bonds (1-4) in unbranched straight chains that h may be an extension of the composition of maltose and contains a free sugar group at one of its ends. The second is amylopectine, which is in addition to containing glucose units, which are arranged in straight chains, similar to amylose, these chains are linked together by alpha (1-6) links to form a branched structure.

The molecular weight of amylose, which is isolated from starch, ranges between 4000-400000, while amylopectin, which is separated on the same basis, has a relatively higher molecular weight, ranging between 50,000 to one million. Amylose has the advantage of giving a blue color when combined with iodine, while amylopectin gives a purple-red color when combined with iodine.



Glycogen

A multi-unit polymer, glucose is the basic building unites of this molecule that acts as an energy store in animals and fungi. Each glucose unit is associated with the next unit by an alpha bonds (1,4), while the branches consist of bonds (1,6). When blood glucose decreases, the process of breaking down glycogen into its building unites begins. Whereas, the reverse process of converting glucose molecules into glycogen occurs when the level of glucose in the blood rises. Insulin is the hormone responsible for the formation of glycogen in the human body, while the liver and muscles are the two organs responsible for storing it.

Glycogen formation

It is a synthesis process that occurs inside cells in which glycogen is built from glucose. The main site for this process is the cytosol of the liver and muscle cells. Liver cells make up 8-10% of the weight of glycogen formed, while muscles make up 1-2% of its weight. As for the rest of the other cells, they manufacture small amounts of glycogen. The process of glycogen from uridine glucose diphosphate (UDPG) begins with the presence of the two enzymes

1-Glycogen Synthase: This is the primary enzyme in the synthesis of glycogen. Where it stimulates the transfer of glucose units from uridine glucose diphosphate, to what is called a glycogen primer, and thus leads to the linkage of the first carbon atom of the transferred glucose to the fourth carbon atom of the last glucose in the primary glycogen chain by "alpha-1,4 glycosidic bond" ". This process can be repeated more than once, leading to elongation of the primary glycogen until it reaches a minimum of 11 units of glucose, and the chain is called the immature glycogen chain, and then comes the role of the branching enzyme.

2- Branching enzyme: This enzyme carries out the transfer of a part of the immature glycogen chain (the transported part consists of a minimum of 6 glucose units) to link it to the nearest chain with the "alpha-1,6 glycosidic bond" to form another branching point acts as a starting point for replication of the glycogen Synthase work.

The importance of glycogen

1- Liver glycogen: It acts as a reserve of glucose that helps maintain blood sugar, especially between meals, and after 12-18 hours of food abstinence, the liver glycogen is depleted.

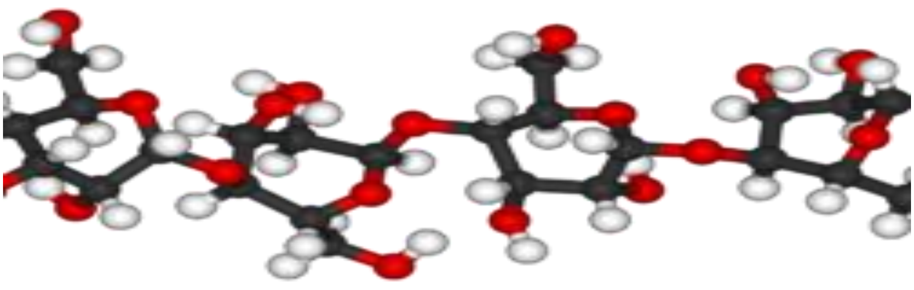
2- Muscle glycogen: It acts as a reserve for the manufacture of adenosine triphosphate (ATP) within the same muscle, especially during contraction, and this glycogen is depleted after prolonged muscle exercise.

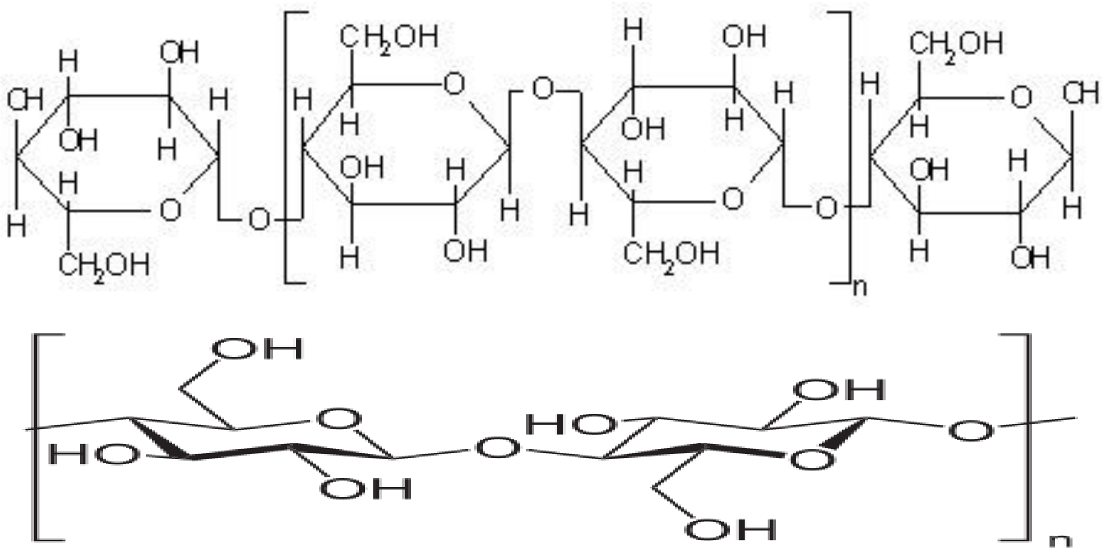
Cellulose

Like other polysaccharides, cellulose is characterized by its insolubility in water and impermeability through cell membranes. In 1838 Anselme Payen named cellulose the substance that makes up plant cell walls. But cellulose is never found pure in nature.. It is the basic raw material in many different industries, such as paper industry.

Cellulose does not decompose by the enzyme amylase, so cellulose in food passes through the gut without digestion, but it is of great importance in preventing constipation and regulating intestinal movement.

Cellulose gives the general structure (C6H10O5) n, where (n) represents a large number called Degree-of Polymerization. The decomposition of cellulose with the effect of acids leads to glucose. Cellulose consists of glucose, where one molecule of water is lost for every molecule of glucose, and it consists of a long, straight and unbranched chain resulting from the union of a large number of beta-glucose molecules, and the connection between beta-glucose molecules (β (1 → 4)) formed between carbon atoms No. (1) and carbon atom No. (4) in one of the two glucose units that are linked by an oxygen bond with the adjacent unit.





The chemical composition of cellulos

Photosynthesis

All the free energy that biological systems consume comes from the sun through the process of photosynthesis. A green plant, with light, is able to convert carbon dioxide and water into carbohydrates, releasing oxygen in a process called photosynthesis that represents the ability of plants to make their own organic food, in that process Photo energy is transformed into chemical energy that leads to the reduction of carbon dioxide to the level of carbohydrates. The general equation for photosynthesis can be written as follows.

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

There are living organisms that perform the formation of carbohydrate in different ways. In some types of bacteria, the process is carried out in a way that does not produce oxygen, as these bacteria use H_2S instead of water and thus produce sulfur instead of oxygen according to the following equation

$6CO_2 + 12H_2S + energy \longrightarrow C_6H_{12}O_6 + 12S + 6H_2O$

Photosynthetic Pigments:

Photosynthetic pigments are of three types namely:

1. Chlorophylls. 2. Carotenoids. 3. Phycobilins.

These pigments are present on the membranes of thylakoids. They are concerned with the absorption of light in the visible spectrum.

1. Chlorophylls:

The chlorophyll contains porphyrin structure in which four pyrrole rings are united by their nitrogen atoms to magnesium. Each chlorophyll has a fifth ring containing only carbon atom and the long chain phytol alcohol. There are different types of chlorophylls. They vary in the structure of the side chains attached to the pyrrole rings. Chlorophylls a and b differ in that chlorophyll a has a methyl group on ring 3, while chlorophyll b has an aldehyde in the same place. Cholorophyll a is the chief pigment associated with photosynthesis.

Most plants contain two or three times more chlorophyll a than chlorophyll b. The molecular structures were largely solved by the Germans R. Wilstatter, A. Stoll and by the famous organic chemist Hans Fisher. In 1960, Robert Woodward synthesized chlorophyll a for which he was awarded Nobel Prize in Chemistry in 1965.

2. Carotenoids:

These pigments are a group of pigments which are usually red, orange, yellow or brown and are associated with chlorophyll in the chloroplast.

The carotenoids are divided into two chemical groups, the carotenes and the xanthophylls. These are insoluble in water but soluble in organic solvents such as ether or acetone.

The carotenes are characterised chemically by the presence of a short chain of unsaturated hydrocarbon which makes them completely hydrophobic. Xanthophylls have several hydroxyl groups.

The carotenoids are important to photosynthesis for two reasons:

a. The carotenes appear to prevent a destruction of chlorophyll in the presence of light and oxygen. Such a destructive phenomenon is called photooxidation.

b. The second function of carotenoids particularly the xanthophylls has a role in absorption of light and transfer the absorbed energy to chlorophyll molecules.

3. Phycobilins:

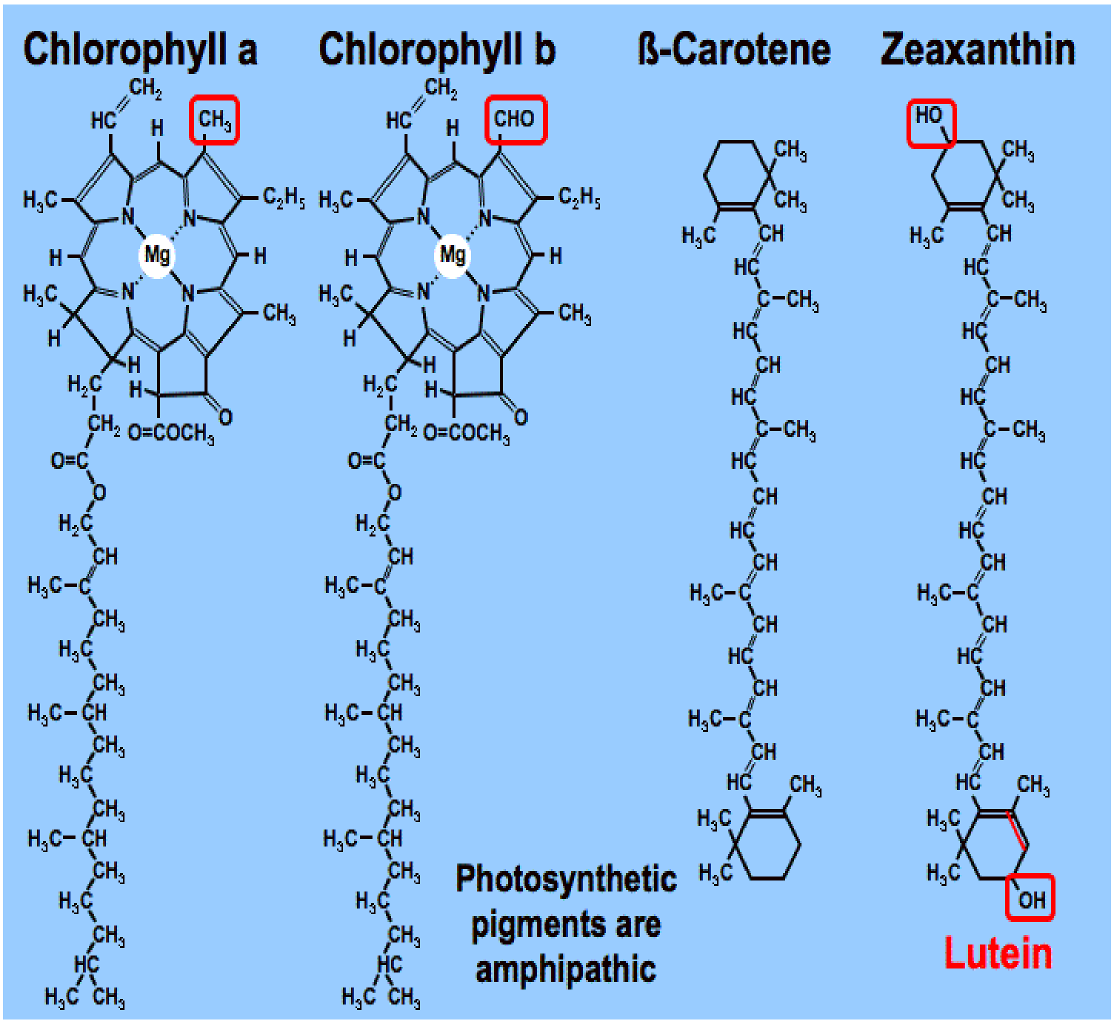
The phycobilins are the third group of photosynthetic pigments present in blue- green and red algae. These are classified into two types- the red phycoerythrin and the blue phycocyanin.

These phycobilins are tetrapyrroles. These are open pyrroles attached to proteins in the living cell and they are water soluble.

Phycobilins absorb light and help in photosynthesis as accessory pigments.

The phycobilins are like carotenoids and transfer the excitation energy to chlorophyll a, which are utilised by chlorophyll a to drive photosynthesis.

Such pigments as carotenoids and phycobilins, which absorb and transfer energy to an absorption sink like chlorophyll a, are called accessory pigments.



The process of photosynthesis takes place inside green plastids that are composed of particles surrounded by a double cytoplasmic membrane that contains two types of platelets. The first is called **grana** (singular granum). Grana contains the pigments for the photosynthesis process. In each plastid there is 60 grana in which light energy is converted into chemical energy. The second is called **stroma**, in which carbon dioxide is reduced to carbohydrates.

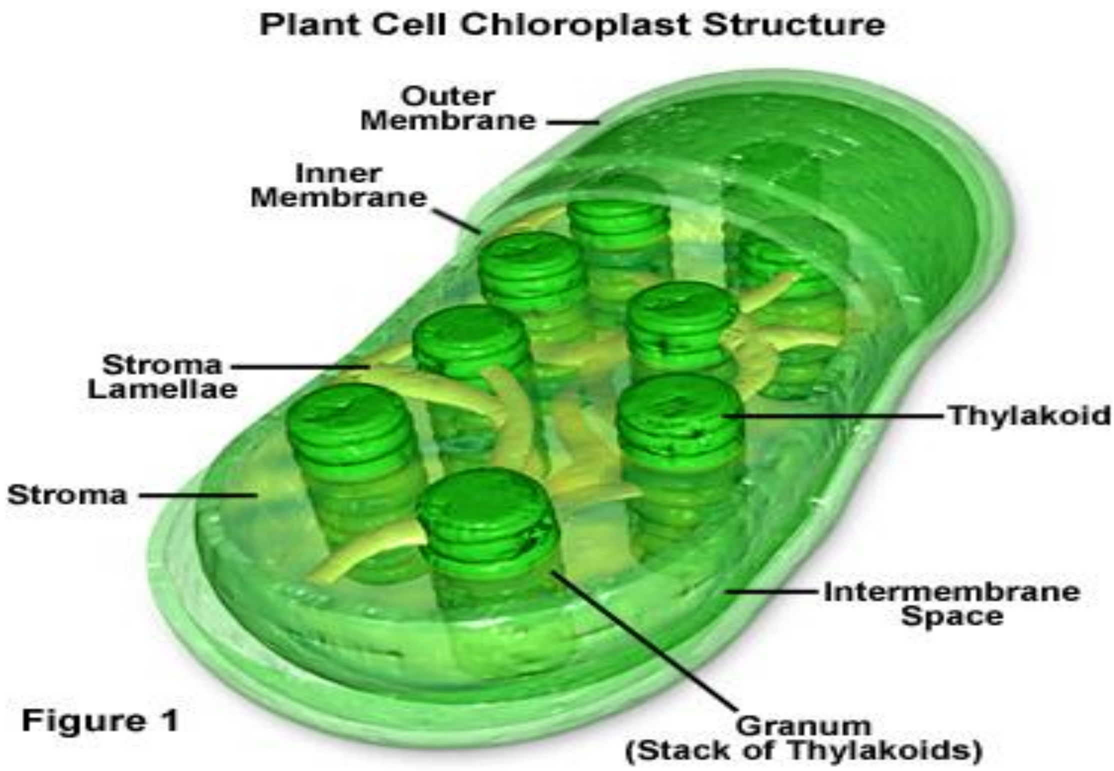


Figure 1

The Electromagnetic Spectrum

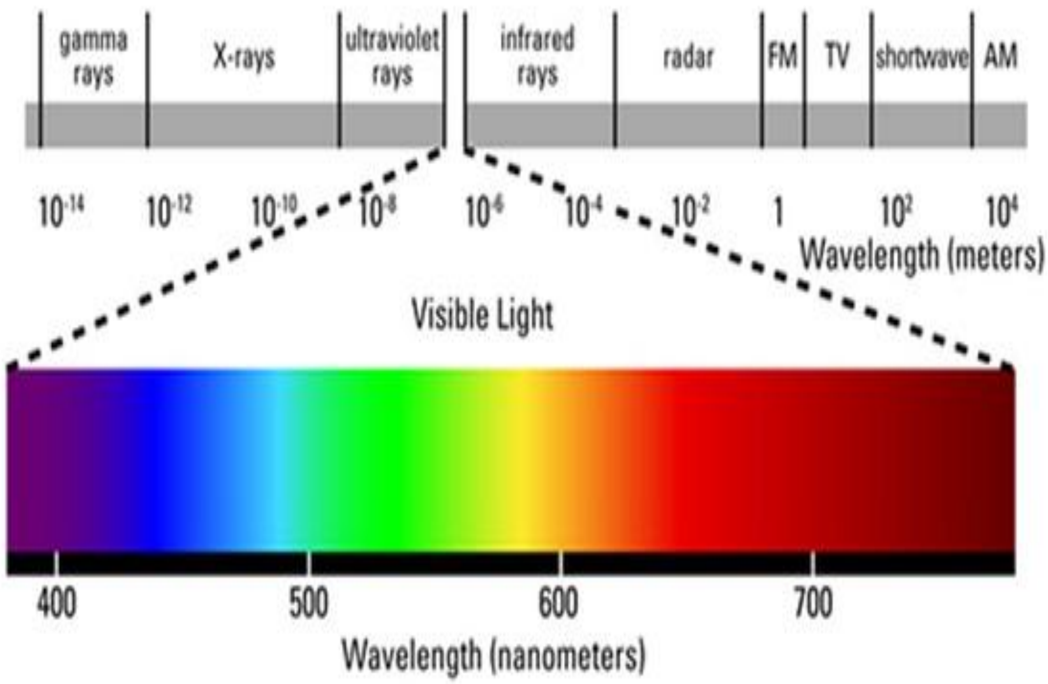
Radiation is energy that moves from one place to another in a form that can be described as waves or particles. light which our eyes can detect is part of the visible spectrum. There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage. The visible wavelengths cover a range from approximately 400-700 nanometers , so, ultra violet radiation or UV ,which is portion of the spectrum has the shortest wavelengths and located under this region , while infrared one which is **the longest wavelength of the red light is** located above the region .

Light intensity is directly proportional to the number of photons that are emitted from a given beam of light. This phenomenon is known as the photoelectric effect.

A light beam consists of particles known as photons, and the scientist Einstein was the first to suggest the use of photons as units of energy, or light quanta. The equivalent energy to a certain amount of light is not constant, but rather depends on the wavelength of the light. For example, photons in long wavelenghths such as those at the red end of the spectrum contain the least amount of energy. The blue light spectrum contains the largest amount of energy and the following equation shows the relationship between the energy content of photons and the wavelengths and frequency of those photons.

$$E = h\,v = h\,\frac{c}{\lambda}$$

Where E represents the energy of a certain amount of light (photon energy), V is the frequency per second, and h is Planck's constant and equals 6.62607015 × 10−34 joules/sec, c is the speed of light in a vacuum and λ the wavelength of a photon, and since c and h are constant, the photon energy E is inversely proportional to the wavelength



Red drop phenomenon, Photosystem I (PSI) and Photosystem II (PS II)

Researcher Emerson and others, while studying the efficiency of photosynthesis for different wavelengths absorbed by Chlorelle algae, recorded a decrease in the production of quantum at a wavelength of more than 680 nanometers, as they were able to calculate the production of quantum, meaning the number of oxygen molecules released in the process of photosynthesis for each absorbed quantum, and this phenomenon was called red drop, meaning **a drop in the efficiency of photosynthesis**. They also found that the use of two types of rays, the first is shorter than 680 nanometers and the second is longer than 680 at the same time, exceeds the sum of both types when using each of them alone, and thus the red drop phenomenon has been overcome. **This increase in the rate of photosynthesis as a result of the use of both types of rays at the same time is called the Emerson effect.**

Emerson's discovery of the red drop phenomenon as well as the Emerson effect has resulted in a new view of the role of chlorophyll and accessory pigments in the process of photosynthesis. It seems that the photosynthesis in green plants is regulated by two successive photoreactions, each of which is associated with a special group of pigments, namely:

1.photosystem I (PSI)

2. Photo system II (PS II)

These two systems of light reaction or photo-chemical phase of photosynthesis are rich in chlorophyll and carotenoids pigments. In both systems, the pigments harvest and collect light energy and transfer it to the main activity centers in all systems (Reaction Centers), which are called traps.

Quantum light absorbed by one molecule of chlorophyll is carried over from one molecule to another, and in the end it is used in a chemical work, which is the formation of (NADPH2 & ATP), when the activity centers of the two photosystems P680 (Reaction Center Of PS II) and P700 (Reaction Center Of PS I) are excited, electrons are release and thus the electron acceptors have been reduced, which in turn release the electrons to other acceptors.

Photosynthesis reactions

Studies have shown that photosynthesis includes two types of reactions: the light reaction and the dark reaction

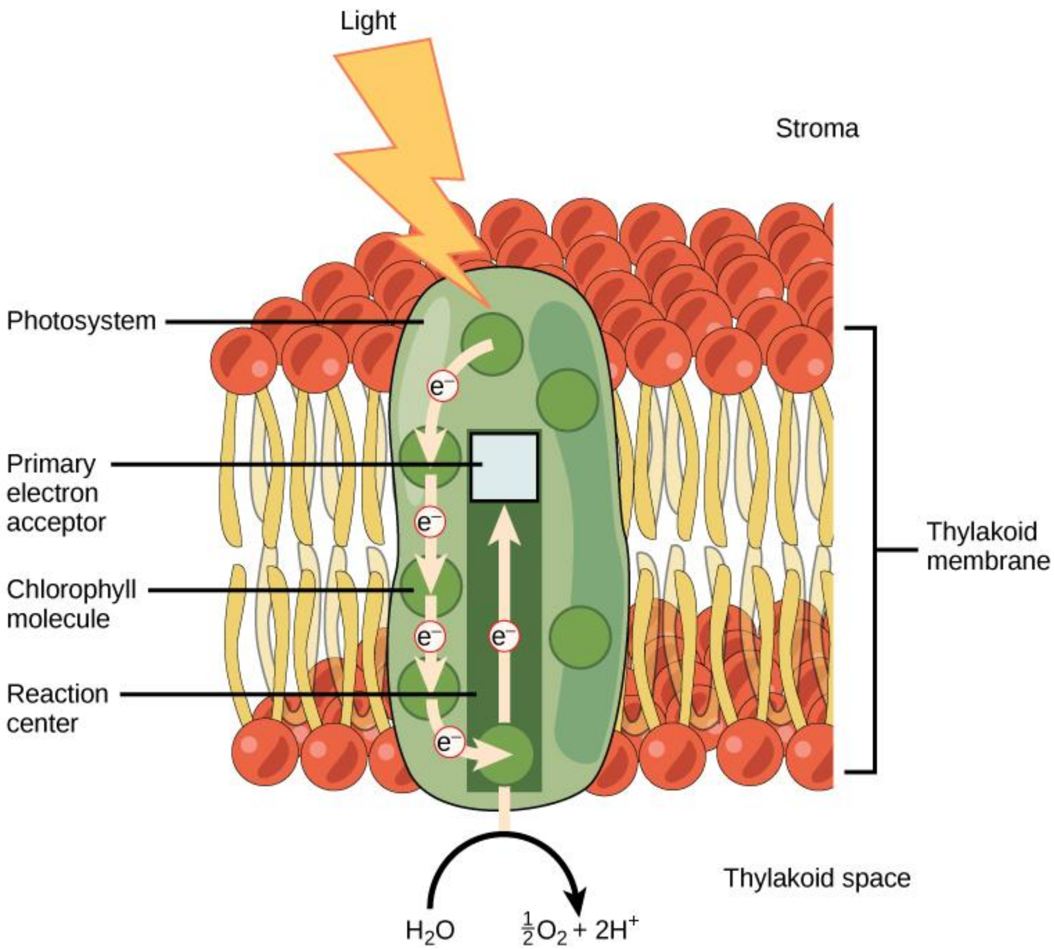
1. The Light-Dependent Reactions of Photosynthesis

It is also called the Hill reaction, as the scientist Robert Hill in 1937 studied photosynthesis reactions at the level of isolated chloroplasts instead of whole plants.. Light energy enters the process of photosynthesis when pigments absorb the light. In plants, pigment molecules absorb only visible light for photosynthesis.

The overall purpose of the light-dependent reactions is to convert light energy into chemical energy.

The light-dependent reactions begin in a grouping of pigment molecules and proteins called a photosystem. Photosystems exist in the membranes of thylakoids. A pigment molecule in the photosystem absorbs one photon, a quantity of light energy, at a time.

A photon of light energy travels until it reaches a molecule of chlorophyll. The photon causes an electron in the chlorophyll to become "excited." The energy given to the electron allows it to break free from an atom of the chlorophyll molecule. Chlorophyll is therefore said to **"donate"** an electron

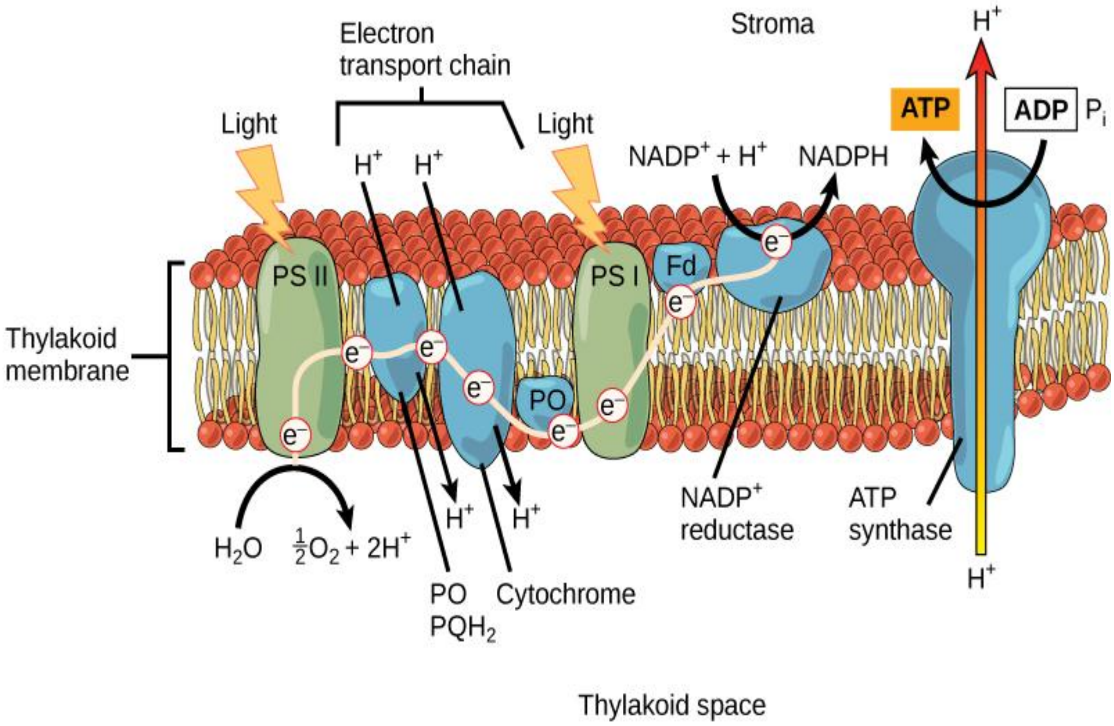


To replace the electron in the chlorophyll, a molecule of water is split. This splitting releases an electron and results in the formation of oxygen (O2) and hydrogen ions (H+) in the thylakoid space. Technically, each breaking of a water molecule releases a pair of electrons, and therefore can replace two donated electrons.

The replacing of the electron enables chlorophyll to respond to another photon. The oxygen molecules produced as byproducts find their way to the surrounding environment. The hydrogen ions play critical roles in the remainder of the light-dependent reactions.

Keep in mind that the purpose of the light-dependent reactions is to convert solar energy into chemical carriers that will be used in the Calvin cycle. In eukaryotes, two photosystems exist, the first is called photosystem II, which is named for the order of its discovery rather than for the order of function.

After the photon hits, photosystem II transfers the free electron to the first in a series of proteins inside the thylakoid membrane called the electron transport chain. As the electron passes along these proteins, energy from the electron fuels membrane pumps that actively move hydrogen ions against their concentration gradient from the stroma into the thylakoid space. This is quite similar to the process that occurs in the mitochondrion in which an electron transport chain pumps hydrogen ions from the mitochondrial stroma across the inner membrane and into the intermembrane space, creating an electrochemical gradient. After the energy is used, the electron is accepted by a pigment molecule in the next photosystem, which is called photosystem I



Generating an Energy Carrier: ATP

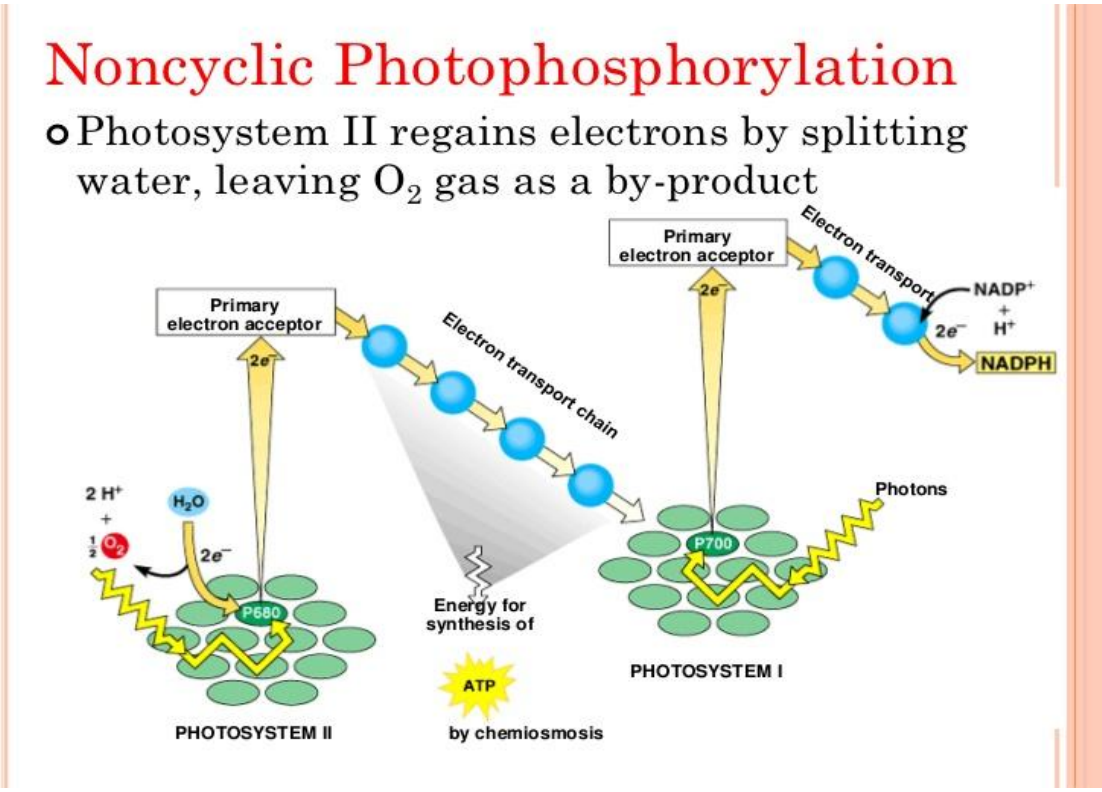
In the light-dependent reactions, energy absorbed by sunlight is stored by two types of energy-carrier molecules: ATP and NADPH. The energy that these molecules carry is stored in a bond that holds a single atom to the molecule. For ATP, it is a phosphate atom, and for NADPH, it is a hydrogen atom. Recall that NADH was a similar molecule that carried energy in the mitochondrion from the citric acid cycle to the electron transport chain. When these molecules release energy into the Calvin cycle, they each lose atoms to become the lower-energy molecules ADP and $NADP^+$.

The buildup of hydrogen ions in the thylakoid space forms an electrochemical gradient because of the difference in the concentration of protons (H+) and the difference in the charge across the membrane that they create. This potential energy is harvested and stored as chemical energy in ATP through chemiosmosis, the movement of hydrogen ions down their electrochemical gradient through the enzyme ATP synthase.

The hydrogen ions are allowed to pass through the thylakoid membrane through an ATP synthase.,that generated ATP from ADP . The energy generated by the hydrogen ion allows ATP synthase to attach a third phosphate to ADP, which forms a molecule of ATP in a process called photophosphorylation. The flow of hydrogen ions through ATP synthase is called chemiosmosis, because the ions move from an area of high to low concentration through a semi-permeable structure.

Generating Another Energy Carrier: NADPH

The remaining function of the light-dependent reaction is to generate the other energy-carrier molecule, NADPH. As the electron from the electron transport chain arrives at photosystem I, it is re-energized with another photon captured by chlorophyll. The energy from this electron drives the formation of NADPH from NADP+ and a hydrogen ion (H+). Now that the solar energy is stored in energy carriers, it can be used to make a sugar molecule.



Summary of the light-dependent reactions

1. These reactions take place on the thylakoid membrane inside the chloroplast.

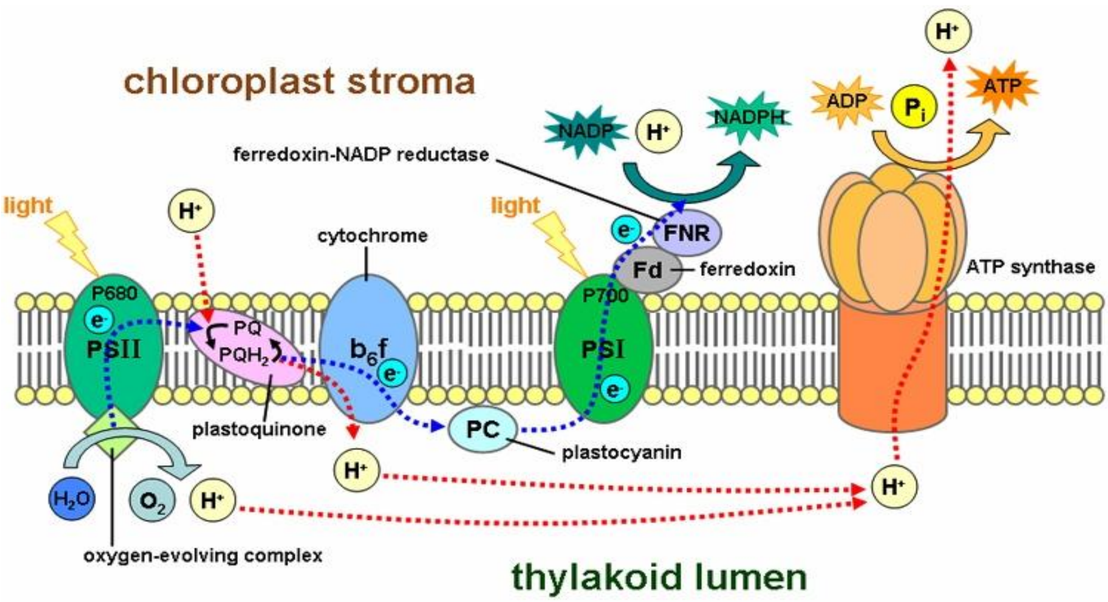
During this stage light energy is converted to ATP (chemical energy) and NADPH (reducing power).**Light is absorbed by two Photosystems called Photosystem I (PSI) and Photosystem II (PSII).** These protein complexes contain light harvesting chlorophyll molecules and accessory pigments. The photosystems are also equipped with reactions centers (RC). These are complexes of proteins and pigments which are responsible for energy conversion. The chlorophyll molecules of PSI absorb light with a peak wavelength of 700nm and are called P700 molecules. The chlorophyll molecules of PSII absorb light with a peak wavelength of 68Onm and are called P68O molecules.

2. The light dependent reactions begin in PSII.

- A photon of light is absorbed by a P680 chlorophyll molecule in the light harvesting complex of PSII.

- The energy that is generated from the light is passed from one P680 chlorophyll molecule to another until it reaches the reaction center (RC) of PSII.

- At the RC is a pair of P680 chlorophyll molecules. An electron in the chlorophyll molecules becomes excited as a result of a higher level of energy. The excited electron becomes unstable and is released. Another electron is released following the capture of another photon of light by the light harvesting complex and the transfer of energy to the reaction center.



- The electrons are transported in a chain of protein complexes and mobile carriers called an electron transport chain (ETC). Plastoquinone is the mobile carrier that transports the electrons from the reaction center of PSII to the Cytochrome b6f Complex as shown in the diagram above.

- The electrons lost from PSII are replaced by splitting water with light in a process called Photolysis. Water is used as the electron donor and is split into electrons (e-), hydrogen ions (H+, protons) and oxygen (O2). The hydrogen ions and oxygen are released into the thylakoid lumen. Oxygen is later released into the atmosphere as a by-product of photosynthesis.

- While the electrons pass through the ETC via Plastoquinone, **hydrogen ions (protons)** from the **stroma** are also tranferred and released into the thylakoid lumen. This results in a higher concentration of hydrogen ions (proton gradient) in the lumen.

- As a result of the proton gradient in the lumen, **hydrogen ions are transferred to ATP synthase** and provide the energy needed for combining ADP and Pi to produce ATP.
- Cytochrome b6f transfers the electrons to Plastocyanin which then transports them to **Photosystem I.**

The electrons have now arrived at PSI.

- They again receive energy, but this time from light absorbed by P700 chlorophyll molecules.
- The electrons are transferred to mobile carrier, **ferredoxin.**
- They are then transported to ferredixin NADP reductase (FNR), which is the final electron acceptor. At this point the electrons and a hydrogen ion are combined with NADP+ to produce NADPH.
- The lost electrons from PSI are replaced by electrons from PSII via the electron transport chain.

Flow of Electrons

Photosystem II ——> b6-f complex ——> Photosystem I —–> NADP reductase

Role of Photolysis

Utilizes light to split water into the following:

- Electrons – donated to PSII to replace lost electrons
- Hydrogen ions – carried to ATP synthase to provide energy for the production of ATP
- Oxygen – released into the atmosphere as a by-product

Products

- ATP – chemical energy

- NADPH – reducing power/electron donor

2. Light-independent reactions

The reactions of this stage take place in the stroma of the chloroplasts, and they are reactions that do not depend on the presence of light, but to complete them must be preceded by light reactions. The reactions of this stage start with carbon dioxide and need NADPH as well as ATP.

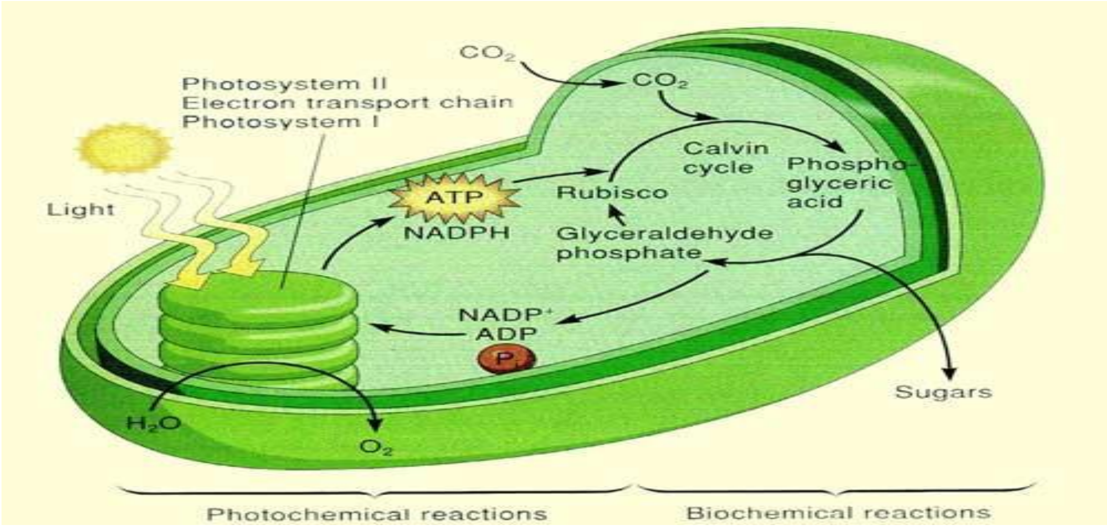
One of the steps that was surrounded by a lot of mystery in the photosynthesis process from a biochemical point of view is the chemical and enzymatic nature of the first reaction in which a carbon dioxide molecule is combined with another more complex organic molecule on its way to form glucose. This mystery has been revealed using radioactive CO2 ($^{14}CO_2$) in an experiment performed by Calvin on algae ,that were exposed to light energy for a very short period, which led to their brilliance, and some algae extracts were taken and examined to detect the first compound that was formed and radioactive CO2 was included in its composition. As a result, 3-Phosphoglyceric acid was among the first compounds that radioactive CO2 entered in its composition. The result of the chemical analysis of this acid also found that most of the radioactive carbon was in the carboxyl group, and therefore it was found that the first step of CO2 reduction was the reaction of CO2 with a phosphorous sugar containing 5 carbon atoms.

The cycle can be clarified as follows

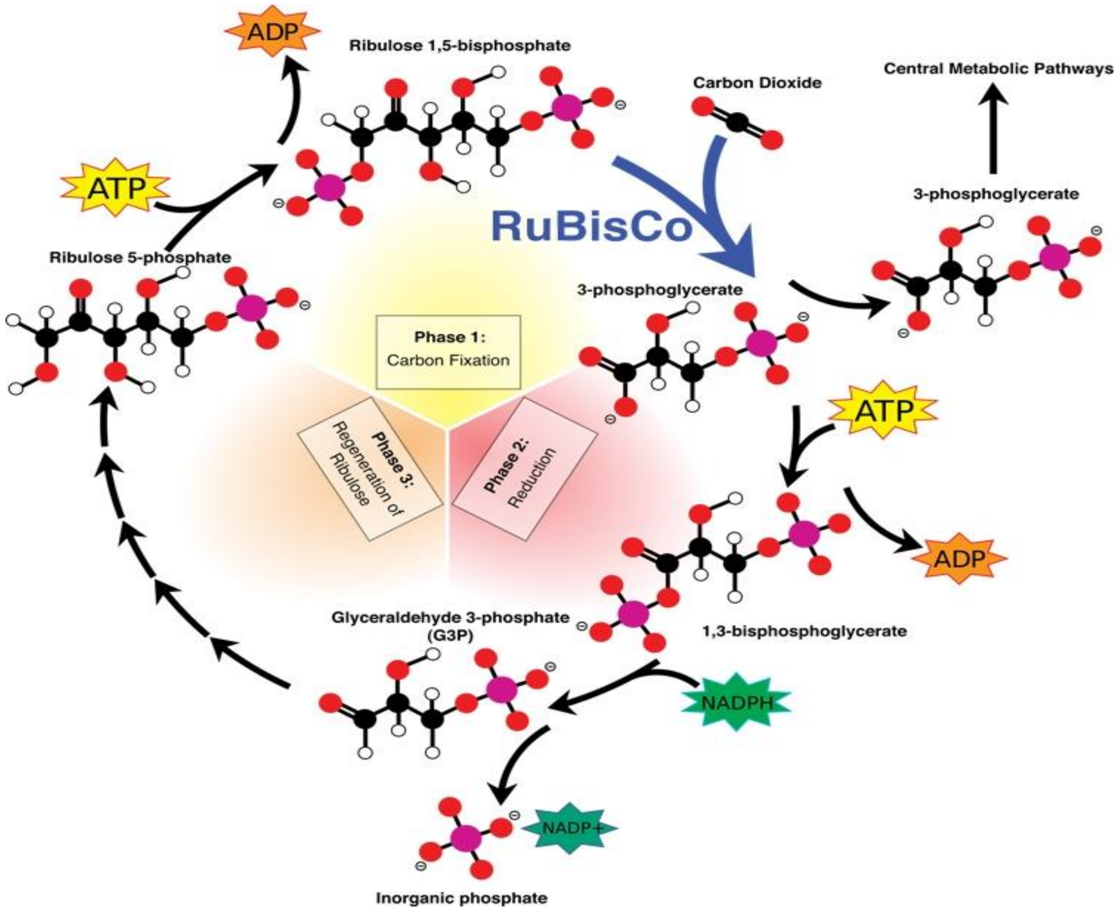
In the Calvin cycle, **6 molecules of CO2 are used**, and the result is **one molecule of glucose.** As for the details of the cycle, we note that **6 molecules of CO2** combine with **6 molecules of a phosphorous sugar containing 5 carbon atoms(Ribulose, 1,5-bisphosphat**e), and this reaction results in **12 molecules of 3 - phosphoglycerate** .The reaction requires an enzyme called **Rubisco**, **then 12 molecules of ATP** are used, which gives a **molecule of phosphate to 3-phosphoglycerate** to convert to **1,3-bisphosphoglycerate**.

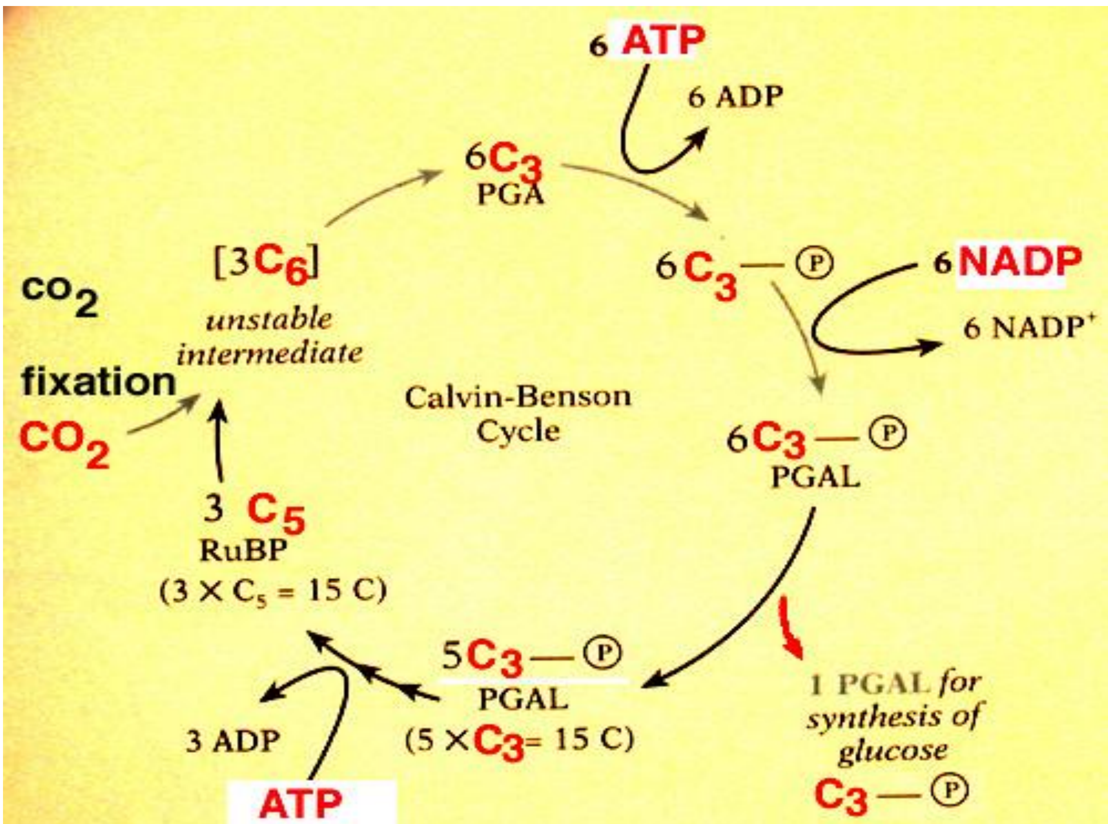
NADPH gives **hydrogen with electrons** to this compound to give **12 molecules of glyceraldehyde-3-phosphate** . **Two of the 12 molecules** were left to form a **molecule of glucose**, while the remaining **10 molecules** are transformed by the Rubisco enzyme into **Ribulose-5-**

phosphate, which later converts to **Ribulose, 1,5-bisphosphate**. It is noted from the **dark reactions** that ADP and NADP are produced, which are used in the light reactions again to produce ATP and NADPH.



This pathway is called the Calvin pathway or the triple carbon pathway, and the plants in which this pathway is found are called C3-plants, and most of them live in temperate and cold regions


ADP
Ribulose 1,5-bisphosphate
Carbon Dioxide
Central Metabolic Pathways
ATP
RuBisCo
3-phosphoglycerate
Ribulose 5-phosphate
3-phosphoglycerate
Phase 1:
Carbon Fixation
Phase 3:
Regeneration of
Ribulose
Phase 2:
Reduction
ATP
ADP
Glyceraldehyde 3-phosphate
(G3P)
1,3-bisphosphoglycerate
NADPH
NADP+
Inorganic phosphate


6 ATP
6 ADP
6C3
PGA
[3C6]
unstable
intermediate
6C3 — (P)
6 NADP
6 NADP+
CO2
fixation
CO2
Calvin-Benson
Cycle
6C3 — (P)
PGAL
3 C5
RuBP
(3 × C5 = 15 C)
5C3 — (P)
PGAL
(5 × C3 = 15 C)
3 ADP
ATP
1 PGAL for
synthesis of
glucose
C3 — (P)

Studies have also shown that in some plants, especially tropical ones, the first stable compound in the photosynthesis process is **Oxaloacetic acid (OAA)**. These plants are known as the **C4- plants**, and these plants usually grow perfectly under conditions characterized by high light intensity and are characterized by the following:

1.They have a high photosynthetic rate of 40-80 mgco2/dm²/h, while the C3- plants have a photosynthetic rate of 15-40 mgco2/dm²/h

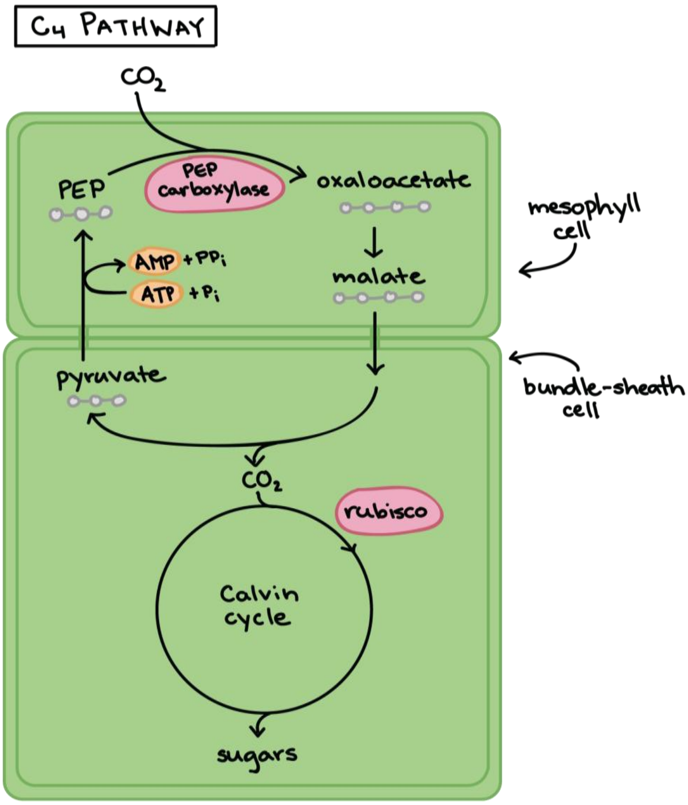
2.Do not have the phenomenon of photorespiration, or it may occur at a very low rate.

3. They are characterized by a low amount of water lost compared to the C3- plants .

4. They have an anatomical structure of the leaf that is different from the anatomical structure of the leaf in C3- plants.

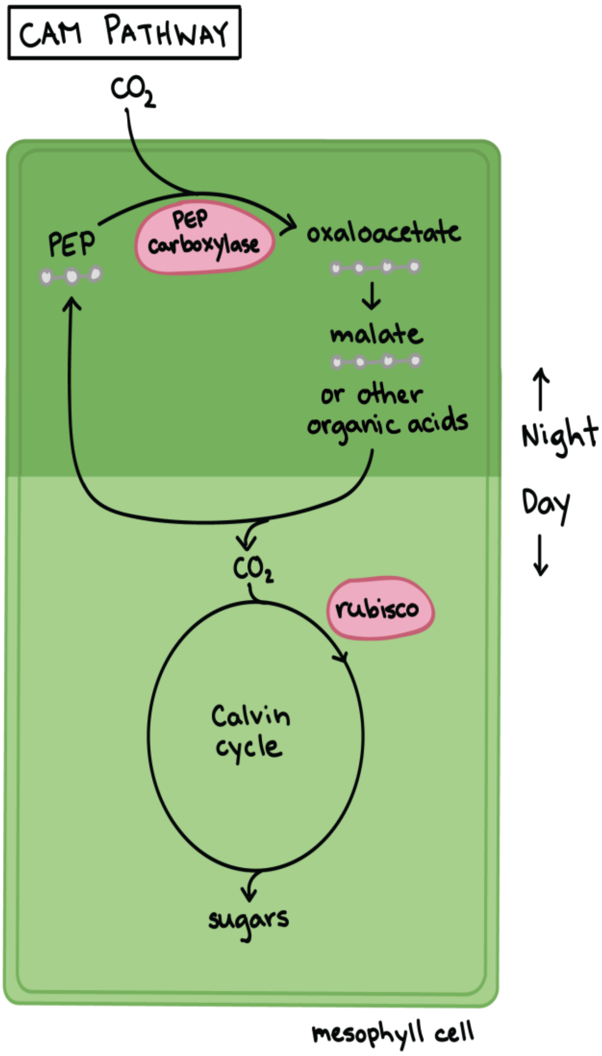
5.Tolerance of salinity and sodium is essential because they increase the activity of the enzyme PEP-Carboxylase

In this pathway, known as the Hatch and Slack pathway, which is found in some plants, especially **tropical and subtropical plants**, such as corn and sugar cane, the acceptor for carbon dioxide is PEP to form OAA, which is reduced to malic acid, which moves from the mesophyll cells where there are grana to the bundle sheath as CO_2 reduced to the level of carbohydrates during the Calvin cycle. These plants are called C4-plants, and they are more efficient in the photosynthesis process than the C3-plants, as they have two pathways, Hats and Slack, as well as the Calvin pathway. As for the C3-plants, only the Calvin pathway occurs.



Crassulacean acid metabolism (CAM) - Photosynthesis

Some plants such as aloe, which grow in an acidic environment, have fleshy stems and the rate of transpiration is low, so they are called succulents. These plants fix CO2 as it occurs in C4-plants. These plants open their stomata at night and close during the day, so CO2 enters at night through the stomata and binds to the receptor PEP which is reduced to OAA and then to MA, which is stored in the vacuole,while in the daytime, in the presence of light, the stomata are closed, and the MA transferred to the chloroplast, as CO2 is removed from the MA and it turns into PEP, and the CO2 enters the Calvin cycle, and the pH of the vacuole decreases .



Photorespiration

Rubisco enzyme is one of the most available enzymes and it is distinguished by its active site and ability to bind to CO2 and O2, which depends on the relative concentration of both, although it is more inclined to bind to CO2. In C3-plants some O2 molecules bind with the enzyme and lead to decrease in photosynthesis rate then , instead of ribulose-1,5-bisphosphate (RuBP) being transformed into two 3PGA molecules, it will bind with O2 to form one molecule of two-carbon compound, phosphoglycolate and 3PGA. This process is called photorespiration. In this process, neither sugars nor ATP nor NADPH are produced, but rather results in CO2 release and energy consumption. C4-plants have ability to increases the CO2 concentration at the enzyme site by forming tetra-carbonic acid in the mesophyll cells and then destroying it in the bundle sheath cells. Thus, these plants are characterized by high productivity and resistance to high temperatures to prevent photorespiration.

Respiration

Respiration is the process of oxidation of carbohydrates and sometimes fats or any other organic matter with oxygen. Usually the organic compound is completely oxidized so that the final products are carbon dioxide CO2 and H2O water with a release of energy. In the case of the sugar substance hexose (glucose or fructose) The amount of energy produced is 686 K Cal.mole^{-1}, and this type called aerobic respiration.

C6H12O6 + 6O2 ——> 6CO2 + 6H2O +686 cal . mole^{-1}

C6H12O6 + 6O2 ——> 6H20 + 6CO2 + 686 kilocalories of energy/mole of glucose

When plant tissues are deprived of oxygen, the plant resorts to anaerobic respiration, as the organic compounds that are oxidized in the process of respiration are partially destroyed so that the products are carbon dioxide CO2 and ethanol, in the case of hexose, the reaction is as follows:

$C_6H_{12}O_6$ ——> $2CO_2$ + 2C2H_5OH + 56 K cal . mole^{-1}

It is well known that yeast and some types of bacteria can partially destroy some compounds under anaerobic conditions. In the case of the action of yeast on glucose, the products are also carbon dioxide CO2 and alcohol. This type of respiration is called alcoholic fermentation.

Studies have shown that the process of respiration in general does not take place in one step, but it includes three steps that can be summarized as follows:

1.The glycolysis stage:

Glycolysis stage begins with hexose and ends with pyruvic acid. The reactions of this phase occur in the cytoplasm or may occur in the plasma membrane and low amount of energy is released in the form of ATP .This stage does not need oxygen O2 and can be divided into two basic steps:

A-Convert glucose to fructose

Glucose ——> Fructose – 1,6 – diphosphate

The phosphorylation of the sugary substance is usually done at the expense of the energy-rich compounds ATP.

B - the division of this compound into two ones

Dihydroxyacetone diphosphate + Phosphoglyceraldehyde (PGA),

and this reaction is activated by the enzyme (Aldolase) .

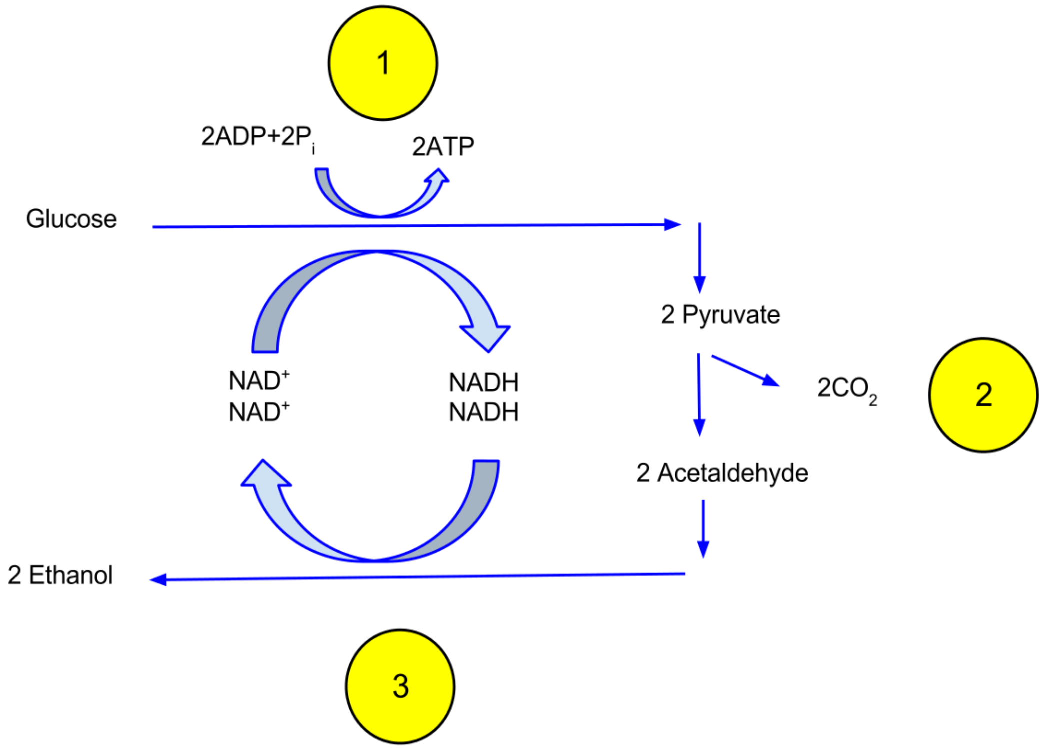
As for the first compound, it does not enter into the reaction, but gradually turns into the second compound as its concentration decreases, and then it turns into (PGA) .

PGA $\rightarrow$ Phosphoglyceric acid $\rightarrow$ Phosphopyruvic acid$\rightarrow$ Pyruvic acid.

By the end of these steps, a single molecule of fructose (Fructose - 1,6 - diphosphate) was broken down, two molecules of pyruvic acid and two molecules of (ATP) as well as coenzyme ($NADH^+ + H^+$).

Steps of alcohol formation from pyruvic acid in anaerobic respiration and alcoholic fermentation

The alcoholic fermentation process begins when the pyruvic acid molecule loses a carbon dioxide molecule CO2, where it turns into acetaldehyde , the enzyme decarboxylase helps or activates this reaction, and then it is reduced to ethanol. The reaction can be expressed by the following equations.



The enzymes responsible for alcoholic fermentation are present in the fruits and on this basis they can carry out this process and obtain the necessary energy for their vitality in the absence of oxygen O2.

Fruit tissues cannot survive for a long time under anaerobic conditions for two reasons: 1. The lack of energy produced. 2. The formation of some substances with a harmful effect of protoplasm (ethanol).

2. The Kreb's cycle:

This stage occurs in the mitochondria and requires oxygen and its products are non-toxic. In it, complete oxidation of carbohydrates or organic acids and others occurs. At this stage, the pyruvic acid is oxidized to carbon dioxide CO2 and water H2O , through a circular chain of reactions known as **tricarboxylic acid cycle (TCA) or Kreb's cycle**.

In this cycle pyruvic acid enters into a series of reactions characterized by the formation of certain organic acids and in some stages CO2 releases .Reactions of this stage depend on the presence of oxygen and are activated by oxidizing enzymes present in the mitochondria..

Steps of the Krebs Cycle

The Krebs cycle actually begins when acetyl-CoA combines with a four-carbon molecule called OAA (oxaloacetate) . This produces citric acid, which has six carbon atoms. This is why the Krebs cycle is also called the citric acid cycle.

After citric acid forms, it goes through a series of reactions that release energy. The energy is captured in molecules of NADH, ATP, and $FADH_2$, another energy-carrying compound. Carbon dioxide is also released.

The final step of the Krebs cycle regenerates OAA, the molecule that began the Krebs cycle. This molecule is needed for the next turn through the cycle. Two turns are needed because glycolysis produces two pyruvic acid molecules when it splits glucose.

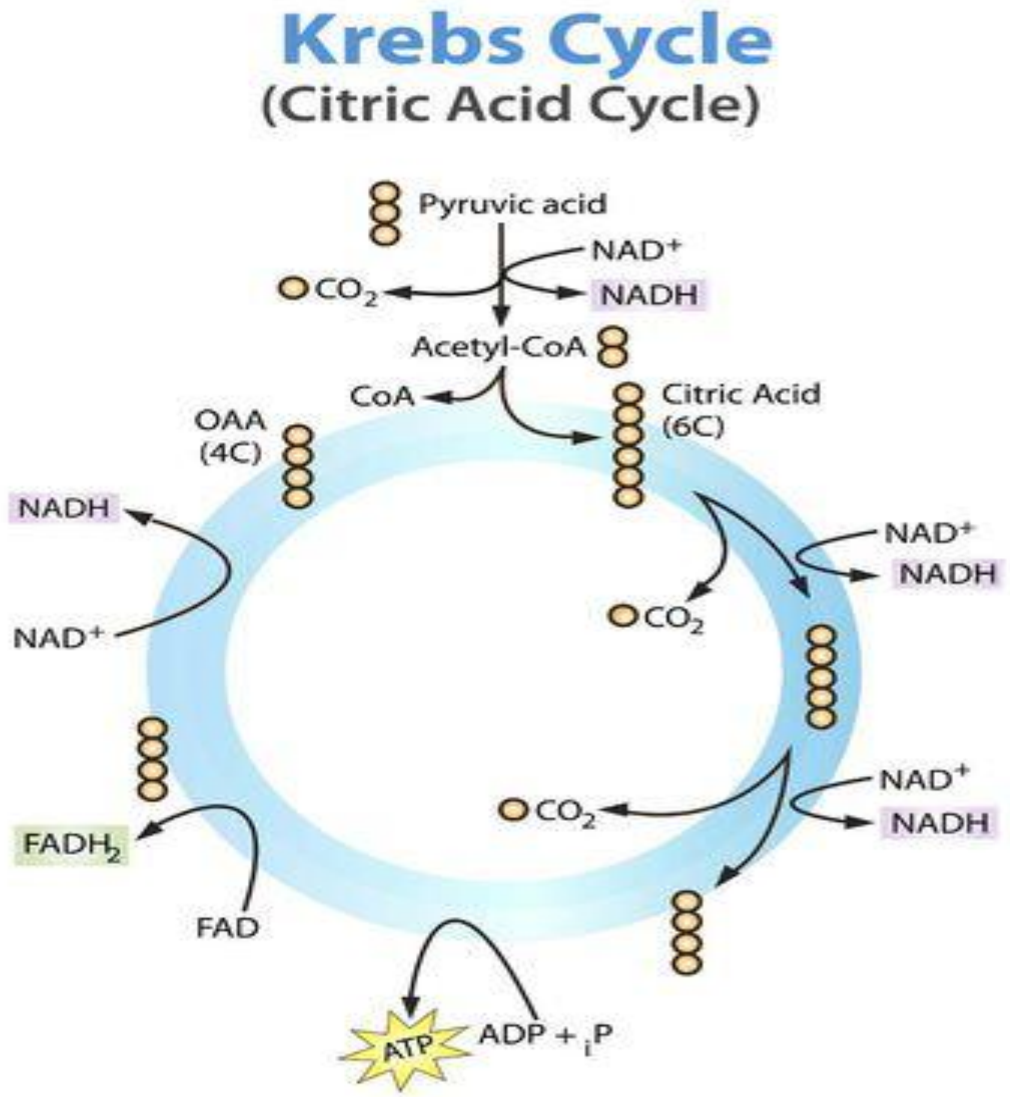
Results of the Krebs Cycle.

After the second turn through the Krebs cycle, the original glucose molecule has been broken down completely. All six of its carbon atoms have combined with oxygen to form carbon dioxide. The energy from its chemical bonds has been stored in a total of 16 energy-carrier molecules. These molecules are:

4 ATP (including 2 from glycolysis)

10 NADH (including 2 from glycolysis)

2 FADH2



3. The electron transport chain

In in this stage, about 95% of ATP produced during the process of aerobic respiration is formed, and ATP is formed by the transfer of electrons from the electronic receptors NADH + H + and FADH2 that were formed during the glycolysis and the kerbs cycle. Meanwhile, the energy of these electrons is converted into chemical energy in the form of ATP, as the hydrogen atoms in NADH2 and FADH2 cannot directly combine with oxygen and form water, but must pass through a series of reactions before the formation of water. This chain is called the electron transport chain, or the Cytochrome system.

The transfer of electrons occurs in the inner membrane of mitochondria, as the hydrogen that has been removed from the glucose molecule is captured by the electron receptor NAD+ ,that reduces it to NADH + H +. This compound is the first receptor for electrons in the cytochrome system. The next step is to pass the hydrogen atoms from **NADH + H +** to **FAD** to be reduced to **FADH2** .The process of ionization of hydrogen atoms takes place into protons that are released into the cytoplasm in the form of H + and electron, used in the cytochrome system.When the electrons reach the end of the system, they are released by the enzyme, , **Cytochrome oxidase** , to O2, which captures the **protons** produced from water ionization and forms **water,** which is one of the products of the respiration process. During the passage of electrons through the cytochrome system, its energy level decreases, and the energy difference is used to form energy-rich phosphorous bonds by converting ADP to ATP., as each pair of electrons passes through the cytochrome system, we have three molecules of ATP. The number of ATP molecules that are formed upon complete oxidation of a gram molecular weight (one mole) from glucose to carbon dioxide CO2 and H2O water, are **38 molecules of ATP.**

Summary: the three stages of Aerobic Respiration

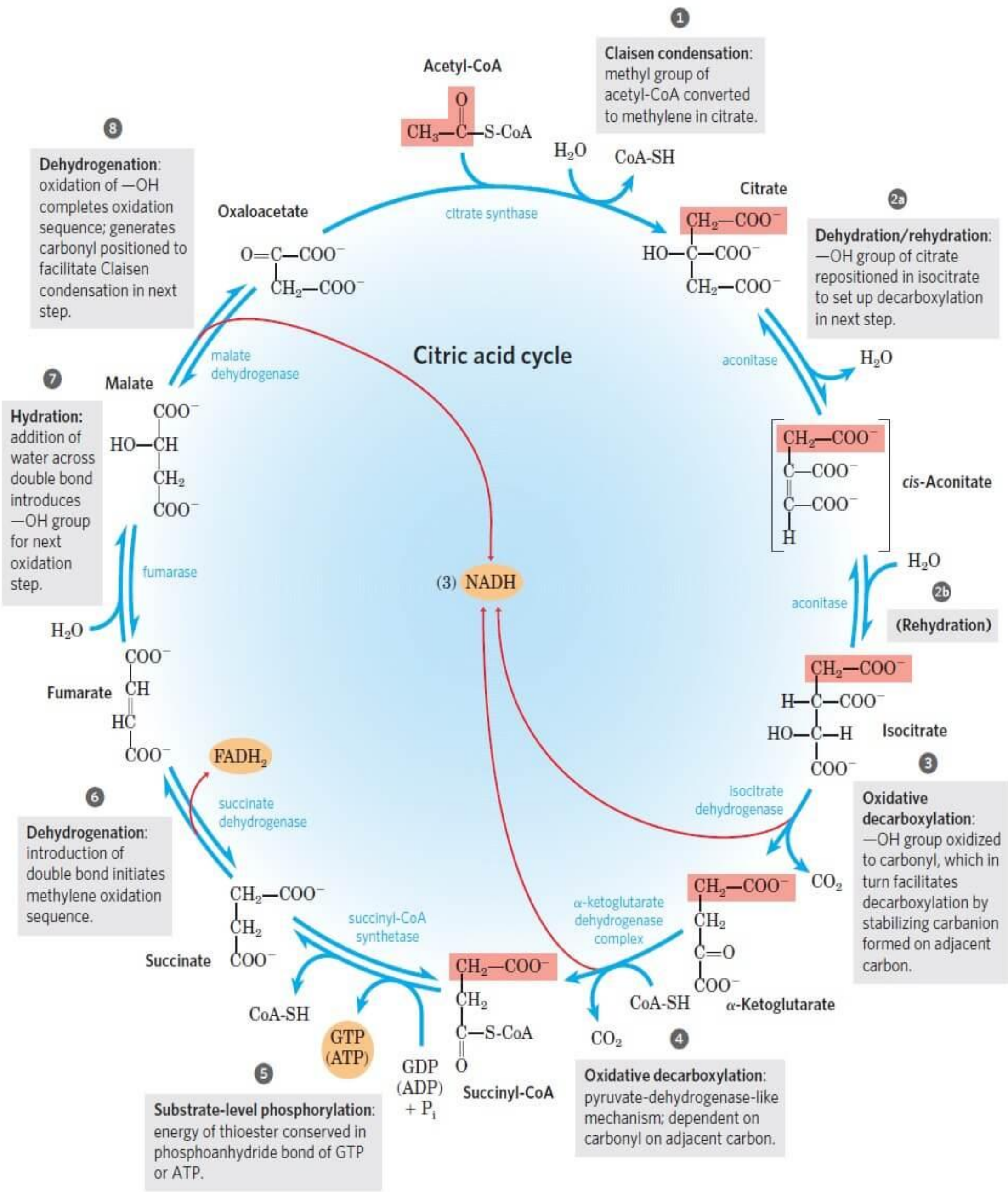
Glycolysis	***Citric acid cycle***	***Electron transport chain***
Cytoplasm	**Mitochondria**	**Mitochondria**
Breaks down Glucose to Pyruvate	**Turns Pyruvate into CO_2**	**Converts NADH and $FADH_2$ into ATP**

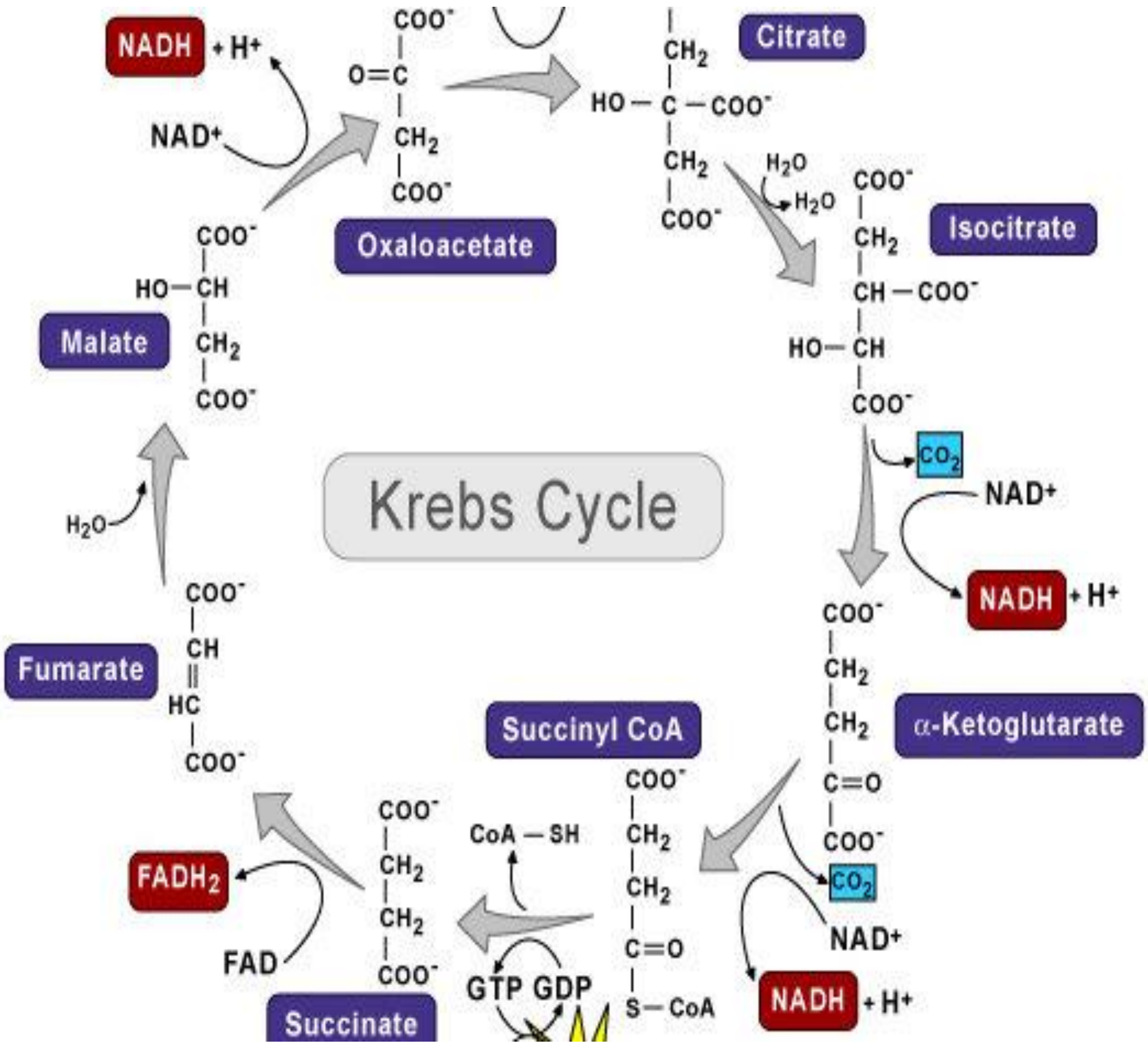
2 ATP **2 NADH**	**2 ATP** **6 NADH** **2 $FADH_2$**	**32-34 ATP**

Krebs cycle Enzymes

In eukaryotic cells, the enzymes that catalyze the reactions of the citric acid cycle are present in the matrix of the mitochondria except for succinate dehydrogenase and aconitase, which are present in the inner mitochondrial membrane.
One common characteristic in all the enzymes involved in the citric acid cycle is that nearly all of them require Mg^{2+}
The following are the enzymes that catalyze different steps throughout the process of the citric acid cycle:

1. Citrate synthase
2. Aconitase
3. Isocitrate dehydrogenase
4. α-ketoglutarate
5. Succinyl-CoA synthetase
6. Succinate dehydrogenase
7. Fumarase
8. Malate dehydrogenase


Citric acid cycle
Acetyl-CoA
Claisen condensation: methyl group of acetyl-CoA converted to methylene in citrate.
citrate synthase
CoA-SH
Oxaloacetate
Citrate
Dehydration/rehydration: —OH group of citrate repositioned in isocitrate to set up decarboxylation in next step.
aconitase
cis-Aconitate
(Rehydration)
Isocitrate
isocitrate dehydrogenase
Oxidative decarboxylation: —OH group oxidized to carbonyl, which in turn facilitates decarboxylation by stabilizing carbanion formed on adjacent carbon.
α-Ketoglutarate
α-ketoglutarate dehydrogenase complex
Oxidative decarboxylation: pyruvate-dehydrogenase-like mechanism; dependent on carbonyl on adjacent carbon.
Succinyl-CoA
succinyl-CoA synthetase
GTP (ATP)
GDP (ADP) + Pi
Substrate-level phosphorylation: energy of thioester conserved in phosphoanhydride bond of GTP or ATP.
Succinate
succinate dehydrogenase
FADH2
Dehydrogenation: introduction of double bond initiates methylene oxidation sequence.
Fumarate
fumarase
Malate
Hydration: addition of water across double bond introduces —OH group for next oxidation step.
malate dehydrogenase
Dehydrogenation: oxidation of —OH completes oxidation sequence; generates carbonyl positioned to facilitate Claisen condensation in next step.
(3) NADH

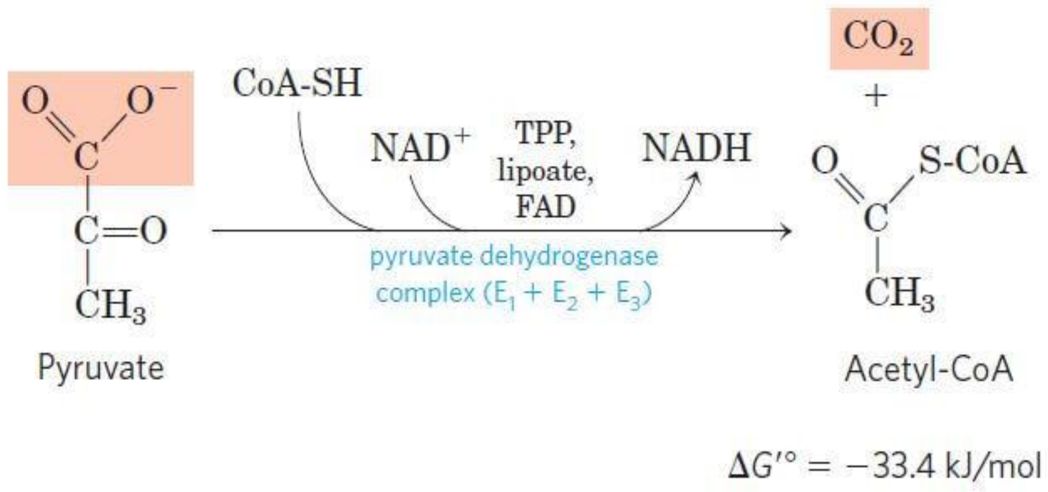


After glycolysis, in aerobic organisms, the pyruvate molecules are decarboxylated to form acetyl CoA and CO_2.

Oxidative Decarboxylation of pyruvate to Acetyl CoA

- The **oxidative decarboxylation of pyruvate** forms a link between **glycolysis** and the **citric acid cycle**.
- In this process, the pyruvate derived from glycolysis is oxidatively decarboxylated to acetyl CoA and CO_2 catalyzed by the **pyruvate dehydrogenase complex** in the mitochondrial matrix in eukaryotes and in the cytoplasm of the prokaryotes.
- From **one molecule of glucose**, **two molecules of pyruvate are formed**, each of which forms **one acetyl CoA** along with **one NADH** by the end of the pyruvate oxidation.

- The acetyl CoA formed from pyruvate oxidation, fatty acid metabolism, and amino acid pathway then enter the citric acid cycle.



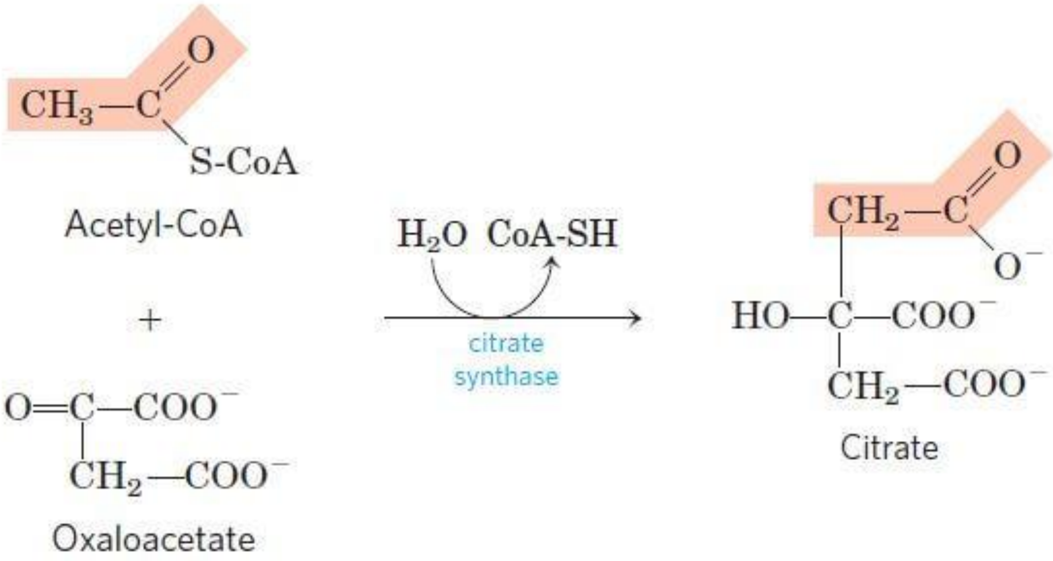
The following are the eight enzyme-catalyzed reactions/ steps in the aerobic oxidation of glucose through the citric acid cycle:

Step 1: Condensation of acetyl CoA with oxaloacetate

- The first step of the citric acid cycle is the joining of the four-carbon compound oxaloacetate (OAA) and a two-carbon compound acetyl CoA.

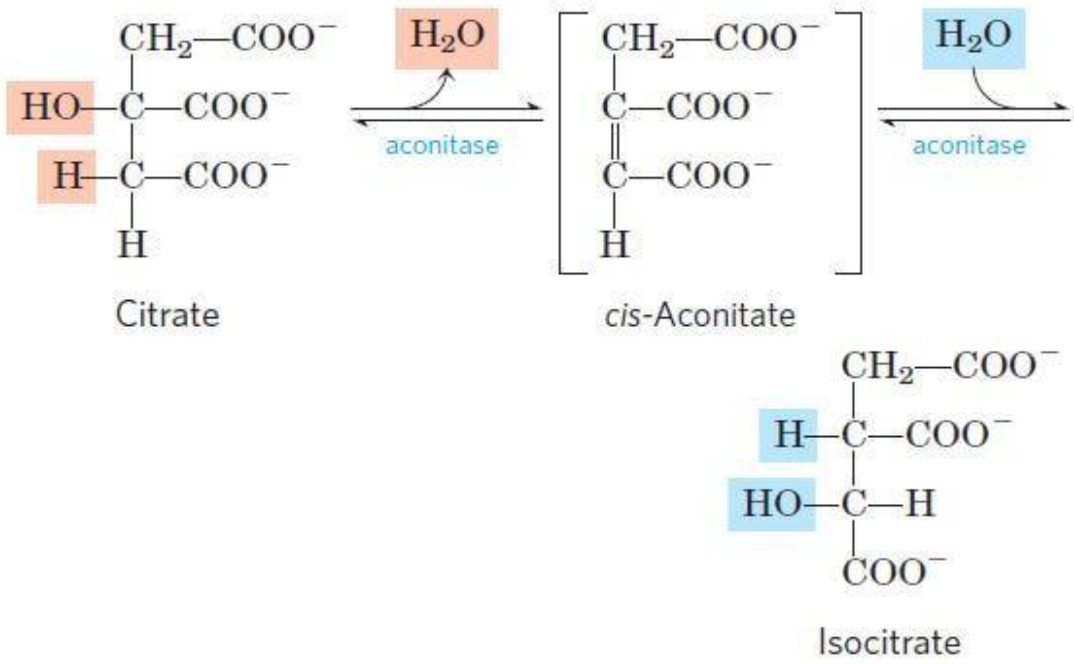
- The oxaloacetate reacts with the acetyl group of the acetyl CoA and water, resulting in the formation of a six-carbon compound citric acid, CoA.

- The reaction is catalyzed by the enzyme **citrate synthase** that condenses the methyl group of acetyl CoA and the carbonyl group of oxaloacetate resulting in citryl-CoA which is later cleaved to free coenzyme A and to form citrate.



Step 2: Isomerization of citrate into isocitrate

- Now, for further metabolism, citrate is converted into isocitrate through the formation of intermediate cis-aconitase.
- This reaction is a reversible reaction catalyzed by the enzyme (**aconitase**).
- This reaction takes place by a two-step process where the first step involves dehydration of citrate to cis-aconitase, followed by the second step involving rehydration of cis-aconitase into isocitrate.



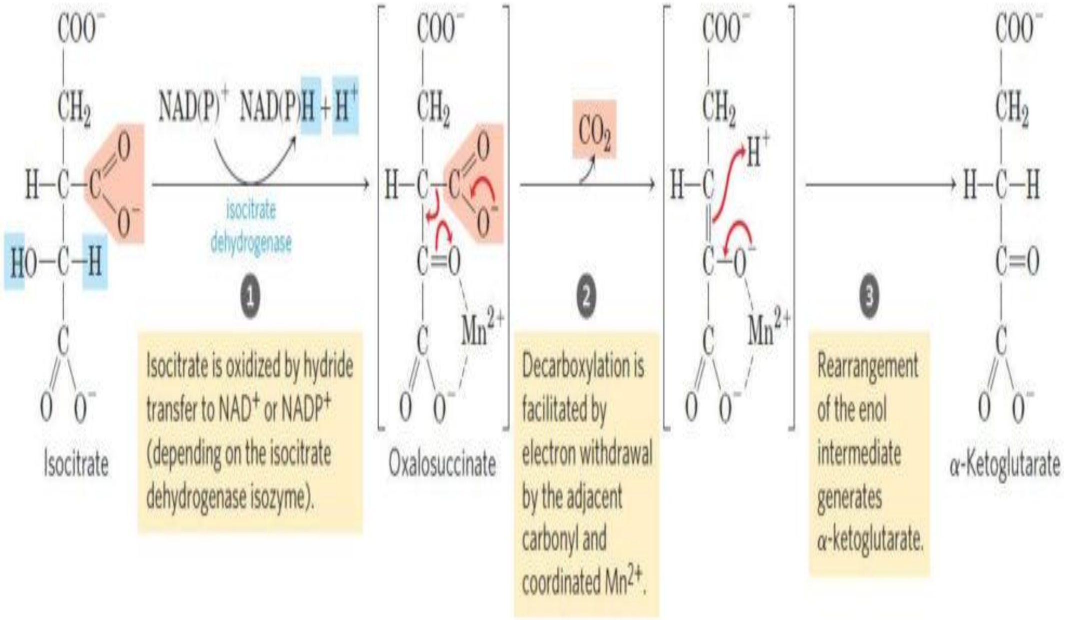
Step 3: Oxidative decarboxylations of isocitrate

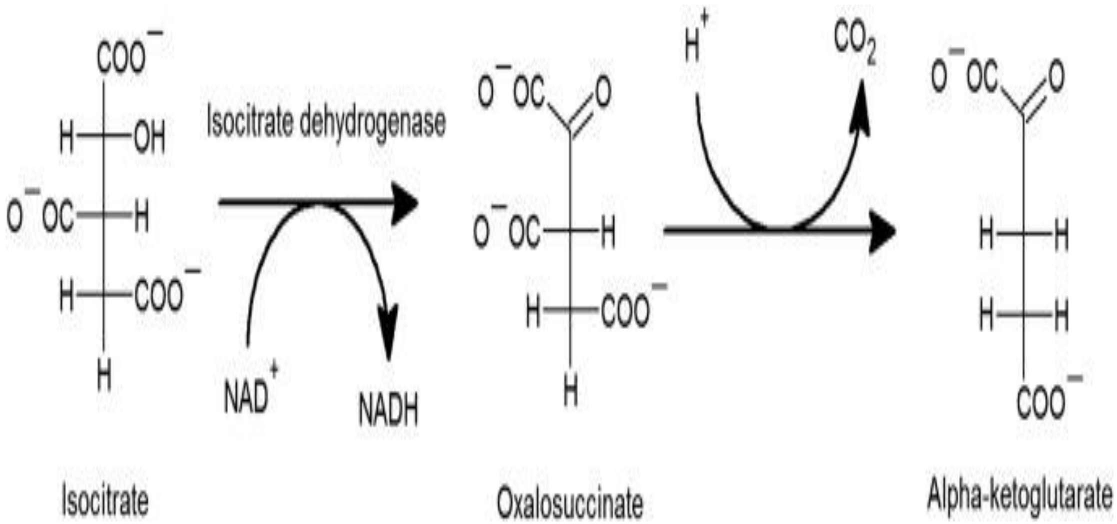
Oxidative decarboxylation reactions :

are oxidation reactions in which a carboxylate group is removed, forming carbon dioxide. They often occur in biological systems: there are many examples in the citric acid cycle.

- The third step of the citric acid cycle is the first of the four oxidation-reduction reactions in this cycle.
- **Isocitrate** is oxidatively decarboxylated to form a five-carbon compound, **α-ketoglutarate** catalyzed by the enzyme **isocitrate dehydrogenase**.
- This reaction, like the second reaction, is a two-step reaction.
- In the first step, **isocitrate** is dehydrogenated to **oxalosuccinate** while the second step involves the **decarboxylation** of **oxalosuccinate** to **α-ketoglutarate**.
- Both the reactions are irreversible and catalyzed by the same enzyme.

- The first step, however, results in the formation of NADH while the second step involves the release of CO_2.



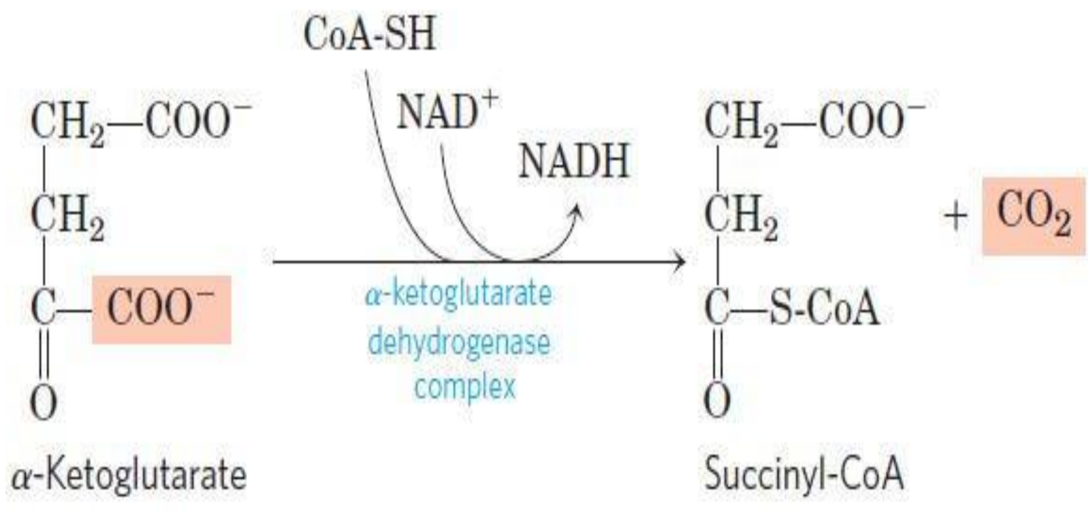


Step 4: Oxidative decarboxylation of α-ketoglutarate

- This step is another one of the oxidation-reduction reactions where α-ketoglutarate is oxidatively decarboxylated to form a four-carbon compound, succinyl-CoA, and CO_2.

- The reaction irreversible and catalyzed by the enzyme complex α-ketoglutarate dehydrogenase complex found in the mitochondrial space.

- This reaction is similar to the oxidative decarboxylation of pyruvate involving the reduction of NAD^+ into NADH.



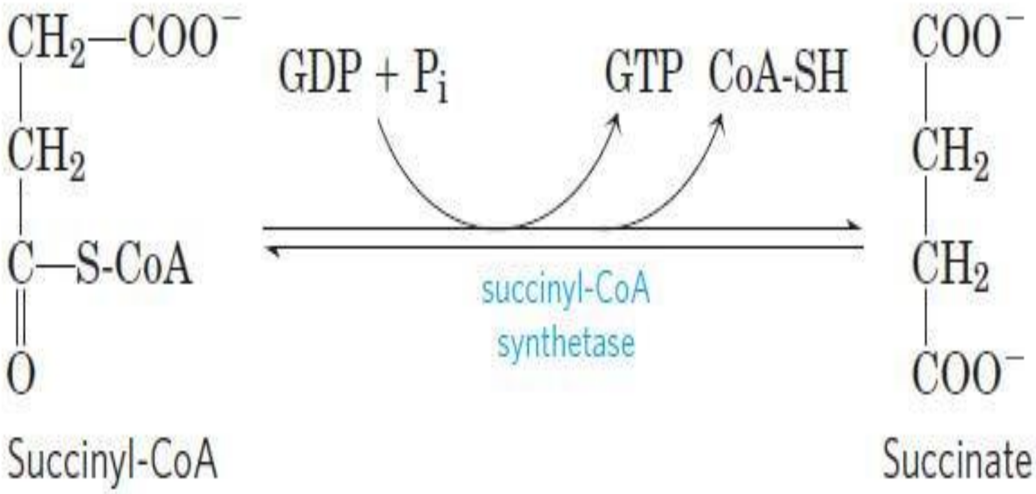
Step 5: Conversion of succinyl-CoA into succinate

- In the next step, succinyl-CoA undergoes an energy-conserving reaction in which succinyl-CoA is cleaved to form succinate.

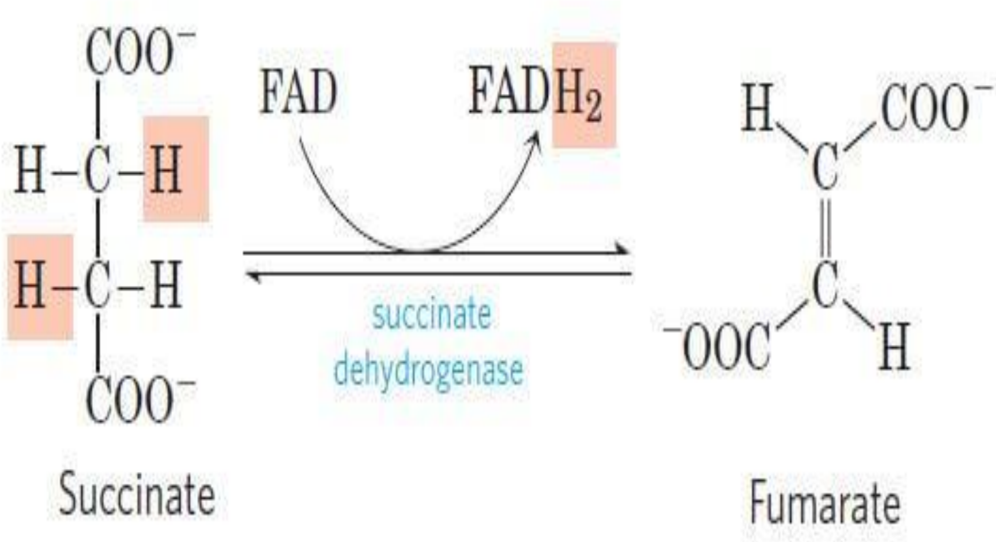
- This reaction is accompanied by phosphorylation of guanosine diphosphate (GDP) to guanosine triphosphate (GTP).

- The GTP thus formed then readily transfers its terminal phosphate group to ADP forming an ATP molecule.

- The reaction is catalyzed by the enzyme, succinyl-CoA synthase.

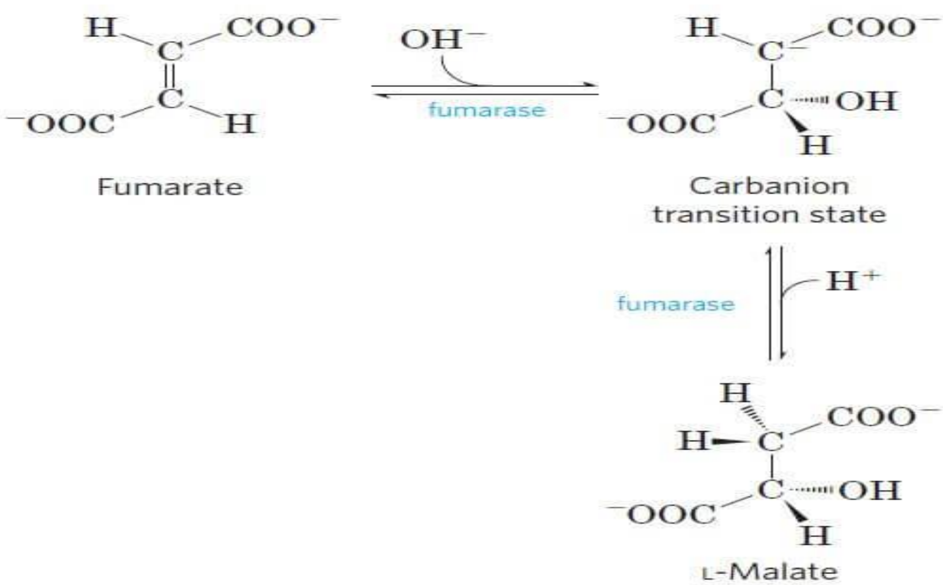


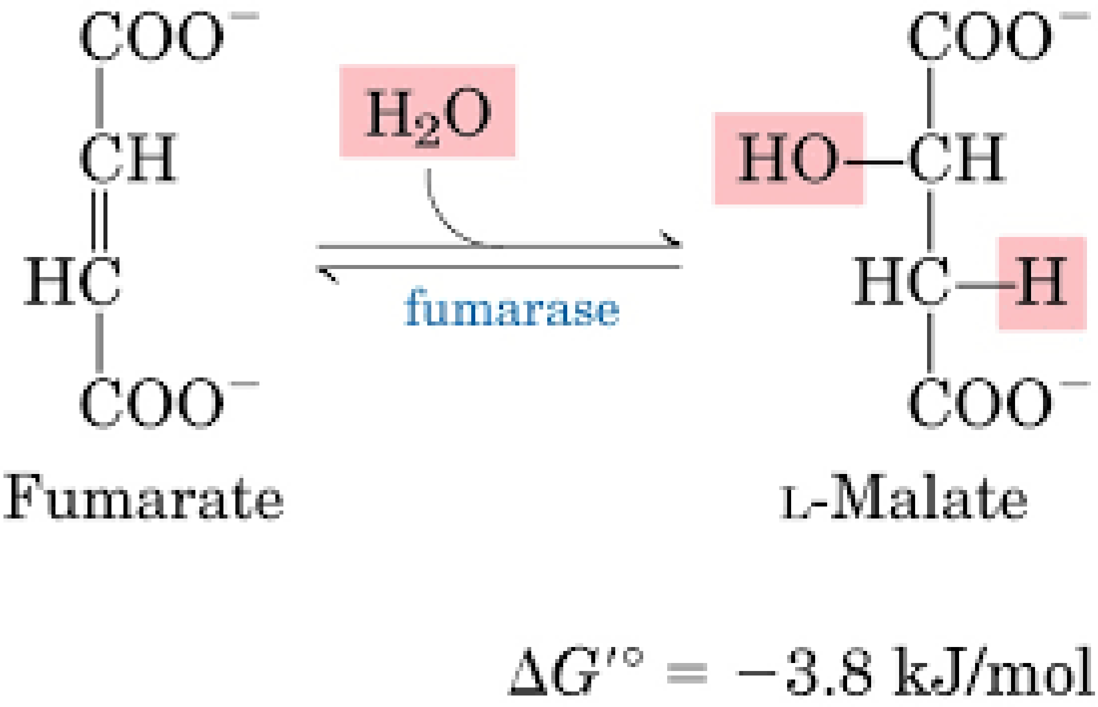
- ***Step 6: Dehydrogenation of succinate to fumarate***
- Here, the succinate formed from succinyl-CoA is dehydrogenated to fumarate catalyzed by the enzyme complex succinate dehydrogenase found in the intramitochondrial space.
- This is the only dehydrogenation step in the citric acid cycle in which NAD^+ doesn't participate.
- Instead, another high-energy electron carrier, flavin adenine dinucleotide (FAD) acts as the hydrogen acceptor resulting in the formation of $FADH_2$.
- The $FADH_2$ then enters the electron transport chain transferring the electrons to ubiquinone also known as coenzyme Q (Q), finally forming 2ATPs.



Step 7: Hydration of fumarate to malate

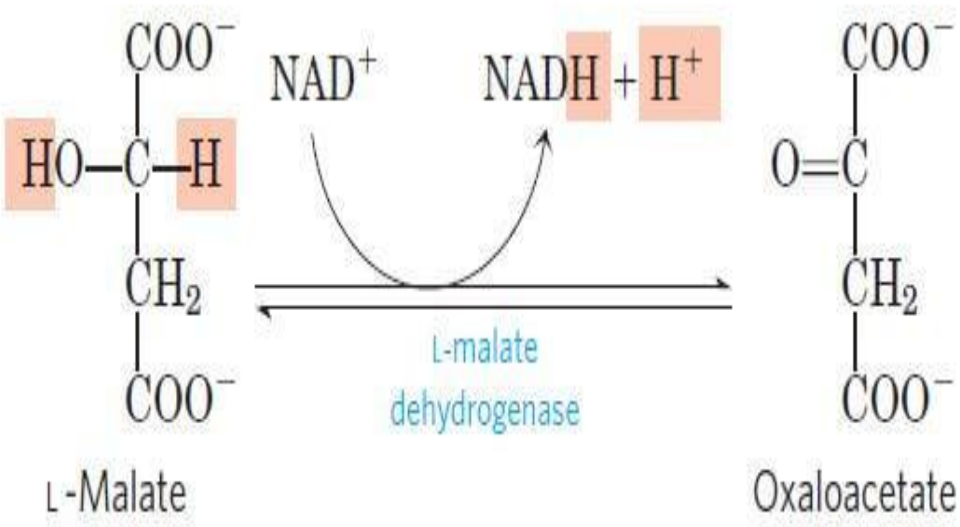
- The fumarate is reversibly hydrated to form L-malate in the presence of the enzyme fumarate hydratase.
- As it is a reversible reaction, the formation of L-malate involves hydration, whereas the formation of fumarate involves dehydration.





Step 8: Dehydrogenation of L-malate to oxaloacetate

- The last step of the citric acid cycle is also an oxidation-reduction reaction where L-malate is dehydrogenated to oxaloacetate in the presence of L-malate dehydrogenase, which is present in the mitochondrial matrix.
- This is a reversible reaction involving oxidation of L-malate and reduction of NAD^+ into NADH.
- Oxaloacetate thus formed, allows the repetition of the cycle and NADH formed participates in the oxidative phosphorylation.
- This reaction completes the cycle.



Post-harvest respiration of horticultural crops

The respiration rate of postharvest horticultural crop is considered a direct evidence of its marketing age, as well as its storage ability , It can be said that the higher the respiration of the postharvest horticultural crop, the faster its deterioration, and its limited marketing and storage life, and vice versa.

The following table shows the division of horticultural crops in terms of their rate of deterioration after harvesting and its relationship to their respiratory rate

Examples	Respiration rate mg co_2/kg/h	The rate of postharvest deterioration of the horticultural crop
Dry legumes, Nuts (Walnuts, almonds), dates	Less 5	**Very slow deterioration**

Onions, garlic, apples, grapes, bulbs of ornamental plants	10-5	**slow deterioration**
Radish without leaves, cucumber, tomato	20-10	**Medium deterioration**
Cauliflower, leafy lettuce	40-20	**fast deterioration**
Okra, green beans	60-40	**Very fast deterioration**
Strawberry, asparagus, parsley	More 60	**Superfast deterioration**

How will you prepare ethylene from acetylene?

Acetylene, is made of two hydrogen and two carbon atoms and is chemically represented as $C2H2$. This hydrocarbon is produced by one of two process, that are: chemical reaction or thermal cracking, using different types of raw materials. Calcium carbide with chemical formula $CaC2$, is the most popular raw material used for the commercial production of acetylene. Calcium carbide is generally by mixing lime and coke in a blast furnace and then the product formed is calcium carbide.

When calcium carbide is reacted with water, it tends to produce acetylene gas and this whole process can be shown by the below balanced chemical equations.

Preparation of acetylene from calcium carbide includes these steps:

- Preparation of CaO from calcium carbonate ($CaCO_3$): $CaCO_3 \rightarrow CaO + CO_2$

- Preparation of calcium carbide by heating (CaO) in presence of coke (C):

$CaO + 3C \rightarrow CaC_2 + CO$

Hence, acetylene can be prepared from calcium carbide by reacting calcium carbide with water and the balanced chemical reaction of this process is given by: $CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$.

And finally, preparation of ethylene by hydrogenation of Acetylene.

$CH \equiv CH + H_2 \longrightarrow CH_2 = CH_2$

Biosynthesis of ethylene

The amino acid Methionine, which contains sulfur in its composition, is the primary substrate for the formation of ethylene, and it was later found that treating the fruits and green parts of the plant with methionine greatly increases the formation of ethylene. The mechanism of biosynthesis of ethylene,is shown in the following two figures .

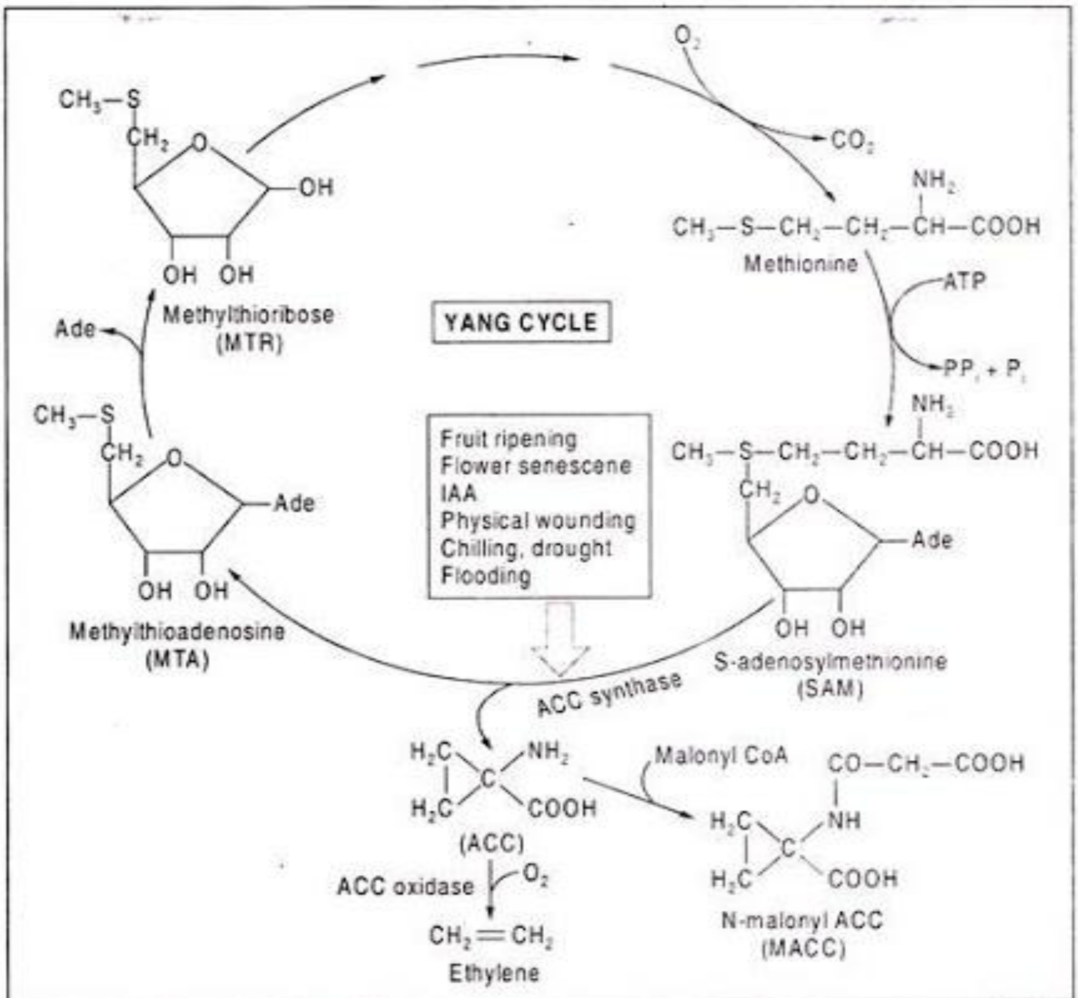
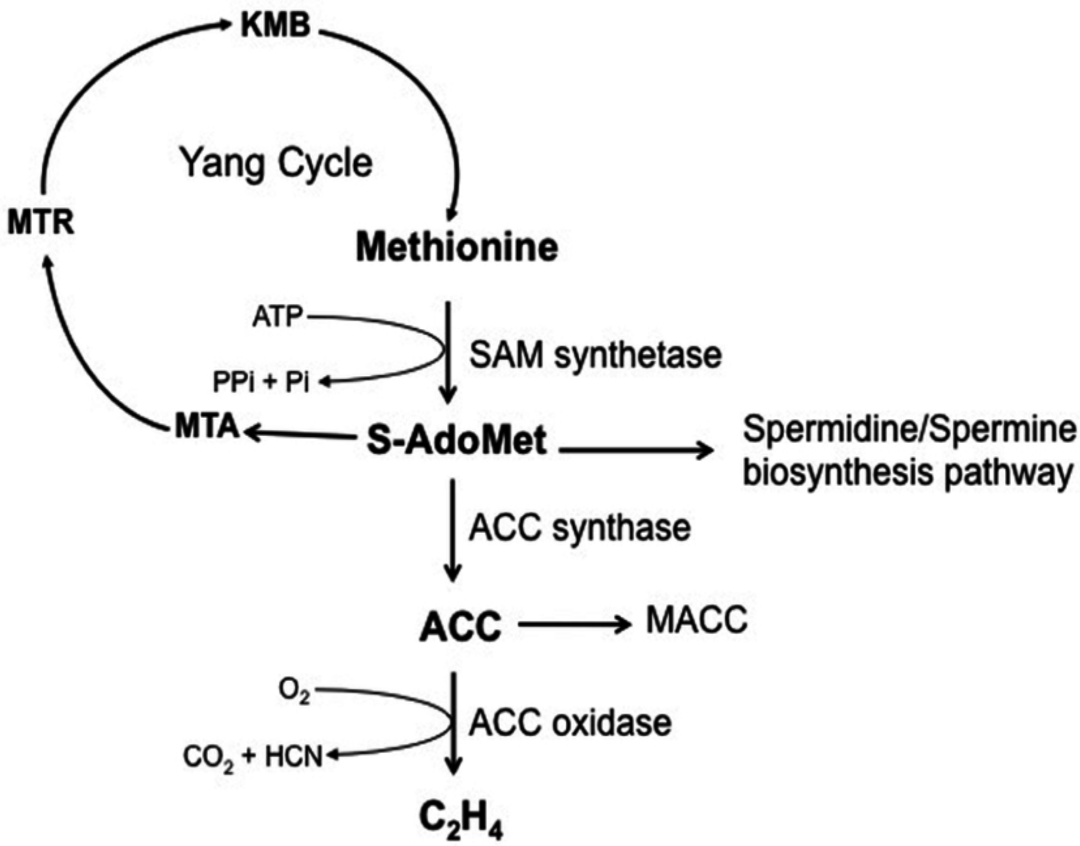


Fig. 13.24 : Methionine cycle (or Yang cycle) in relation to the biosynthesis of ethylene



Ethylene is naturally created in higher plants or in horticultural fruits in three basic ways depending on the physiological age of the plant or fruit or the surrounding environmental conditions.

The first model: -

It is a form of production of ethylene by basal ethylene

It is the ethylene produced by plants or their fruits throughout their life, naturally, and in very small concentrations, not exceeding several parts per million, and this is the basic model for activating some of the necessary biological processes.

The second model: -

Autocatalytic ethylene

it is the result of the action of ethylene to create itself when the fruits reach a limited physiological age, and is evident in the climacteric fruits, where the autocatalytic ethylene begins to appear accompanying the process of development of fruits, which are produced in several parts per million.

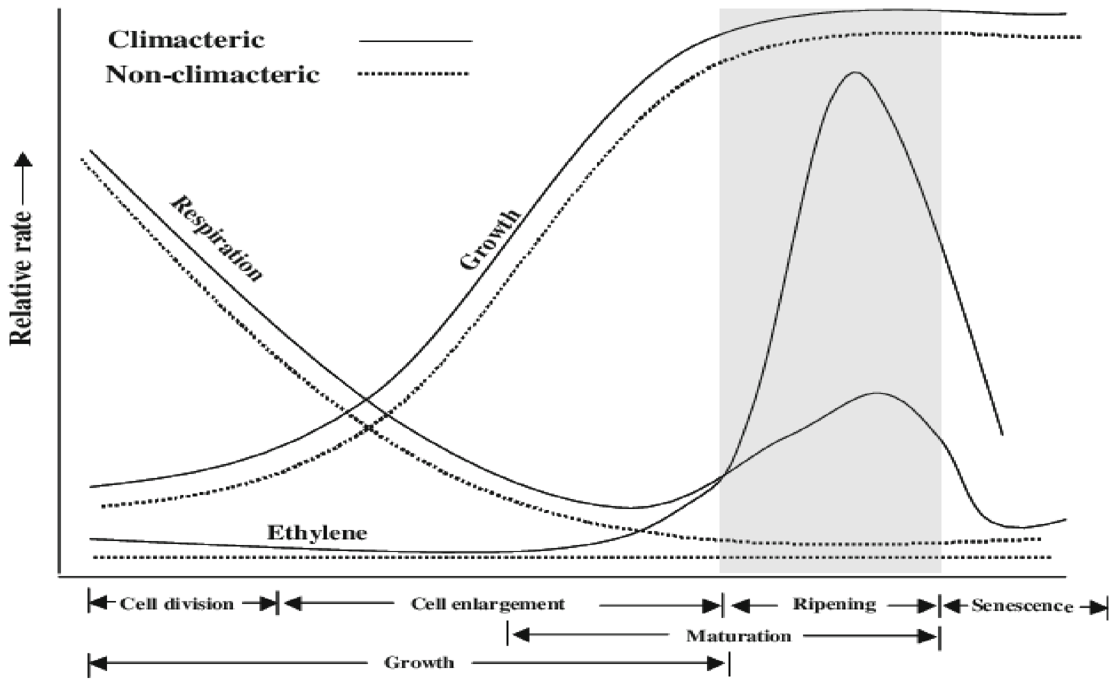
The third model: -

Stress ethylene

This model of ethylene is created when the plant or fruits are exposed to one or more stress factors such as water stress conditions or chemical damage such as treatment with pesticides or heavy metals or exposure to mechanical deformation such as wounds or bruises that the horticultural fruits are exposed to when harvesting or during handling and packing.

Climacteric pattern:

It is the occurrence of a sudden increase in the rate of respiration of fruits when they enter the ripening stage, this phenomenon has been studied in detail in many types of fruits and found that the main reason for their occurrence is the accumulation of ethylene gas in the tissues of the fruits to the levels that lead to this sudden rise in the respiration rate .The fruits were divided into climacteric fruits, which are the fruits whose ripening is accompanied by an increase in the rate of respiration and production of ethylene and are often rapidly deteriorating after harvesting unless their respiratory rate and production of ethylene are reduced by refrigerated storage or storage under modified or controlled air conditions. Examples include tomato fruits, bananas, apples, pears, apricots, and guavas, as for non-climacteric fruits, they are fruits that do not ripen with an increase in the rate of their respiration or production of ethylene, and most of them are slow-deteriorating fruits unless they are picked before their maturity.eggplant, pepper, strawberries, grapes, olives, pomegranates, and all kinds of citrus fruits.



Lipids

The lipids, along with carbohydrates and proteins, are the most important nutritional components of the human, and lipids in particular are very important from a biochemical point of view for two main reasons, the first of which is the high energy contained in the fat store inside the body, which greatly exceeds the energy stored in the form of carbohydrates and the second reason is the role that these compounds play in cellular structures In addition, it is important from a commercial point of view, as soaps and detergents are extracted from it, and some oils have a role in the manufacture of dyes.

Lipid are heterogeneous organic compounds that contain atoms of carbon, hydrogen, oxygen and the last two, which are not present in proportion to their presence in water, but the ratio of hydrogen to oxygen is large. Lipids are characterized by their insolubility in water because they are non-polar compounds, but they dissolve in non-polar solvents such as ether, chloroform, benzene, lipids, and fats are not composed of one type of molecules, but rather of more than one type.

The term lipids are used to denote a wide range of compounds, sometimes including everything that is not dissolved in water, or what may be considered non-polar materials of organic including waxes, fatty acids and their derivatives of phospholipids, sphencolipids or glycolipids or terpenoids and others

Benefits of lipids

1- A source of energy. Where one gram gives 9 kcal.

2- It is involved in the synthesis of components of cell membranes

3- It is involved in the composition of blood plasma in a certain percentage.

4- Interferes with the synthesis of animal hormones

5- Its presence under the skin makes it an insulator for heat exchange - and it gives the skin its elasticity

6- Fats are substances that carry vitamins dissolved in fats and are necessary for their absorption and transport inside the body.

7- It protects some of the body's internal organs (kidney and heart), thus absorbing shock.

8- It is found in great concentration in the nervous tissue and is an electrical insulator

- 9- The electron transfer device in the mitochondria of the animal is located inside the phospholipids

10-It is involved in the formation of brain cells and nerve tissues

Lipids

Classification of lipids

Lipids are divided into several sections according to their chemical structure, food sources, or functions.

1. Simple lipids:

High fatty acid esters combined with simple alcohols such as glycerol include:

A- Oils and fats (animal fats): These are the esters of fatty acids with glycerol or glycerin.

B - Waxes: It is the esters of fatty acids (of high weights) with alcohol (of high weight) other than glycerol such as cholesterol. Waxes have no nutritional importance, especially for poultry.

2.Compound lipids:

They are substances whose molecules consist of several compounds linked to each other by different chemical bonds.

It is the esters of fatty acids with glycerol, as previously mentioned in oils and fats, except that they contain other additional groups as follows:

A- Phospholipids:

Combination of fats (glycerol esters or high alcohols with fatty acids) and phosphoric acid such as lecithin and cephalin (found in eggs, brain tissue and nervous tissue). A nitrogen base is included in its construction and is divided into two types, the first is the **derivatives of glycerol phosphate** in which phosphoric acid is linked by an ester bond with a nitrogenous or non-nitrogenous alcohol while, the second is **phosphate derivative of Sphingosine** that contain fatty acids linked by an ester bond in addition to phosphate linkage to a nitrogen base such as choline and ethanol amine.

B- Glycolipids:

They are fats attached to a carbohydrate molecule (glucose or galactose) found in the brain.

C- Lipoprotein:

They are fats linked with a protein molecule such as blood lipoprotein, in which cholesterol binds with the protein molecule and plays an important role in the transfer of fats within the body, and there is such a type as a component of cell membranes.

D- Amino lipids: combine with an amine group

E - Sulfo-lipid: they bind with sulfur, like those found in brain cells

3. Derived lipids:

They are lipolysis products and include free fatty acids or various alcohols such as glycerol or cholesterol and may be single or incomplete linked to some fatty acid , or may be vitamins such as A, D, and K.

They include:

1. Steroids, which are high fatty acid esters with cyclic alcohols, including cholesterol.

2. Sterols

3. Bile Acids

4.hormones

5. Carotenoids

Fatty acids

Fatty acids are a group of **organic acids**, so named because of their presence as major components in fatty compounds such as glycerides, phosphoglycerides, waxes, and others. Fatty acids can be defined as they are aliphatic carboxylic acids with one carboxyl group on one end, often attached to an unbranched carbon chain ending with a methyl group on the other end. The carbon chain can be saturated or unsaturated. Most naturally occurring fatty acids contain a carbon chain with an even number of carbon atoms ranging from 4 to 28.

Fatty acids are present in association with glycerol alcohol, in the form of esters and rarely in a free form in living tissues. A large number of fatty acids have been separated from each other, such as butyric acid, palmitic acid and stearic acid, (saturated fatty acids), oleic acid and linoleic acid (unsaturated fatty acids) . fatty acids are the building block of fats, of which there are many types and the general formula of fatty acids is (R-COOH).

Fatty acids are divided into two types according to their sources for humans:

1. Essential Fatty Acids: **EFAs** They are what the **human body cannot manufacture and must obtain from food**. they consist of two groups: **omega-3 fatty acids**, such as **alpha-linolenic acid**, and **omega-6 fatty acids**, such as **linoleic acid**.

2- Non-essential fatty acids: **These are what the body can manufacture** (The body do not need them from an external source). such as, **palmitic acid, stearic acid**.

Properties of fatty acids

1. **Saturated fatty acids** are fatty acids in which all the carbon atoms are saturated with hydrogen, and the general formula is CH3(CH2)nCOOH. When the n is between 2 and 10, the fatty acid is a short-chain, but when n is greater than 11, the fatty acid is an a long-chain .

Unsaturated fatty acids are fatty acids that contain at least a double or triple bond between two carbon atoms.

2. The difference of saturated and unsaturated fatty acids in their physical and chemical properties is due to the differences that exist in their hydrocarbon chains, as saturated acids are found in the zigzag, and unsaturated acids, because they contain unsaturated places, make their hydrocarbon chains bend at approximately 30 ° angles and led to make them take a small space, which gives them great vital importance when entering as a component of cell membranes in various tissues.

3- The presence of unsaturated fatty acids in a linked form in glycerides in a large amount that makes glycerides in liquid form (Oils), but the presence of saturated acids in a large amount in the previous compounds (glycerides) makes them in the solid form (fats).

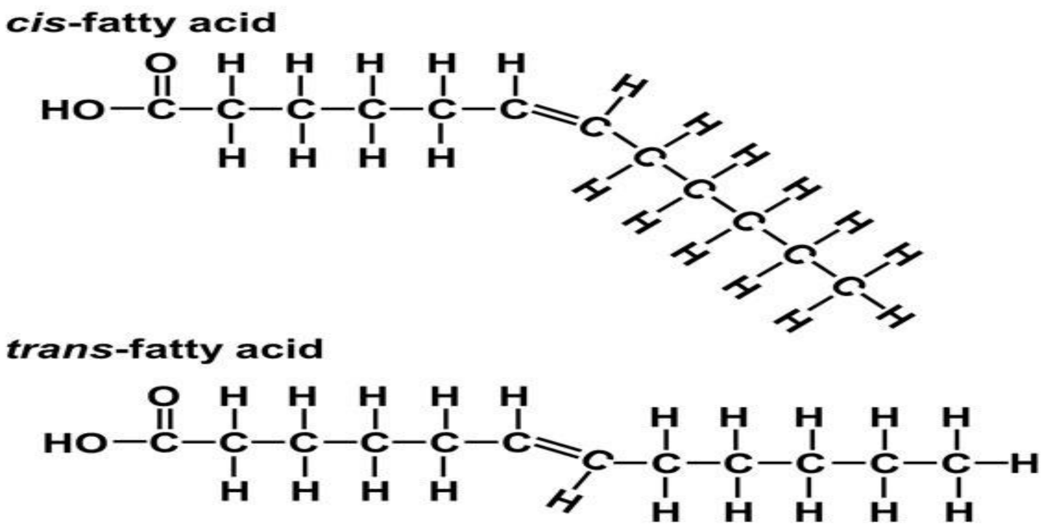
4- Long-chain fatty acids (16-18 carbon atoms) do not dissolve in water, but the sodium and potassium salts of these acids are colloid with water.

5- Unsaturated fatty acids which contain more than one double bond in the hydrocarbon chain, these bonds are separated from each other by a --CH2 group. Note the formula

- CH = CH - CH2 - CH = C H -

6. Fatty acids with pattern (Cis) is less stable than with pattern (Trans), as Cis pattern can be converted to the Trans by heating in the presence of an oxidizing agent .

For example Oleic acid of **Cis pattern** has a melting point of (13.5 °) that turns into **eliadic acid** of the Transe pattern that has a melting point of (43.5 °), meaning that the Cis pattern is less stable than the Trans one.



Glycerol Definition

Glycerol is a colorless, odorless liquid with a sweet taste. It is viscous at room temperature and non-toxic in low concentrations. Glycerol was discovered in 1779. It is also called glycerin alcohol or glycerin.

Glycerol is seen in biological systems as an intermediate in carbohydrate and lipid metabolism because excess carbohydrate can be converted into long chain fatty acids and esterified with the three hydroxyl groups.

Glycerol can increase antibody production and by enhancing immune cell activity and can be classified as an allergen.

Properties of Glycerol

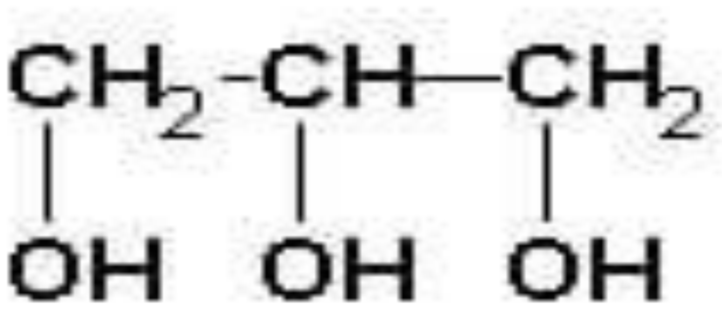
Pure glycerol has a melting point of 17.8°C. Its boiling point is 290°C but it also decomposes at that temperature. The presence of three hydroxyl groups makes the compound hygroscopic, with a tendency to absorb moisture from the air, retaining water and preventing the substance from drying out.

Glycerol is easily soluble in water, due to the ability of the polyol groups to form hydrogen bonds with water molecules. Glycerol is slightly denser than water with a specific gravity of 1.26. This means that when glycerol is poured into a container of water, it will sink to the bottom. However, due to its solubility, over time and with mild agitation, glycerol will form an aqueous solution.

The three hydroxyl groups of glycerol allow reactions with many organic acids to form esters. When all three reactive groups are esterified with long chain organic fatty acids, a triglyceride is formed. Triglycerides are among the most common lipids in the human body.

Glycerol Structure

Glycerol is a trihydroxy sugar alcohol with three carbon atoms and three hydroxyl groups. The structure of glycerol can be represented in different forms. The simplest is



Glycerol synthesis mechanism

Glucose (hexose) is decomposed in the glycolysis stage (EMP) into

3- phosphoglyceraldehyde and

dihydroxyacetonphophate ,so from these sugars we notice the beginning of the formation of glycerol as follows: